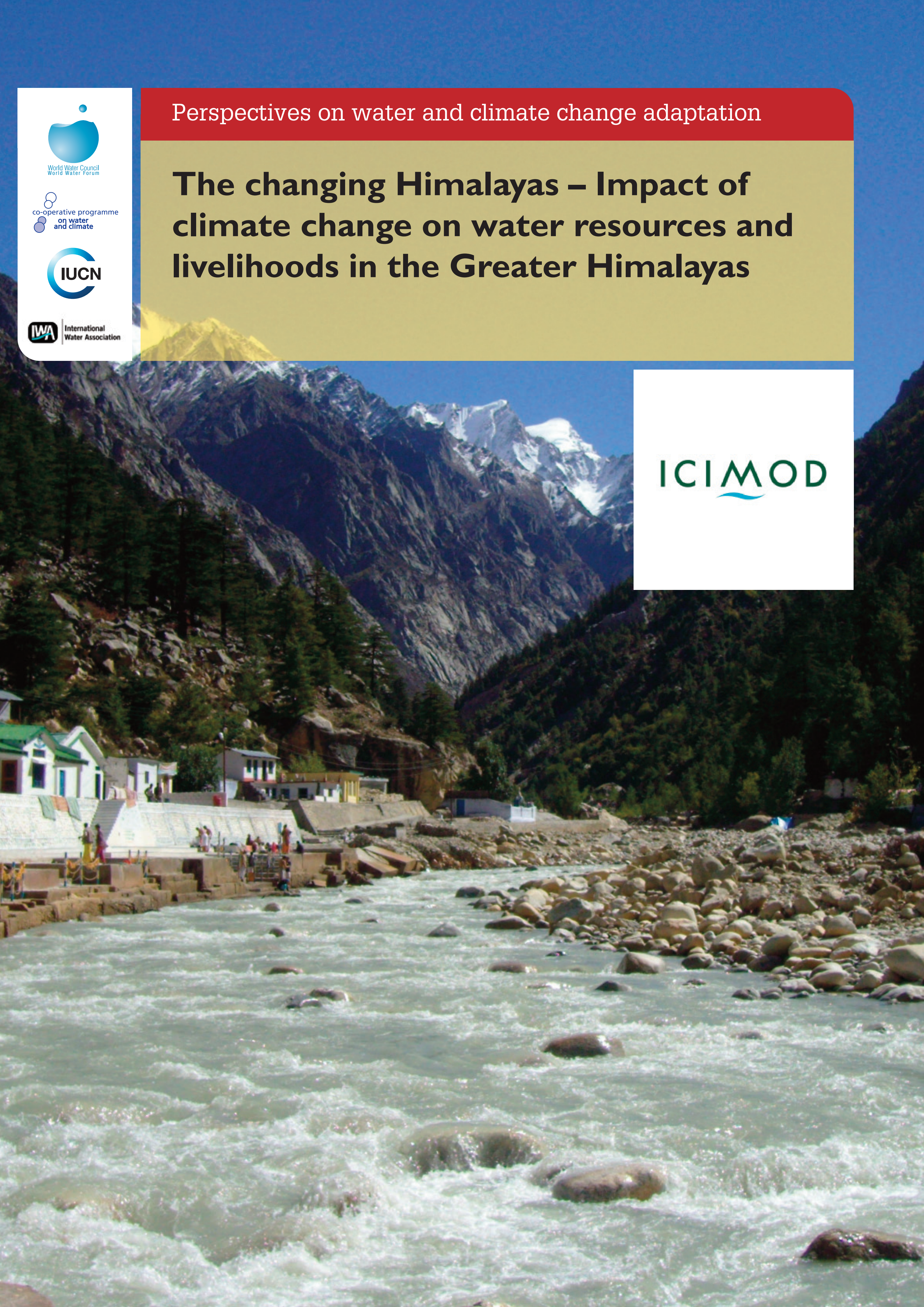
Perspectives on water and climate change adaptation

The changing Himalayas – Impact of climate change on water resources and livelihoods in the Greater Himalayas



World Water Council
World Water Forum

co-operative programme on water and climate

IUCN

IWA International Water Association

ICIMOD

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

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

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

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

Participants were invited to contribute perspectives from three categories:

1 **Hot spots** – These papers are mainly concerned with specific locations where climate change effects are felt or will be felt within the next years and where urgent action is needed within the water sector. The hotspots selected are: Mountains (number 1), Small islands (3), Arid regions (9) and 'Deltas and coastal cities' (13).

2 **Sub-sectoral perspectives** – Specific papers were prepared from a water-user perspective taking into account the impacts on the sub-sector and describing how the sub-sector can deal with the issues. The sectors selected are: Environment (2), Food (5), 'Water supply and sanitation: the urban poor' (7), Business (8), Water industry (10), Energy (12) and 'Water supply and sanitation' (14).

3 **Enabling mechanisms** – These documents provide an overview of enabling mechanisms that make adaptation possible. The mechanisms selected are: Planning (4), Governance (6), Finance (11), Engineering (15) and 'Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA)' (16).

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

1 The changing Himalayas – Impact of climate change on water resources and livelihoods in the Greater Himalayas

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The changing Himalayas – Impact of climate change on water resources and livelihoods in the Greater Himalayas

The 'greater Himalayan region', sometimes called the 'Roof of the World', is noticeably impacted by climate change. The most widely reported impact is the rapid reduction in glaciers, with profound future implications for downstream water resources. The impacts of climate change are superimposed on a variety of other environmental and social stresses, many already recognised as severe (Ives and Messerli, 1989).

1 Introduction

1.1 The region

The 'Roof of the World' is the source of ten of the largest rivers in Asia (Table 1). The basins of these rivers are inhabited by 1.3 billion people and contain seven megacities. Natural resources in these basins provide the basis for a substantial part of the region's total GDP, and important environmental services, which are also of importance beyond the region (Penland and Kulp, 2005; Nicholls, 1995; Woodroffe et al., 2006; Niou, 2002; She, 2004; Macintosh, 2005; Sanlaville and Prieur, 2005). China and India are today experiencing strong economic growth, growing international importance, and a rapid reduction in poverty. China and India are also the two leading producers of rice in the world, most of the harvest coming from irrigated agriculture in the Ganges, the Yangtze, and the Yellow River basins. However, as noted in the Stern Report on 'The Economics of Climate Change', "China's human development could face a major 'U-turn' by this mid-century unless urgent measures are now taken to 'climate proof' development results" (Stern, 2006).

Continuing climate change is predicted to lead to major changes in the strength and timing of the Asian monsoon, inner Asian high pressure systems, and winter westerlies – the main systems affecting the climate of the Himalayan region. The impacts on river flows, groundwater recharge, natural hazards, and the ecosystem, as well as on people and their livelihoods, could be dramatic, although not the same in terms of rate, intensity, or direction in all parts of the region. Given the current state of knowledge about climate change, determining the diversity of impacts is a challenge for researchers, and risk assessment is needed to guide future action.

1.2 Himalayan climate and water

The Himalayas display great climatic variability. The mountains act as a barrier to atmospheric circulation for both the summer monsoon and the winter westerlies. The summer monsoon dominates the climate, lasting eight months (March–October) in the Eastern Himalayas, four months (June–September) in the Central Himalayas, and two months (July–August) in the Western Himalayas (Chalise and Khanal, 2001). The east-west variation is based on the dominance of different weather systems, which in turn cause the monsoon to weaken from east to west. The monsoon penetrates northwards along the Brahmaputra River into the southeast Tibetan Plateau, but rarely as far as the Karakoram (Hofer and Messerli, 2006; Rees and Collins, 2006). The highest annual rainfall in the region occurs in Cherapunjee in India, amounting to more than 12,000 mm.

The monsoon rainfall is mainly of an orographic nature, resulting in distinct variations in rainfall with elevation between the southern slopes of the Himalayas and the rain shadow areas on the Tibetan Plateau (Mei'e, 1985). On the meso-scale, the impacts of climate are mainly due to local topographic characteristics (Chalise and Khanal, 2001), with dry inner valleys receiving much less rainfall than the adjacent mountain slopes due to the lee and orographic effect. This suggests that the currently measured rainfall, which is mainly based on measurements of rainfall in the valley bottoms, is not representative for the area, and the use of these data results in significant underestimates.

Table 1: Principal rivers of the Himalayan region – basin statistics.

	River		River basin			
River	**Annual mean discharge m³/sec***	**% of glacier melt in river flow+**	**Basin area (km²)**	**Population density**	**Population x1000**	**Water availability (m³/person/ year)**
Amu Darya	1376*	not available	534739	39	20855	2081
Brahmaputra	21261*	~ 12	651335	182	118543	5656
Ganges	12037*	~ 9	1016124	401	407466	932
Indus	5533	up to 50	1081718	165	178483	978
Irrawaddy	8024	unknown	413710	79	32683	7742
Mekong	9001*	~ 7	805604	71	57198	4963
Salween	1494	~ 9	271914	22	5982	7876
Tarim	1262	up to 50	1152448	7	8067	4933
Yangtze	28811*	~ 18	1722193	214	368549	2465
Yellow	1438*	~ 2	944970	156	147415	308
Total					1,345,241	

Source: IUCN et al. 2003; Mi and Xie 2002; Chalise and Khanal 2001; Merz 2004; Tarar 1982; Kumar et al. 2007; Chen et al. 2007

* The data were collected from the Global Runoff Data Centre (GRDC) from the following most downstream stations of the river basin; Chatly (Amu Darya), Bahadurabad (Brahmaputra), Farakka (Ganges), Pakse (Mekong), Datong (Yangtze), Huayuankou (Yellow)

+ Estimation of the melt water contribution is difficult and varies in an upstream and downstream situation; approximates are given here.

Note:
The hydrological data may differ depending on the location of the gauging stations. The contribution of glacial melt is based on limited data and should be taken as indicative only.

Table 2: Glaciated areas in the greater Himalayan region.

Mountain range	Area (km²)
Tien Shan	15,417
Pamir	12,260
Qilian Shan	1,930
Kunlun Shan	12,260
Karakoram	16,600
Qiantang Plateau	3,360
Tanggulla	2,210
Gandishi	620
Nianqingtangla	7,540
Hengduan	1,620
Himalayas	33,050
Hindu Kush	3,200
Hinduradsh	2,700
Total	**112,767**

Source: Dyurgerov and Meier 2005

Table 3: Glaciated areas in the Himalayan Range.

Drainage basin	No. of glaciers	Total area (km^2)	Total ice reserves (km^3)
Ganges River	6,694	16,677	1971
Brahmaputra River	4,366	6,579	600
Indus River	5,057	8,926	850
Total	**16,117**	**32,182**	**3,421**

Source: Qin 1999

A substantial portion of the annual precipitation falls as snow, particularly at high altitudes (above 3000m) feeding the Himalayan glaciers. The high Himalayan and inner Asian ranges have the most highly glaciated areas outside the polar regions (Owen et al., 2002; Dyurgerov and Meier, 2005). Glaciated areas in the greater Himalayan region cover an area of more than 112,000 km^2 (Table 2). The Himalayan Range alone (a sub-region) has a total area of 33,050 km^2 of glaciers or 17% of the mountain area (as compared to 2.2% in the Swiss Alps) with a total ice volume of ca 3,421 km^3 (Table 3), which provides important short and long-term water storage facilities. These figures are very tentative, however, and need to be followed up with more research.

Glaciers undergo winter accumulation and summer ablation in the west, but predominantly synchronous summer accumulation and summer melt in the east. The main melting occurs in high summer; however, when this coincides with the monsoon, it may not be as critical for water supply as when the melting occurs in the shoulder seasons: spring and autumn. When the monsoon is weak, delayed, or fails, melt-water from snow and ice may limit or avert catastrophic drought.

Water from both permanent snow and ice and seasonal snow is released by melting, some to be temporarily stored in high altitude wetlands and lakes, but most flowing directly downstream in the large river systems, giving a distinct seasonal rhythm to annual stream flow regimes in these rivers. The contribution of snow and glacial melt to the major rivers in the region ranges from 2% to 50% of the average flow (see Table 1). In the 'shoulder seasons', before and after precipitation from the summer monsoon, snow and ice melt contribute about 70% of the flow of the main Ganges, Indus, Tarim, and Kabul rivers (Kattelmann, 1987; Singh and Bengtsson, 2004; Barnett et al., 2005). The rivers of Nepal contribute about 40% of the average annual flow in the Ganges Basin, which alone is home to 500 million people, about 10% of the total human population of the region. Even more importantly, they contribute about 70% of the flow in the dry season (Alford, 1992). In western China, glacial melt provides the principal water source in the dry season for 25% of the population (Xu, 2008). The Indus Irrigation Scheme in Pakistan depends on 50% or more of its runoff originating from snowmelt and glacial melt from the eastern Hindu Kush, Karakoram, and western Himalayas (Winiger et al., 2005).

2 Observed and projected effects of climate change

Climate change is currently taking place at an unprecedented rate and is projected to compound the pressures on natural resources and the environment associated with rapid urbanisation, industrialisation, and economic development. It will potentially have profound and widespread effects on the availability of, and access to, water resources. By the 2050s, access to freshwater in Asia, particularly in large basins, is projected to decrease.

2.1 Rising temperatures

IPCC's Fourth Assessment Report (IPCC, 2007a; 2007b) concludes that there is more than a 90% chance that the observed warming since the 1950s is due to the emission of greenhouse gases from human activity. Temperature projections for the 21st Century suggest a significant acceleration of warming over that observed in the 20th Century (Ruosteenoja et al., 2003). In Asia, it is very likely that all areas will warm during this century. Warming is least rapid, similar to the global mean warming, in Southeast Asia, stronger over South Asia and East

Asia, and greatest in the continental interior of Asia (Central, West, and North Asia). Warming will be significant in arid regions of Asia and the Himalayan highlands, including the Tibetan Plateau (Gao et al., 2003; Yao et al., 2006).

Based on regional climate models, it is predicted that the temperatures in the Indian sub-continent will rise between 3.5 and 5.5 °C by 2100, and on the Tibetan Plateau by 2.5 °C by 2050 and 5 °C by 2100 (Rupa Kumar et al., 2006). However, because of the extreme topography and complex reactions to the greenhouse effect, even high resolution climatic models cannot give reliable projections of climate change in the Himalayas.

Various studies suggest that warming in the Himalayas has been much greater than the global average of 0.74 °C over the last 100 years (IPCC, 2007a; Du et al., 2004). For example, warming in Nepal was 0.6 °C per decade between 1977 and 2000 (Shrestha et al., 1999). Warming in Nepal and on the Tibetan Plateau has been progressively greater with elevation (Tables 4a and 4b and Figure 1), and suggests that progressively higher warming with higher altitude is a phenomenon prevalent over the whole greater Himalayan region (New et al., 2002) (Figure 2).

In many areas, a greater proportion of total precipitation appears to be falling as rain than before. As a result, snowmelt begins earlier and winter is shorter; this affects river regimes, natural hazards, water supplies, and people's livelihoods and infrastructure, particularly in basins such as the Tarim, which is dependent upon glacial melt in summer. The extent and health of high altitude wetlands, green water flows from terrestrial ecosystems, reservoirs, and water flow and sediment transport along rivers and in lakes are also affected.

Table 4a: Regional mean maximum temperature trends in Nepal from 1977–2000 (°C per year).

Region	Seasonal				Annual
	Winter (Dec–Feb)	Pre-monsoon (Mar–May)	Monsoon (Jun–Sep)	Post-monsoon (Oct–Nov)	(Jan–Dec)
Trans-Himalayas	0.12	0.01	0.11	0.1	0.09
Himalayas	0.09	0.05	0.06	0.08	0.06
Middle Mountains	0.06	0.05	0.06	0.09	0.08
Siwaliks	0.02	0.01	0.02	0.08	0.04
Terai	0.01	0	0.01	0.07	0.04
All Nepal	0.06	0.03	0.051	0.08	0.06

Updated after Shrestha et al., 1999

Table 4b: Average annual increase in temperature at different altitudes on the Tibetan Plateau and surrounding areas 1961–1990 (°C per decade).

Altitude (m)	No. of stations	Spring	Summer	Autumn	Winter	Annual average change
< 500	34	–0.18	–0.07	0.08	0.16	0.00
500–1500	37	–0.11	–0.02	0.16	0.42	0.11
1500–2500	26	–0.17	0.03	0.15	0.46	0.12
2500–3500	38	–0.01	0.02	0.19	0.63	0.19
> 3500	30	0.12	0.14	0.28	0.46	0.25

Source: Liu and Hou,1998.

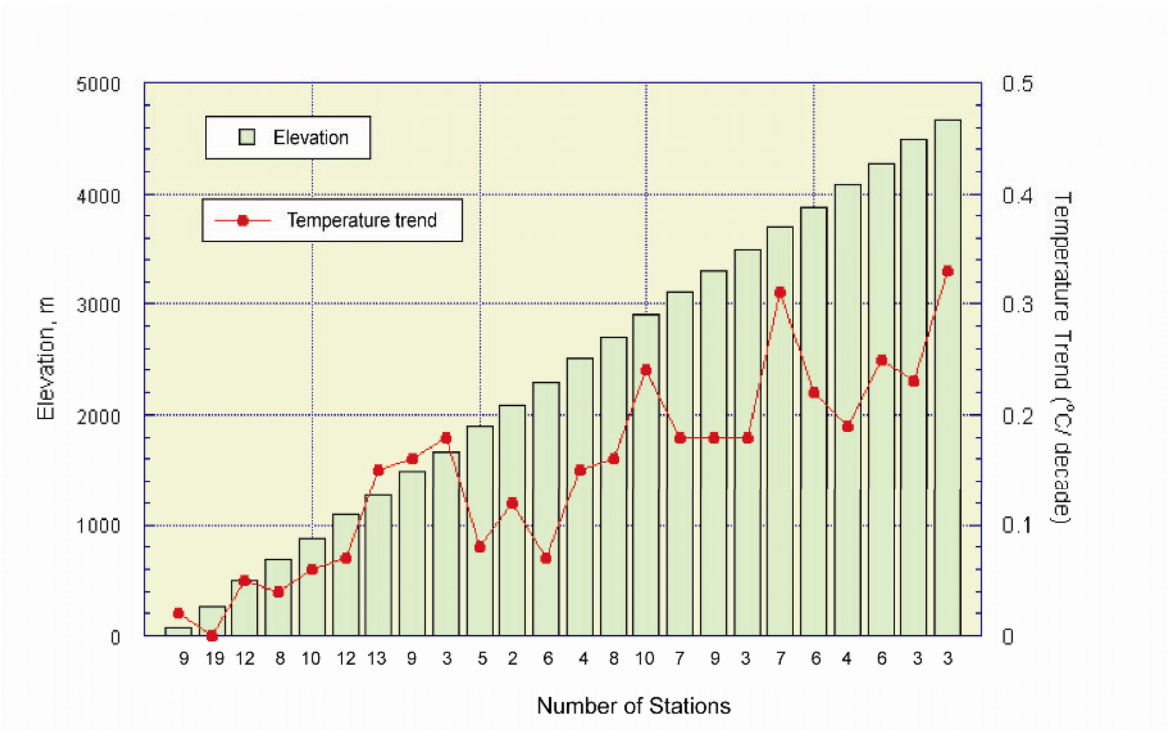

Figure 1: Dependence of warming on elevation on the Tibetan Plateau (Liu and Chen, 2000).

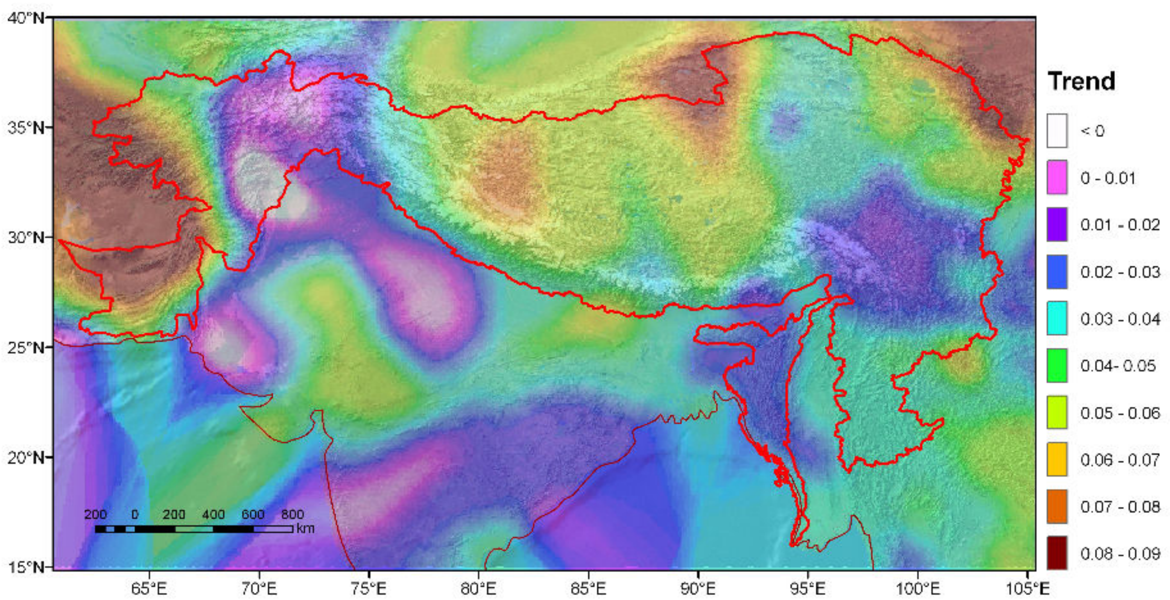

Figure 2: Spatial distribution of annual temperature trends for the period 1970–2000 (Data Source: New et al., 2002)

2.2 Precipitation trends

Long-term paleo-climatic studies (e.g. ice core studies on the Tibetan Plateau) show that both wet and dry periods have occurred in the last millennium (Tan et al., 2008, Yao et al., 2008). During the last few decades, inter-seasonal, interannual, and spatial variability in rainfall trends have been observed across Asia. In the Himalayan region, both increasing and decreasing trends have been detected. Increasing trends are found on the Tibetan Plateau in the north-east region (Zhao et al., 2004) and eastern and central parts (Xu et al., 2007), while the western Tibetan region exhibits a decreasing trend; northern Pakistan also has an increasing trend (Farooq and Khan, 2004); Nepal showed no long-term trend in precipitation between 1948 and 1994 (Shrestha et al., 2000; Shrestha, 2004).

A decrease in monsoon precipitation by up to 20% is projected by the end of the century in most parts of Pakistan and in south-eastern Afghanistan. A similar reduction in precipitation is projected for the southern and eastern Tibetan Plateau and for the central Himalayan range. Increases in the range of 20 to 30% are projected for the western Himalayan Kun lun Range and the Tien Shan Range (Rupa Kumar et al., 2006).

There is a major need for more research on Himalayan precipitation processes, as most studies have excluded the Himalayan region due to the region's extreme, complex topography and lack of adequate rain-gauge data (Shrestha et al., 2000).

2.3 Glacial retreat

Himalayan glaciers are receding faster today than the world average (Dyurgerov and Meier, 2005) (Figure 3). In the last half of the 20th Century, 82% of the glaciers in western China have retreated (Liu et al. 2006). On the Tibetan Plateau, the glacial area has decreased by 4.5% over the last twenty years and by 7% over the last forty years (CNCCC, 2007), indicating an increased retreat rate (Ren et al., 2003). Glacier retreat in the Himalayas results from "precipitation decrease in combination with temperature increase. The glacier shrinkage will speed up if the climatic warming and drying continues" (Ren et al., 2003).

The IPCC Fourth Assessment Report (IPCC, 2007a; 2007b) states that there is a high measure of confidence that in the coming decades many glaciers in the region will retreat, while smaller glaciers may disappear altogether. Various attempts to model changes in the ice cover and discharge of glacial melt have been made by assuming different climate change scenarios. One concludes that with a 2 °C increase by 2050, 35% of the present glaciers will disappear and runoff will increase, peaking between 2030 and 2050 (Qin, 2002).

Retreat in glaciers can destabilise surrounding slopes and may give rise to catastrophic landslides (Ballantyne and Benn, 1994; Dadson and Church, 2005), which can dam streams and sometimes lead to outbreak floods. Excessive melt waters, often in combination with liquid precipitation, may trigger flash floods or debris flows. In the Karakoram, there is growing evidence that catastrophic rockslides have a substantial influence on glaciers and may have triggered glacial surges (Hewitt, 2005).

2.4 Runoff over time and space

Mountain regions provide more than 50% of the global river runoff, and more than one-sixth of the Earth's population relies on glaciers and seasonal snow for its water supply. The effects of climatic change are of tremendous importance to the often densely populated lowland regions that depend on mountain water for their domestic, agricultural, and industrial needs (e.g., Barnett et al., 2005; Graham et al., 2007). The processes that determine the conversion of precipitation into runoff and downstream flow are many and complex. Changes in precipitation type (rain, snow) and its amount, intensity, and distribution over time and space have a direct impact on total and peak river runoff, potentially moving it away from agricultural and dry season demands and towards monsoon flash floods. Evapotranspiration rates, linked to temperature, have an effect on the amount of water available for runoff. However, one of the main concerns in relation to climate change in the Himalayan region is the reduction of snow and ice, which reduces the water storage capacity. Initially, it is likely that the stable base-flow – derived from melting ice and snow – will increase, particularly during warm and dry seasons. It is not unlikely that this will appear as a positive, comforting sign,

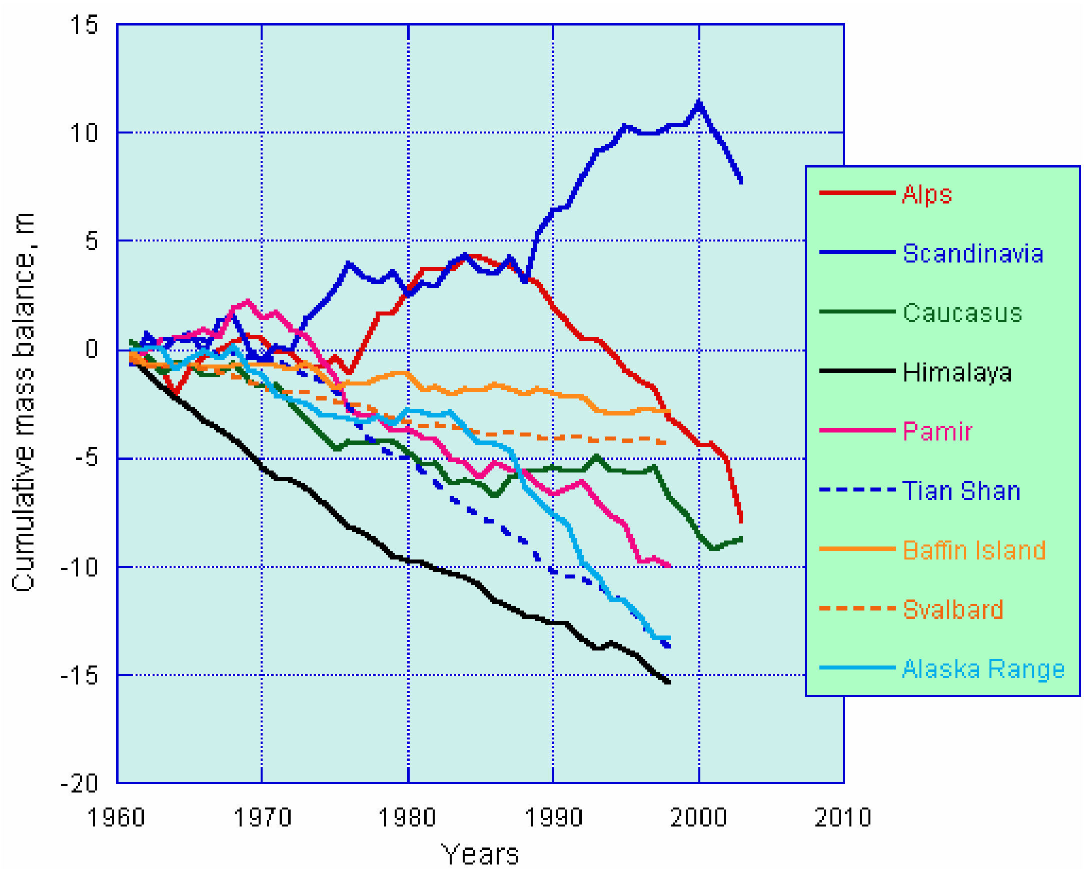

Figure 3: Rapid retreat of greater Himalayan glaciers in comparison to the global average (Source: Dyurgerov and Meier 2005).

deterring and delaying required emergency initiatives. However, as the far-away and high-altitude reservoirs of snow and ice continue to decrease, eventually disappearing, the variability of downstream runoff will increase, potentially dramatically, and progressively reflect direct rainfall-runoff, which in turn will mirror precipitation and evapotranspiration rates.

In Asia, climate change induced glacial melt could seriously affect half a billion people in the Himalayan region overall and a quarter of a billion people in China, who all depend on glacial melt for their water supply (Stern, 2007). In South Asia, hundreds of millions of people depend on perennial rivers such as the Indus, Ganges, and Brahmaputra – all fed by the unique water reservoir formed by the 16,000 Himalayan glaciers. The current trends in glacial melt suggest that the low flow will become substantially reduced as a consequence of climate change (IPCC, 2007a). The effect of this on, for example, food production and economic growth is likely to be unfavourable. The situation may appear to be normal in the region for several decades to come, and may even include increased amounts of water available to satisfy dry season demands. However, when the shortage arrives, it may happen abruptly, with water systems going from plenty to scarce in perhaps a few decades or less. Some of the most populated areas of the world may "run out of water during the dry season if the current warming and glacial melting trends continue for several more decades" (Barnett et al. 2005). Flooding may also arise as a major development issue. It is projected that more variable, and increasingly direct, rainfall runoff will also lead to more downstream flooding.

2.5 Permafrost

Areas in the high mountains and on the high plateaus not covered in perennial snow and ice are underlain by permafrost. Permafrost areas will be sensitive to degradation with climate warming. Recent studies show that the extent of permafrost is shrinking and that the active layer thickness (the upper portion of soil that thaws each summer) is increasing, and, further, that this has altered the hydrological cycle, vegetation composition, and carbon dioxide and methane fluxes that appear linked to permafrost degradation (Lawrence and Slater, 2005). The areas covered by permafrost are much larger than those covered by glaciers or perennial snow, especially in China. Permafrost plays a critical role in ecology, slope stability and erosion processes, and surface water hydrology. On the Tibetan Plateau, the recent warming has been associated with decreasing areas of permafrost and a rise in the elevation of its lower altitude, as well as progressive thinning. For example, in the past three decades, on the Central Tibetan Plateau in the Kekexeli Wildland Area, the lower limit of permafrost has risen by approximately 71 m, while the sustained thickness has decreased by at least 20 cm (Wu et al., 2001). Meanwhile, the extent of seasonal thawing has intensified over large areas of permafrost causing increased ground instability and erosion (Zhao et al., 2004), with consequences such as the activation of the soil carbon pool and northward expansion of shrubs and forests (Lawrence and Slater, 2005). The disappearance of permafrost and expansion of non-permafrost will accelerate desertification on the Tibetan Plateau (Ni, 2000). Notwithstanding, there is almost no information about the full extent and behaviour of high mountain permafrost areas in the region.

2.6 Water-related hazards

According to the United Nations International Strategy for Disaster Reduction (UNISDR), in 2007, seven of the top ten natural disasters by number of deaths occurred in four of ICIMODs member countries (Bangladesh, China, India, and Pakistan), accounting for 82% of total natural disaster related deaths worldwide. This indicates not only the prevalence of disasters in the region, but also the susceptibility of the region to such events (Table 5). Climate change involves, perhaps most seriously, changes in the frequency and magnitude of extreme weather events. There is widespread agreement that global warming is associated with extreme fluctuations, particularly in combination with intensified monsoon circulations.

The lack of data frequently observed in the region hinders a comprehensive assessment of changes in extreme climatic events. Available studies suggest changes in climatic patterns and an increase in extreme events. An increase in the frequency of high intensity rainfall often leading to flash floods and land slides has been reported (Chalise and Khanal, 2001; ICIMOD, 2007a; Figure 4). In parts of Central Asia, regional increases in temperature will lead to an increased probability of events such as mudflows and avalanches that could adversely affect human settlements (Iafiazova, 1997).

Table 5: Natural disasters in 2007 by number of deaths.

Type of disaster (month)	Country	Number of deaths
Cyclone Sidr (November)	Bangladesh	4234
Flood (July–August)	Bangladesh	1110
Flood (July–September)	India	1103
Flood (August)	Korea DPR	610
Flood (June–July)	China PR	535
Earthquake (August)	Peru	519
Heat wave (July)	Hungary	500
Cyclone Yemyin (June)	Pakistan	242
Flood and landslides (June)	Pakistan	230
Flood (July)	India	225

Source (UNISDR, 2007)

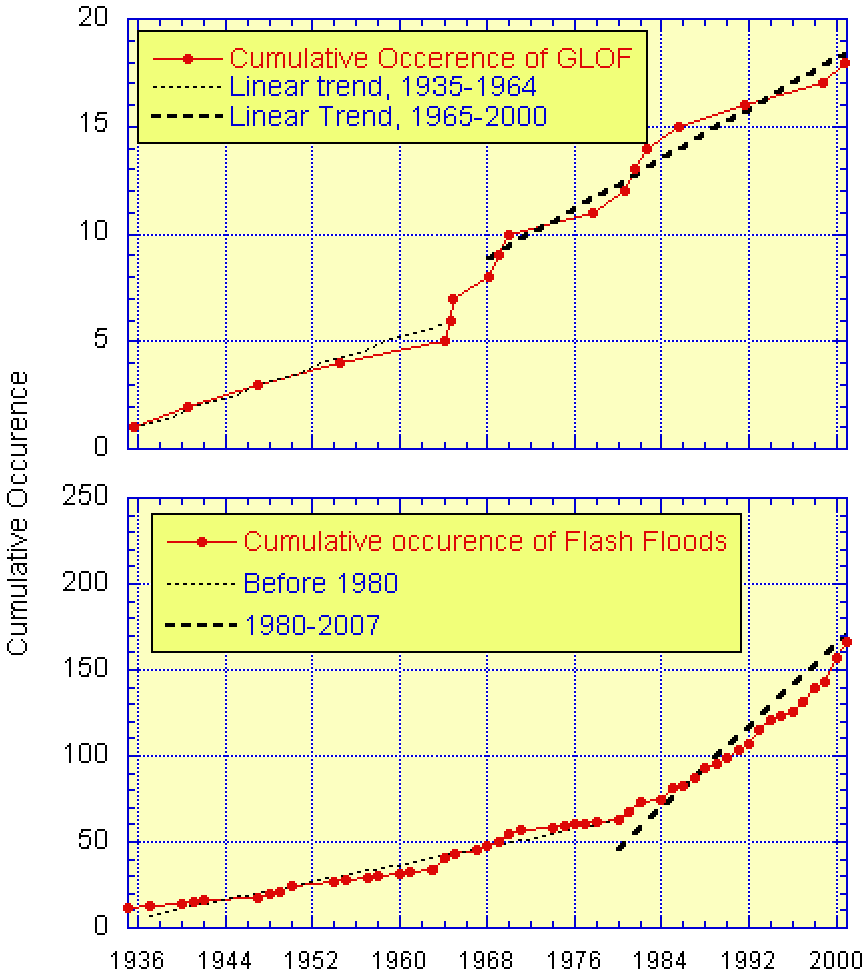

Figure 4: Cumulative frequency of GLOFs and flash floods in the HKH region.

In the eastern and central Himalayas, glacial melt associated with climate change, has led to the formation of glacial lakes behind terminal moraines. Many of these high-altitude lakes are potentially dangerous. The moraine dams are comparatively weak and can breach suddenly, leading to the discharge of huge volumes of water and debris. The resulting glacial lake outburst floods (GLOFs) can cause catastrophic flooding downstream, with serious damage to life, property, forests, farms, and infrastructure. In Nepal, twenty-five GLOFs have been recorded in the last 70 years, including five in the sixties and four in the eighties (Mool, 2001; NEA, 2004; Yamada, 1998). There is an indication that the frequency of GLOF events has increased in recent decades (Figure 4). In the HKH region two hundred and four glacial lakes have been identified as potentially dangerous lakes, which can burst at any time (ICIMOD, 2007b).

3 Consequences for livelihoods and the environment

3.1 Pastures and agriculture

The location and areas of natural vegetation zones on the Tibetan Plateau will substantially change under projected climate change scenarios. Areas of temperate grassland and cold temperate coniferous forest could expand, while temperate and cold deserts may shrink. The vertical distribution of vegetation zones could move to higher altitude. Climate change may also result in a shift of the boundary of the farming-pastoral transition region to the south in Northeast China, which may increase grassland areas and provide more favourable conditions for livestock production. However, the transition area of the farming-pastoral region is also an area of potential desertification, and if protection measures are not taken in new transition areas, desertification may occur (Li and Zhou, 2001; Qiu et al., 2001). More frequent and prolonged droughts as a consequence of climate change together with other anthropogenic factors may also result in desertification.

There is significant uncertainty about the effects of global warming on the vegetation and animal productivity of large dryland ecosystems. Although high altitude drylands might enjoy increases in net primary productivity (NPP), locally, the greatest confidence is in predicting implications for vegetation production, with lesser confidence in implications for vegetation composition, animal production, and adaptation options (Campbell and Stafford Smith 2000). Climate change has been reported to impact on grassland productivity, ecosystems, and the distribution and composition of plant communities (Wilkes, 2008). Some rangelands might suffer from degradation due to the warmer and drier climate (Dirnbock et al., 2003). Degraded rangeland already accounts for over 40% of dryland on the Tibetan Plateau (Zhong et al., 2003; Gao et al., 2005); and it is expanding at a rate of 3 to 5% each year (Ma and Wang, 1999). Increases in evaporation, reduction in snow cover, and fluctuations in precipitation are key factors contributing to the degradation of dryland ecosystems.

The possibility of alterations in the overall albedo, water balance, and surface energy balance in high-altitude grasslands and the increasing degradation and desertification of arid areas is causing concern. Signs of the effects of climate change on grasslands have been documented in the northeast Tibetan Plateau where Kobresia sedge and alpine turf communities are changing to semi-arid alpine steppes, known as 'black bleaching' (Ma and Wang, 1999; Miller, 2000). Qinghai Province in China alone has more than 20,000 km^2 of degraded rangeland.

Upward movement of the tree line and encroachment of woody vegetation on alpine meadows are reported widely. In the eastern Himalayas, the tree line is rising at a rate of 5 to 10 m per decade (Baker and Moseley, 2007). As temperature rises, species shift their ranges to follow their principal habitats and climatic optima.

Increasing temperatures and water stress are expected to lead to a 30% decrease in crop yields in Central and South Asia by the mid-21st Century (UNDP, 2006). At high altitudes and latitudes, crop yields should increase because of reductions in frost and cold damage. It will be possible to grow rice and wheat at higher latitudes than is currently the case in China.

Irrigated lowland agriculture, found in all of the large basins receiving their runoff from the Hindu Kush-Himalayan system, is projected to suffer negatively from lack of dry season water. Considering that the reported or projected glacial melt water component amounts to, for example, 20 to 40% per capita in Western China (Tao et al., 2005), 50% or more in the Indus (Tarar, 1982), and 30% in the major rivers in Nepal during pre-monsoon (Sharma 1993), the implications of dry season water stress are likely to be massive. In addition, an increase in agricultural water demand by 6 to 10% or more is projected for every 1 °C rise in temperature (IPCC, 2007a). As a result, the net cereal production in South Asian countries is projected to decline by at least between 4 to 10% by the end of this century, under the most conservative climate production projections (IPCC, 2007a).

3.2 Ecosystems

Mountain ecosystems contain a series of climatically very different zones within short distances and elevations. They display a range of micro-habitats with great biodiversity (Körner, 2004). Mountain ecosystems are sensitive to global warming and show signs of fragmentation and degradation (Xu and Wilkes, 2004; Körner, 2004). Species in high-elevation ecosystems are projected to shift to higher altitudes, although alpine plant species with restricted habitat availability above the tree line are projected to experience severe fragmentation, habitat loss, or even extinction if they cannot move to higher elevations (Dirnbock et al., 2003). Climate warming may increase suitable habitats for the water hyacinth (*Eichhornia crassipes*), a noxious weed able to survive winter temperatures.

The impacts of climate change on forest ecosystems include shifts in the latitude of forest boundaries and the upward movement of tree lines to higher elevations; changes in species composition and in vegetation types; and an increase in net primary productivity (NPP) (Ramakrishna et al., 2003). In the eastern Himalayas, forest vegetation will expand significantly; forest productivity will increase from 1 to 10%; and it is expected that forest fires and pests such as the North American pinewood nematode

(*Bursaphelenchus xylophilus*) will increase as dryness and warmth increase (Rebetez and Dobbertin, 2004).

3.3 Human health

The impact of climate change on health conditions can be broken into three main categories: (i) direct impacts from phenomenon such as drought, heat waves, and flash floods, (ii) indirect effects due to climate-induced economic dislocation, decline, conflict, crop failure, and associated malnutrition and hunger, and (iii) indirect effects due to the spread and aggravated intensity of infectious diseases due to changing environmental conditions (WHO, 2005). The latter effect includes the expansion of vector-borne diseases such as malaria and dengue, and water-related diseases such as diarrhoea. Regions such as the Hindu Kush-Himalayas, located at the fringe of the current geographic distribution of these and many other diseases, are particularity susceptible to the negative effect of rising temperatures. It is projected that the spread of malaria, Bartonellosis, tick-borne diseases and infectious diseases linked to the rate of pathogen replication will all be enhanced. Malaria mosquitoes have recently been observed at high altitudes in the region (Eriksson et al., 2008).

Endemic morbidity and mortality due to diarrhoeal disease associated with floods and droughts are expected to rise in East, South and South-East Asia due to projected changes in the hydrological cycle (IPCC, 2007a). This will be on top of an already very high global burden of diarrhoea attributable to climate change. Empirical studies project that the population at risk of dengue fever will be larger in India and China. In these countries, a high increase in mortality due to heat stress is also projected.

However, there are also expected to be positive climate change induced effects on the health status of certain populations in the HKH region. High altitude areas, formerly too cold, will open up to new types of agricultural production and new livelihood opportunities, people will find their homes and villages more comfortable due to warmer conditions, and the risks associated with cold and respiratory diseases will be reduced as the use of fuelwood for heating is reduced.

3.4 Mountain infrastructure

Valuable infrastructure, such as hydropower plants, roads, bridges, and communication systems, will be increasingly at risk from climate change. Entire hydropower generation systems established on many rivers will be in jeopardy if landslides and flash floods increase, and hydropower generation will be affected if there is a decrease in the already low flows during the dry season. Engineers will have to consider how to respond to these challenges (OECD, 2003).

A specific hazard related to glacier retreat is the formation of pro-glacial lakes and in some cases the events of glacial lake outburst floods (GLOFs). These can have a devastating effect on important and vulnerable infrastructure downstream such as hydropower stations. Equally important, the operations of hydroelectric power stations will become more complex. With climate change, the complexity and variability of river flow generation will both rise (Renoj et al., 2007) and become increasingly difficult to predict. For example, although the annual average proportion of meltwater in river flow has been estimated at 13% for rivers flowing to the Ganges from Nepal, from March through May the monthly average proportion is more than 30% (Chaulagain, 2006). This could have serious implications on river flows and water availability for power plants for about six months per year.

The landmark Qinghai-Tibet Railway, built at a huge cost and associated with important development objectives, is partly built on permafrost. Projected widespread permafrost melting on the Tibetan Plateau can threaten future railway services (Xu et al., 2005; Chen et al., 2005). Likewise, the Yangtze River, China's largest river and a crucial supplier of water to industry, agriculture, and 500 million domestic users, experienced its lowest upper reaches flow since the 1920s in 2006. With upstream dryland expansion, melting glaciers, and aggravated sediment deposits that affect downstream flood discharge capacity (Wang et al., 2005), the Three Gorges Dam, the world's largest hydroelectric installation, is at risk.

3.5 Livelihoods, vulnerability and adaptation

The term 'livelihood' comprises the capabilities, assets (material and social resources), and activities required for ensuring a means of living (Carney, 1998). Sustainable livelihood includes the idea of coping with and recovering from stresses and shocks, and maintaining or enhancing existing capabilities and assets. Climate change has made the future of mountain indigenous people and their livelihoods more vulnerable and uncertain. The available scientific evidence suggests that climate change will place significant stress on the rural livelihoods of mountain people. Efforts to reduce vulnerability and enhance the adaptive capacity of at-risk groups need to take a proactive approach that addresses the social processes leading to vulnerability and the structural inequalities that are often at the root of social-environmental vulnerabilities.

Adaptation to climate change is both related to vulnerability, which can be defined as the "degree to which individuals and systems are susceptible to or unable to cope with the adverse effects of climate change" (Smit and Pilifosova, 2001), and to future potential impacts, either avoidable or unavoidable. Effective adaptation includes both the establishment of adaptive capacity (awareness, governance, and knowledge) and the adaptation itself (change of behaviour, practices, and livelihoods according to new conditions) (Mirza, 2007). Adaptation consists of a multitude of options depending on the scale, context, and approach. The scale of adaption may be local, national, or regional; the context of the adaptation will determine the type of adaptation (e.g. new farming practices in a rural context or water demand management in an urban context); and the approach to adaptation may focus on general poverty alleviation, enhanced transparency in decision making, or the empowerment of women, among other things.

Structural inequalities that make adaptation by poor people more difficult will need to be levelled. It is important to note that poor and marginalised people already face all of the difficulties that we usually associate with climate change. This is nothing new to them. They are already facing poor health, susceptibility to floods and landslides, and a lack of adequate shelter, food, and water. While they do need climate change adaptation, they need poverty alleviation even more.

China and India's current rapid economic development, which is moving many tens of thousands of people out of poverty every day, may also provide the best way to handle a changing world. It should be noted that much of the adaptation to climate change will be found outside the sphere of natural sciences. For example, to focus only on flood-safe housing or new types of pest-resistant crops is not enough. The focus must include enhanced capacity to adopt (implying a comprehensive approach) new adaptation strategies. "An adaptation strategy to reduce vulnerability to future climate change needs to be incorporated in regulatory procedures, integrated natural resources management and other development planning procedures" (UNDP-GEF, 2007). As poverty is widespread in the Himalayan region, the empowerment of poor people to adapt to climate change is critical.

Examples of enhancing adaptive capacity at different levels may include introducing and/or enhancing governance to climate focus development, mainstreaming climate change into development planning; and institutional and policy reforms (Mirza, 2007), general political reform and associated openness (ibid), health education programmes (WHO, 2005), and the development of early warning systems for floods, flash floods, and droughts.

4 Lack of knowledge – unknown downstream effects

The impact of climate change on the Himalayan cryosphere is not understood well enough to support estimates of the full scale of the downstream impact of reduced snow and ice coverage. While in-depth studies of glaciers, snow, and permafrost have been carried out in some areas, they are scattered widely in space and time. Few detailed investigations of the response of snow and ice to climate warming have taken place in the Himalayan and other high ranges. Baseline studies are lacking for most areas, particularly for areas higher than 4,000 masl, and there has been little long-term monitoring of climatic variables, perennial snow and ice, runoff, and hydrology in the extraordinary heterogeneity of mountain topography (Liu and Chen, 2000; Rees and Collins, 2006; Messerli et al., 2004). In addition, the one common feature that all mountain areas share with one another – complexity caused by topography – causes temperature and precipitation to vary over very short distances (Becker and Bugmann, 1997), which in turn makes projections difficult.

Three levels of impact to climate change can be identified: i) local effects, ii) downstream effects, and iii) global feedback effects. The development of adaptive strategies can be approached from the perspective of each of these three different levels. Firstly, adaptive strategies can be developed at the local level, looking at local effects within the Himalayas and giving priority to local adaptation. Secondly, adaptive strategies can be developed from the perspective of the downstream level, evaluating the downstream effects of climate change and designing adaptive strategies around these effects. Thirdly, adaptive strategies can be developed on the global level, based on the potential feedback mechanism of the environmental changes in the Himalayas to global warming. All three levels are interlinked and interrelated, but full of uncertainty.

4.1 Local effects

Few model simulations have attempted to address issues related to future climatic change in mountain regions, primarily because the current spatial resolution of models is too crude to adequately represent the topographic and land use details (Beniston et al., 2003). Most climate models and predictions for high-altitude areas (above 4,000 masl) are dependent on extrapolation from hydro-meteorological stations at comparatively low altitudes and upon assumptions based on other, better-studied, parts of the world (Rees and Collins, 2004). The importance of the most widespread cryogenic processes – avalanches, debris flows, rock glaciers, alpine permafrost, and surging glaciers – has been recognised and their incidence recorded for certain areas. Yet, almost no basic scientific investigation of these cryogenic processes has taken place in the greater Himalayan region, even though they involve significant hazards, which may increase or decrease risk in given areas. The immense diversity of local effects found within the region should be recognised: diversity of climates and topo-climates, hydrology and ecology, and, above all, of human cultures and activities. Before effective responses can be developed, much work has to be carried out to identify and predict the possible effects of climate change across different systems – from glaciers to water resources, from biodiversity to food production, from natural hazards to human health – and filtered through diverse contexts. In particular, to date there has been little engagement with local populations to learn from their knowledge and experience in adapting to unique and changing environments and to address their concerns and needs (Xu and Rana, 2005).

4.2 Downstream effects

The downstream effects of changing water flow regimes in the large Himalayan rivers are to a great extent, unknown. Few (if any) studies have attempted to model the impact of a 30–50% reduction in dry season flow on, for example, downstream economic growth, livelihood conditions, and urban water use. It is likely that these changes will have major impacts on downstream societies; however, these impacts are largely unknown. Impacts on water resources will differ depending upon the importance or influence of different sectors (such as tourism, irrigated agriculture, industry and resource extraction), the ecosystems involved, and on the mitigation measures implemented to reduce water-induced hazards. There are substantial variations within, as well as between, these sectors in different countries and valleys in the region.

4.3 Global feedback effects

Glaciation in low latitudes has the potential to play an important role in the global radiation budget. A climatic feedback mechanism for Himalayan glaciation shows that a higher glacier free or low albedo surface has a cooling effect over the Himalayas and a warming effect over the Persian Gulf and the Arabian Peninsula (Bush, 2000). The Himalayan region is also an important carbon sink, particularly in terms of carbon storage in the soil of grasslands, wetlands, and forests. Wang et al. (2002) estimate that the organic carbon content of soils subtending grasslands on the Qinghai-Tibet Plateau total 33,500,000,000 metric tons, representing almost one quarter of China's total organic soil carbon and 2.5% of the global pool of soil carbon. Climatic variables influence soil carbon stocks through their effects on vegetation and through their influence on the rate of decomposition of soil organic matter. In grassland ecosystems, net ecosystem productivity (that is, the amount of carbon sequestered) is very small compared to the size of fluxes, so there is great potential for changes affecting fluxes to change the net flow of carbon, and for grasslands, therefore, to shift from being a CO_2 sink to a CO_2 source (Jones and Donnely, 2004), contributing further to global warming.

5 Policy recommendations

5.1 Reducing scientific uncertainty

Develop scientific programmes for climate change monitoring: Credible, up-to-date scientific knowledge is essential for the development of a climate change policy, including adaptation and mitigation measures. The current review finds a severe lack of field observations. It is essential to develop a scientific basis, in collaboration with government agencies and academia. Remote sensing allows for regular and repeated monitoring of snow cover, which can be carried out by countries such as China and India, with results shared with those lacking such technological infrastructure. Studies need to include both ground-based and satellite-based monitoring. Well-equipped stations and long-term monitoring, networking, and cooperation within and outside the region are essential. Participatory methods of assessing and monitoring climate and environmental change, local perceptions, and practices at the local level are also required. Local communities can play a role in determining adaptation practices based on local information and knowledge. School science programmes can be developed and introduced in local communities.

Application of regional climate models (RCMs): The Himalayas are not well represented in global models because of the coarse resolution of such models. Regional climate models, with a higher resolution than global ones, need to be constructed for 'hotspots' and run for shorter periods (20 years or so). The results of RCMs have to be downscaled and applied to impact assessments, particularly for watersheds or sub-catchments.

5.2 Mitigation measures

Beyond the Kyoto protocol: With rapid regional economic growth, China and India, in particular, should accept equal, albeit differentiated, responsibility as developed countries for controlling increasing carbon emissions. Countries should jointly develop a regional action plan for the control of emissions. Participation of all countries has to be achieved by allowing them to interpret the mandates of international agreements according to their national interests and priorities.

Land-use management for carbon sinks and reduced emissions: Many countries in the Himalayas have experienced forest recovery (or transition), through policy intervention and the participation of local communities in forest management. Examples include forest conservation in Bhutan, tree plantations in China, community forest user groups in Nepal, and joint forest management in India. The forests conserved have contributed significantly to carbon sequestration (Fang et al., 2001).

Payment for ecosystem services (PES): The mountains of the greater Himalayas provide abundant services to the downstream population in terms of water for household purposes, agriculture, hydropower, tourism, spiritual values, and transport. Upstream land and water managers shoulder the heavy responsibility of ensuring reliable provision of good quality water downstream. PES schemes can be developed at different scales, from local to national to regional, and involve local communities, governments, and the private sector. To date, the opportunities to establish PES schemes in the Himalayas to ensure safe provision of good quality water remain largely unexplored. However, land and water managers, as well as policy and decision makers, should be encouraged to look for win-win solutions in this context.

Development of alternative technologies: Novel and affordable technologies and energy resources that do not emit greenhouse gases are needed. Notable examples in the region include the diffusion of hydropower in Bhutan, solar energy and biogas in China, bio-diesel and wind energy in India, and biogas and micro-hydropower in Nepal.

5.3 Adaptation measures

Disaster risk reduction and flood forecasting: Floods are the main natural disaster aggravating poverty in the Himalayas where half of the world's poor live. Technical advances in flood forecasting and management offer an opportunity for regional cooperation in disaster management. Regional cooperation in transboundary disaster risk management should become a political agenda. Preparedness is essential in order to reduce the potential destruction from natural disasters (www.disasterpreparedness.icimod.org).

Supporting community-led adaptation: One approach to vulnerability and local level adaptation is 'bottom-up' community-led processes built on local knowledge, innovations, and practices. The focus should be on empowering communities to base adaptations to a changing climate and environment on their own decision-making processes, and on participatory technology development with support from outsiders. For example, Tibetan nomads have already noticed the earlier spring and moved yaks to alpine meadows earlier than previously practised. Farmers in the floodplains of Bangladesh build houses on stilts, and Nepali farmers store crop seeds for post-disaster recovery. Priority should be given to the most vulnerable groups such as women, the poor, and people living in fragile habitats (e.g. along riversides and on steep slopes).

National adaptation plans of action (NAPAs): NAPAs are currently being prepared by countries under the initiative of the UN Framework Convention on Climate Change. They are expected (a) to identify the most vulnerable sectors to climate change and (b) to prioritise activities for adaptation measures in those sectors. NAPAs need to pay more attention to sectors such as water, agriculture, health, disaster reduction, and forestry, as well as the most vulnerable groups.

Integrated water resources management: Disaster preparedness and risk reduction should be seen as an integral part of water resources management. Integrated water resources management (IWRM) should include future climate change scenarios and be scaled up from watersheds to river basins. Water allocation for households, agriculture, and ecosystems deserves particular attention. Water storage, based on local practices, should be encouraged in mountain regions.

5.4 Public awareness and engagement

Full disclosure and prior information for grass-root societies: Indigenous and local communities should be fully informed about the impacts of climate change. They have a right to information and materials in their own languages and ways of communicating.

Engagement of the media and academia: Awareness and knowledge among stakeholders about the impacts of global warming and the threat to the ecosystem, communities, and infrastructure are generally inadequate. The media and academia together can play a significant role in public education, awareness building, and trend projection.

Facilitation of international policy dialogue and cooperation: Regional and international cooperation needs to advance in order to address the ecological, socioeconomic, and cultural implications of climate change in the Himalayas. The international community, including donors, decision-makers, and the private and public sectors, needs to be involved in cooperative regional ventures. This is of particular importance for achieving sustainable and efficient management of transboundary rivers.

6 Conclusions

The Himalayan region contains one of the most dynamic and complex mountain systems in the world. This mountain system is extremely vulnerable to global warming (Bandyopadhyay and Gyawali, 1994). Uncertainties about the rate and magnitude of climate change and potential impacts prevail, but there is no question that climate change is gradually and powerfully changing the ecological and socioeconomic landscape in the Himalayan region, particularly in relation to water. Business as usual is not an option. It is imperative for environmental decision makers and managers to revisit and redesign research agendas, development policies, and management and conservation practices, and develop appropriate technologies. The mitigation of carbon emissions should be a responsibility shared between citizens and the private sector in the mountains, as elsewhere. Adaptation and mitigation measures intended to cope with climate change can create opportunities as well as offset the dangers of a warming planet; but they must be identified and adopted ahead of, rather than in reaction to, dangerous trends. Policies should be 'adaptation friendly'.

Himalayan uncertainty: Recognising the lack of studies and basic data, we speak of uncertainty on a Himalayan scale. In no context is this more relevant than in predicting what climate change will entail. The physical manifestations of climate change in the mountains include locally, possibly regionally, extreme increases in temperature and in the frequency and duration of extreme events. It seems certain that there will be appreciable changes in the volume and/or timing of river flows and other freshwater sources. There is, however, great uncertainty about the rate, and even the direction, of these changes, because so little is known about the dynamics of Himalayan topo-climates and hydrological processes, and their response to changing climatic inputs. The global circulation models used to model climates capture global warming on a broad scale, but do not have adequate predictive power for even large Himalayan drainage basins. To reduce uncertainty, we need well-equipped baseline stations, long-term monitoring, networking, open data exchange, and cooperation between all Himalayan countries. ICIMOD can play a role in facilitating knowledge generation, exchange, and cooperation with international mountain research programmes such as the Global Observation Research Initiative in Alpine Environments (GLORIA), Global Mountain Biodiversity Assessment (GMBA), UNESCO Biosphere Reserves, Monsoon Asia Integrated Regional Studies (MAIRS), and the Mountain Research Initiative.

Adaptation: Adaptation is the need for flexibility and resilience. Climate change is not new to Himalayan people. During very long time periods every aspect of life has been adapted to, or stressed by, changing temperature regimes, water availability, and extreme events. Himalayan farmers and herders have a long history of adapting to these uncertainties, to other related and unrelated environmental changes, and to ecological surprises, whether through mobility of people and land uses, or flexibility in livelihood strategies and institutional arrangements. Mountain people have lived with and survived great hazards such as flash floods, avalanches, and droughts for millennia. Building on this capacity to adapt and strengthening the socio-ecological system in the face of climate change is extremely important and an important step in achieving sustainable livelihoods. Climate change, as a public and global issue, has evolved from a narrow interest in the hydro-meteorological sciences, to a broad recognition that both the social consequences and policies of the human response to climate change have implications for all aspects of human development. Adaptive policies and major efforts to reverse the human drivers of climate change have to be incorporated into all sectors: land use, water management, disaster management, energy consumption, and human health. Hazard mapping would help both decision-makers and local communities understand the current situation, thereby enabling them to anticipate or assess their flexibility to adapt to future changes through proper planning and technical design.

Linking science and policy in climate change: Good science based on credible, salient, legitimate knowledge can often lead to good policies in the context of climate change and mountain specificities, and vice versa (Thompson and Gyawali, 2007). By credible, we mean knowledge that has been derived from field observations and tested by local communities. Salient information is information that is immediately relevant and useful to policy-makers. Legitimate information is unbiased in its origins and creation and both fair and reasonably comprehensive in its treatment of opposing views and interests. Policy is a formula for the use of power and application of knowledge. The question then becomes who has the power and who has the knowledge, scientific or local, or a combination of the two? Scientific knowledge is useful, but limited and full of uncertainties on the complex Himalayan scale. So, 'nobody knows best' becomes the model (Lebel et al., 2004). Alternative perspectives carry their own set of values and perceptions as to who should be making the rules, where the best knowledge to guide decisions lies, and what additional knowledge is needed. Multiple, sometimes contrasting, perspectives merge together in decision-making processes. In such processes, scientists have to generate new knowledge with reduced uncertainty to facilitate a fact-based dialogue. The role of different actors in contributing to resolving scientific uncertainty, adaptation, mitigation, and public engagement through this approach can be summarised in the form of the matrix in Table 6. In such processes, international cooperation is essential for the transfer of technology from outsiders to locals, to build regional cooperation into a global programme, and to develop the capacity to downscale important results to the regional HKH scale.

Table 6: Nobody knows best: Policy matrix to cope with Himalayan uncertainty.

	Scientific uncertainty	Adaptation	Mitigation
State	Regional cooperation, support long-term research, engage in research processes	Inter-sectoral collaboration, support for poverty alleviation and environmental conservation	Commitment to international treaties, developing good policies
Market	Partnership in research, new hardware and software for monitoring	New technology, support for community development and local education	Self-regulating and reducing greenhouse gas emissions
Civil society	Participatory vulnerability analysis, linking local to global, facilitating knowledge learning	Community preparedness, facilitating local learning and adaptation	Social auditing, green watch, and monitoring
Local community	Local indicators and monitoring, local knowledge, innovations, and practices	Improved land/resource management, preparedness for surprises	Renewable energy, alternative livelihoods, and migration
ICIMOD's role	Impact assessment, knowledge synthesis, regional database, forecasting, monitoring	Capacity building, support for mountain policies, pilot demonstration, optimising land-use patterns and livelihoods in mountain 'niches'	Facilitating the clean development mechanism (CDM) and carbon market place, designing payments for environmental services

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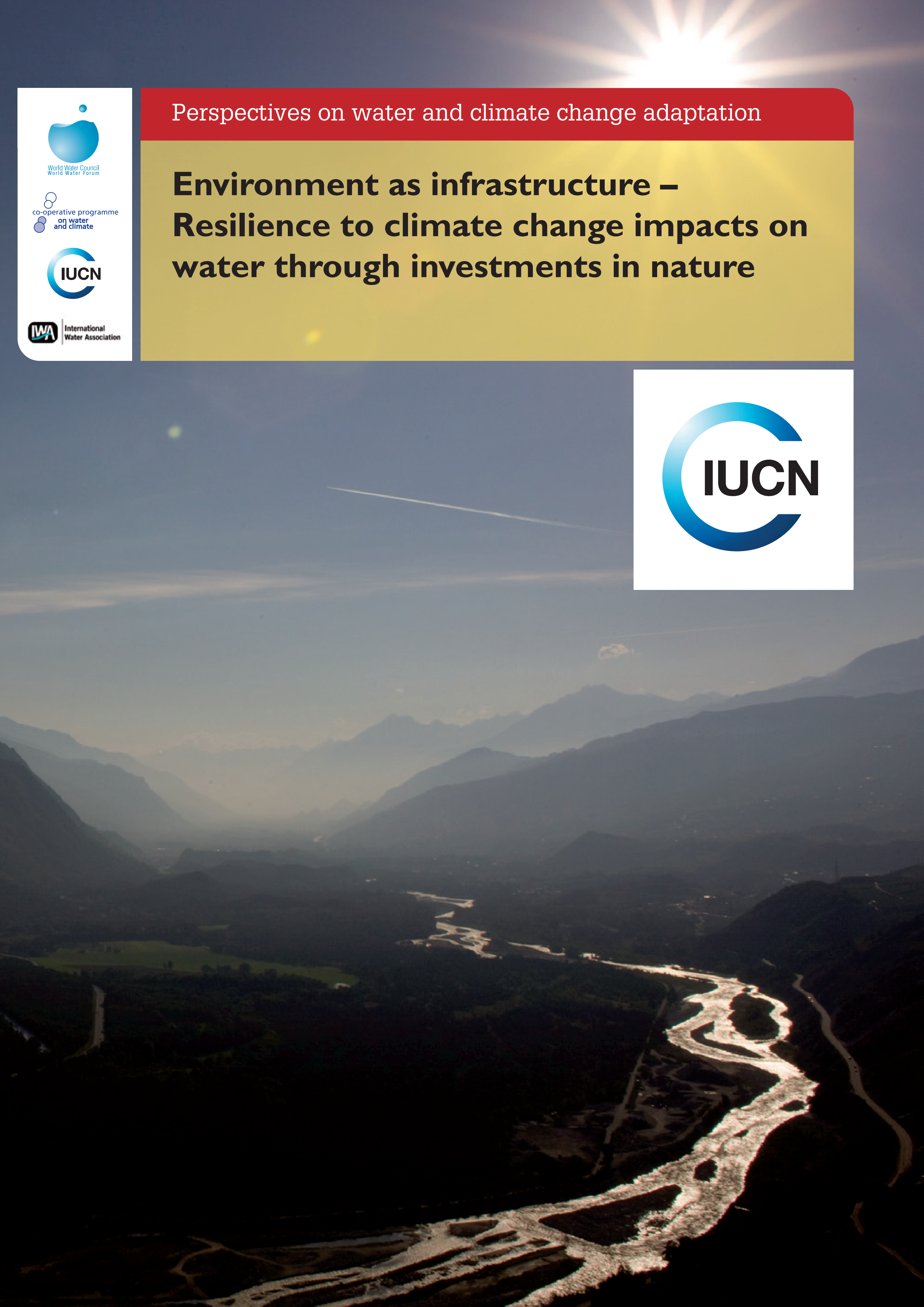

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Perspectives on water and climate change adaptation

Environment as infrastructure – Resilience to climate change impacts on water through investments in nature

IUCN

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

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

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

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

Participants were invited to contribute perspectives from three categories:

1 **Hot spots** – These papers are mainly concerned with specific locations where climate change effects are felt or will be felt within the next years and where urgent action is needed within the water sector. The hotspots selected are: Mountains (number 1), Small islands (3), Arid regions (9) and 'Deltas and coastal cities' (13).

2 **Sub-sectoral perspectives** – Specific papers were prepared from a water-user perspective taking into account the impacts on the sub-sector and describing how the sub-sector can deal with the issues. The sectors selected are: Environment (2), Food (5), 'Water supply and sanitation: the urban poor' (7), Business (8), Water industry (10), Energy (12) and 'Water supply and sanitation' (14).

3 **Enabling mechanisms** – These documents provide an overview of enabling mechanisms that make adaptation possible. The mechanisms selected are: Planning (4), Governance (6), Finance (11), Engineering (15) and 'Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA)' (16).

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

2 Environment as infrastructure: Resilience to climate change impacts on water through investments in nature

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Environment as infrastructure: Resilience to climate change impacts on water through investments in nature

Impacts of climate change, in combination with other drivers of global change, are compromising our ability to address global economic, security and social priorities. As floods, drought and other impacts of climate change on water become more frequent or intense, economies and livelihood security will weaken. Adapting to such impacts by building resilience is integral to addressing these global priorities. As water is at the centre of climate change impacts, this demands a focus on resilience to impacts on water. The environment has a critical role in building resilience to climate change and reducing vulnerabilities in communities and economies. Well-functioning watersheds and intact floodplains and coasts provide water storage, flood control and coastal defence. They are 'natural infrastructure' for adaptation.

Reducing vulnerability to climate change requires a combination of reduced exposure to hazards, reduced sensitivity to their effects and increased adaptive capacity. In each case, the environment, its natural infrastructure and related institutions and governance have key roles to play. Experience from river basins around the world shows that exposure to hazards can be reduced through environmental means. Risk of flooding, for example, can be lessened by restoring floodplains; risk of drought can be minimized by preserving wetlands and groundwater recharge areas; and risk of coastal erosion can be reduced by protecting mangroves. Sensitivity is reduced by using sustainable river basin management to expand livelihood assets and enterprise opportunities. Critically, adaptive capacity is built through water and natural resource governance that builds flexible and coordinated institutions and dissemination of knowledge needed to empower people in planning and decision-making about adaptation. Investing in natural infrastructure and adaptive institutions provides water storage, flood control and coastal defence, while building self-organisation and learning that are characteristics of resilience needed to deal with uncertain future events.

Any rush to invest in engineered infrastructure needs to be reconsidered. The danger of maladaptation – for example infrastructure that weakens resilience – needs to be assessed. All infrastructure options must be on the table, whether engineered or natural. Policymakers need to consider portfolios of approaches that support local actions, development of engineered infrastructure where appropriate and investments in natural infrastructure. Resilience increases where the natural infrastructure of river basins is in place and where basin institutions empower self-organisation and learning. To ensure effective action on global economic, security and social priorities, resilience to climate change impacts on water is vital. With resilience as a goal, natural infrastructure must be central to effective strategies for climate change adaptation.

1 Impacts of Climate Change on Water: Why Does the Environment Matter?

Economic, security and social issues dominate the global political agenda and dictate the parameters of global policy dialogue. At a time of extreme volatility in food and energy prices, concerns over food security and energy security bring demands for rapid response and structural change from world leaders. Governments are scrambling to relieve severe strains in a world financial system increasingly shaped by globalisation and the rapid industrialisation of emerging economies. For the nearly 3 billion people worldwide living on less than $2 per day, above all, the Millennium Development Goals (MDGs) and escaping poverty are the priority (WRI, 2008). Societies are trying to respond and build progress – but doing so in the face of myriad competing and conflicting interests, and in an era of unprecedented global change driven by population growth, urbanisation, deforestation and climate change.

Climate change holds many dangers – and water is at the centre of its impacts. Climate change is expected to bring more frequent drought and floods, and alongside them, more frequent severe storms. The retreat of mountain glaciers, in the Andes and Himalayas most critically, is expected to increase risk of disaster because of flooding and mudslides, and to reduce availability of freshwater in mountain rivers in the long term. Sea-level rise will bring a higher risk of coastal inundation and erosion. Expected impacts among regions vary, but globally the numbers of people living with water scarcity is expected to climb from 1.7 billion to 3.2 billion by 2080 (IPCC, 2008).

These impacts of climate change, in combination with other drivers of global change, are compromising our ability to address global economic, security and social priorities. Floods, drought, storms, loss of land-based ice and sea-level rise lower the resilience of communities and economies. Resilience is the amount of disturbance that can be withstood before a system changes its structure and behaviour – before, for example, it breaks down (Folke et al., 2004). In the case of a resilient community, rapidly rising food prices might have little impact on economic growth, household consumption or public health, but they are much harder to cope with and may lead to social and economic disorder where resilience is low. Unless steps are taken to build resilience, climate change may mean less capability to cope with other stresses as their effects mount. Where floods or drought become more frequent because of climate change, they weaken economies and livelihood security (World Bank, 2006). When crisis then strikes – because of higher food prices, or financial system breakdown, or conflict – people are less able to cope and goals for food and energy security, economic growth or poverty reduction recede (IISD/IUCN/SEI, 2003). Adapting to climate change by building resilience to climate change impacts is therefore integral to addressing global priorities for security and development. As water dominates these impacts, this demands a focus on resilience to impacts on water.

The importance of water in mediating the myriad impacts of climate change has the effect of creating 'hot spots' of vulnerability. These are the places and regions of the globe where susceptibility to adverse impacts of climate change is high. Susceptibility is high in these locations because of exposure to hazards such as floods and drought or storm surges and because of sensitivity to their effects. These hot spots are the highest priority locations for adaptation, and include:

- low-lying deltas and coastal mega-cities – where higher frequency of flooding and coastal inundation will have the most acute impacts
- drylands – where susceptibility to more severe or more frequent water scarcity is high because of threats to food security, health and economic development
- small islands – where sensitivity to coastal erosion, inundation and salt-water intrusion is high at community and national levels
- mountains and their rivers – where retreat of glaciers and reduction in the size of winter snow packs will increase disaster risk and shift the volume and timing of downstream water availability for irrigation, industry and cities.

In the case of each hot spot, the critical question to be addressed is: How can vulnerability to the hazards faced be reduced?

From an environmental perspective, a related question is: Why does the environment matter? What difference does the environment make to resilience in communities and economies and to vulnerability to climate change?

One reason that the environment matters is that climate change impacts pose grave threats to biodiversity, threatening catastrophic loss of species in some regions of the world (Thomas et al., 2004). It is clear, therefore, that finding ways to reduce these threats needs to be a high-priority for adaptation strategies. However, it is just as important to focus on the role of the environment in providing solutions to climate change adaptation, not just the threats that the environment faces. There are links to resilience, which accord the environment a critical role in climate change adaptation.

There are numerous options for adapting to climate change impacts on water, and there are a variety of enabling mechanisms which need to be developed and coordinated for adaptation to be effectively implemented. Coping with floods, drought, storms and sea-level rise will depend on water storage, flood control and coastal defence. However, providing these functions simply by building infrastructure – such as dams, reservoirs, dikes and sea walls – will not be adequate. By itself such engineered infrastructure can weaken resilience, especially in a changing climate where the historic hydrology is no longer a viable guide to the future, because of damage caused to livelihoods and the environment (Palmer et al., 2008). Indeed, the environment has a critical role to play. Well-functioning watersheds and intact floodplains and coasts, likewise, provide water storage, flood control and coastal defence. Thus, the environment itself is infrastructure for adaptation – it is 'natural infrastructure'. Furthermore, when based on principles of good governance, sound investment strategies and learning from integrated water resources management, integrating natural infrastructure into adaptation builds resilience (Nelson et al., 2007)

2 Why Does the Environment Help to Reduce Vulnerabilities to Climate Change?

2.1 Ecosystem Services

Ecosystem services are "the benefits people obtain from ecosystems" (MA, 2005). The implication is that where ecosystems are lost or degraded, so are the services from them that people use. Ecosystem services are commonly categorised as provisioning, regulating, supporting or cultural services (MA, 2005). As examples, supply of food and freshwater are provisioning services, flood attenuation is a regulating service, nutrient cycling is a supporting service and opportunities for recreation are cultural services. Of vital importance is the undeniable fact that human well-being can be damaged when these services are degraded, or else costs must be borne to replace or restore the services lost. The impacts of environmental degradation can be social and economic, and can be felt at community, river basin and national levels.

Ecosystem services are integral to the benefits people derive from the hydrological cycle and to protection against extremes. Consider a river system draining water from upland parts of a basin through floodplains to estuaries and into a coastal zone. Benefits to people of water moving through the basin are mediated by ecosystems and depend upon their integrity. Water is stored in soils, wetlands and lakes, from whence it can be used to satisfy human needs and for production. When flows are high, water spreads across the floodplain, reducing downstream flooding and feeding recharge to underlying groundwater bodies. In estuaries and along the coast, sediments carried by the river replenish those lost through natural coastal erosion, reinforcing protection of the coast. Throughout the basin, soils are held in place by vegetation, whether natural or cultivated.

In principle, the integrity of a river basin and the ecosystems within it smooth and buffer the river's hydrograph. Extremes of flood and drought are attenuated by retention of water in soils and surface water bodies and by slowing of flow on the floodplain, and by maintenance of base flow through drainage of soils and seepage from groundwater. Degradation of the basin because of destruction of ecosystems leads to loss of these services. Clearing of vegetation and erosion of upland slopes, for example, means buffering of runoff by retention of water in soils is weakened, increasing the exposure of downstream communities to hazards from flash-flooding. Drainage and infilling of wetlands means natural water storage is lost and recharge of groundwater reduced, reducing dry-season flows and the options available for coping with drought. Where rivers are disconnected from floodplains by levees and channelisation, water is rushed downstream, raising exposure of towns and cities to flood peaks.

The structures and functions of ecosystems that combine to deliver these services and the benefits they provide for people comprise the natural infrastructure of a river basin. Without this natural river basin infrastructure, people lose benefits and are exposed to hazards and vulnerabilities they would otherwise be able to avoid or have protection against.

Examples of natural infrastructure in river basins abound. Deep, upland soils such as in the páramo grasslands of the Andes store water for use in downstream cities. Without this natural storage, more construction of dams and reservoirs would be needed (Buytaert et al., 2006). Forests in upper watersheds protect soils, retain water and stabilise slopes, reducing disaster caused by storms, as witnessed during Hurricane Mitch in Central America in 1998 when loss of life and economic costs were lower where forests remained intact (Girot, 2001). Mountain glaciers in, for example, the Andes and Himalayas are infrastructure that store and release water for use by downstream populations in agriculture and to sustain cities. Lakes, wetlands and aquifers are natural infrastructure which store water for use during drought. Intact floodplains reduce downstream flood peaks by giving rivers the space needed to dissipate peak flows. Such use of floodplains as flood control infrastructure, recognised, for example, in the Dutch policy of 'making room for the river' (V&W, 2006), has the benefit of reducing the extent and height of flood control infrastructure that must be engineered downstream. At the coast, mangroves, barrier reefs and islands protect against erosion and storm damage, but also attenuate tidal or storm surges, as witnessed in the Asian tsunami of 2004, where damage from coastal inundation was reduced where mangroves were intact (UNEP-WCMC, 2006).

Natural infrastructure has been fundamental to water resources management, and thus to management of climate variability and extremes, throughout history. As such, natural infrastructure has been a critical instrument of development, just as has engineered infrastructure, though usually unseen and uncosted, and therefore receiving much less investment. The focus on reducing water-related vulnerabilities brought by climate change requires, however, that there is new, explicit recognition given to the role of natural infrastructure.

2.2 Reducing Vulnerability

Vulnerability to climate change combines exposure to hazards that result from the changing climate and sensitivity to their impacts when they occur. Vulnerability is thus high if changes in climate increase the exposure of populations to events such as drought, floods or coastal inundation, because of higher frequency or severity, where the ability of people to cope is limited (Yamin et al., 2005). Capacity to cope is most limited, and thus sensitivity highest, where livelihoods and the economy are based on a narrow range of assets that are easily damaged by climate hazards, with few alternate options or means of managing risk. Vulnerability is therefore especially high for the poor in those 'hot spots' where climate change exacerbates exposure to climatic hazards.

If vulnerability is a combination of exposure and sensitivity, then reducing vulnerability demands actions which will: 1. reduce exposure to hazards, 2. reduce sensitivity to their effects, and 3. build capacity to adapt. The latter component, building adaptive capacity, enables communities and nations to mobilise the decisions and resources needed to reduce vulnerability and adapt to climate change (Nelson et al., 2007). Building adaptive capacity means strengthening attributes including the availability of information and skills, access to technologies, access to economic resources and the effectiveness of institutions (Munasinghe and Swart, 2005).

Given the importance of water in climate change impacts, water management and the water sector are fundamental to each of the three components of reducing vulnerability. With appropriate actions, water managers can reduce exposure to hazards, reduce sensitivity and build adaptive capacity. In each case, the environment, its natural infrastructure, and related institutions and governance have key roles to play. For example:

- exposure to flood is reduced by restoring the function of floodplains in combination with sound land-use planning, to drought by maintaining groundwater recharge, and to coastal erosion by protecting mangroves;
- sensitivity to climate hazards is reduced by using sustainable management of river basins to expand livelihood assets and enable economic development, such as through enterprise development related to wetland fisheries or agricultural diversification and agroforestry; and
- adaptive capacity is built through water governance that builds flexible and coordinated institutions, learning and dissemination of knowledge needed to empower people in planning and decision-making related to adaptation.

Natural infrastructure, and the strategies and actions used in associated environmental management, thus need to be integral to portfolios of adaptation measures and to adaptation strategies. If natural infrastructure is overlooked in favour of engineered infrastructure, opportunities to reduce vulnerability will be missed. Moreover, the benefits of ecosystem services for development and the adaptive capacity that can emerge from reform of water governance may be lost, eroding resilience.

3 Building Resilience to Climate Change Using Natural Infrastructure

3.1 Case Story: The Komadugu Yobe Basin, Nigeria

The Komadugu Yobe River is part of the natural infrastructure of northern Nigeria. Part of the Lake Chad basin, it can be counted among the dryland hot spots of vulnerability. With a semi-arid climate, rainfall variability is high and severe drought a frequent hazard. Deep poverty characterises the basin, where population has doubled in three decades to more than 23 million. Over this same time, flow in the Komadugu Yobe has fallen by 35%, due to the combined effects of the construction of two dams since the 1970s, abstraction of water for large-scale irrigation and regional drying of the climate. A society already under social and economic crisis has thus been facing ever-increasing water stress. The river itself has been severely degraded, as the natural cycle of seasonal flows has been replaced by perennial low flows, causing loss of the services from riparian and wetland ecosystems that communities have historically relied on. Fishing, farming and herding livelihoods have been devastated as a result, because fish habitats are choked with invasive weeds, floods used by farmers to fill their soils with water are small or absent, and scarcity of water has led to conflict. The natural infrastructure of the river has been damaged, and as a result communities living with drought hazards are less able to cope. With further climate change looming, the adaptive capacity of ecosystems and communities of the Komadugu Yobe have become brittle, just when resilience is most needed.

Crisis in the Komadugu Yobe basin has led to change. Restoring the river basin's natural infrastructure has become a source of adaptive capacity and renewed resilience. With the six federal Nigerian riparian states unable to coordinate development of water resources in the basin, and with the number of cases of conflicts over land and water resources reaching court running into the hundreds each year, the dysfunctional state of the river had become a barrier to pursuing the Millennium Development Goals in the basin. Beginning in 2006, the federal and state governments and stakeholders, including dam operators and farming, fishing and herding communities, came together to negotiate a plan for coordinating and investing in restoration and management of the basin. In addition to agreeing on a Catchment Management Plan, they drafted a 'Water Charter', spelling out the agreed principles for sustainable development of the basin and the roles and responsibilities of governments and stakeholders. Reform of water governance is enabling transparent coordination of water resources development, including remediation of degraded ecosystems and, eventually, restoration of the river's flow regime. Dialogue has reduced the number of cases of conflict to just a handful per year and governments have pledged millions of dollars in new investment for basin restoration (KYB Project, 2008).

Change achieved in the Komadugu Yobe basin has increased capacity to address critical constraints in development, such as water scarcity, conflict and degradation of natural resources. Under the agreed management plan for the basin, actions are underway to restore ecosystem services and rebuild the natural infrastructure used to cope with drought and sustain the livelihoods and enterprise development needed to reduce poverty. The new institutions and empowerment of stakeholders to participate in planning and management of water resources provide flexible capacity to respond to stresses and shocks that was missing in the past.

Where resilience in the Komadugu Yobe was weakening, it is now strengthening. Ability to adapt in the basin was spiralling downward as the structure and function of the basin – in terms of hydrology, ecology, and social development – degraded. There is promise that the spiral is now slowing and reversing, with much greater capacity for self-organisation than there was previously. Myriad problems remain and barriers to reduced poverty and increased food and water security are profound. These include lack of financial resources, access to technology, skills and knowledge including hydrological and climate information. However, with the changes underway in the basin, governments and communities are acquiring capacities to both learn and to cope with uncertain future events.

So, for the Komadugu Yobe, what difference does the environment make to vulnerability to climate change? Restoration in the basin rebuilds ecosystem services that help to reduce exposure to climatic hazards, but especially, it helps to ensure people have more of the assets needed to make fishing, farming and herding livelihoods less sensitive to climate change. Just as importantly, however, the learning, flexible institutions and investment that underpin effective management and restoration of a river basin's natural infrastructure provide vital adaptive capacity that is based on resilience (Nelson et al., 2007).

3.2 Integrating River Basin Management into Adaptation Decisions

The experience of the Komadugu Yobe is repeated in other river basins globally. The Worldwide Fund for Nature reported in 2008 how investment in the natural infrastructure of river basins and adaptive governance is reducing vulnerability to climate change (Pittock, 2008), including in:

- the Lower Danube, Eastern Europe – where increases in flooding are projected, restoration of floodplains has increased flood storage, diversified livelihood options and reconnected habitats;
- the Great Ruaha River, Tanzania – where greater water scarcity is expected, strengthening of local Water User Associations and basin management institutions has increased water use efficiency by communities, diversified livelihoods and enabled use of hydrological and climate information in decision making;
- the Yangtze Lakes, China – where likely climate change impacts include increased flooding, restoration and reconnection of 450 km^2 of lakes has enabled retention of 285 Mm^3 of floodwaters while increasing fisheries production by 15 %;
- the Rio Conchos, Mexico – where a drying climate is projected, establishment of a multi-stakeholder institution for adaptive management of the basin has led to reduced demand for water and development of conjunctive management for surface and ground waters that expand options for coping with drought;
- the Rio São João, Brazil – where climate change is expected to exacerbate pollution of coastal lagoons, new and adaptive multi-stakeholder institutions have led to a 75 % cut in wastewater discharge, investment in wetland restoration and the prospect of resurrection of the regional fishing and tourism industries.

These examples demonstrate how adaptation that is based on resilience directly integrates reduction in exposure to hazards, reduction in sensitivity to impacts and increase in adaptive capacity. The keystones in practice are natural infrastructure which lower exposure and sensitivity and flexible multi-stakeholder institutions which strengthen and widen adaptive capacity.

River basins and river basin management thus have important benefits for climate change adaptation, but a key challenge is to ensure that effective approaches for gaining these benefits are incorporated into decision making and financing. There is a continuum of decision-making on adaptation which begins with reducing vulnerabilities by adopting best practice. There are then 'climate-justified actions' to be considered which focus on specific vulnerabilities and management of climate risks. These actions vary broadly among vulnerability hot spots, depending upon expected impacts of climate change on water scarcity, floods, disaster risk or sea-level rise. Finally, there are decisions to be made which relate to future unknowns, where scientific understanding is weak or absent.

River basin management is relevant across the continuum of decision making on adaptation. At the level of best practice, implementing integrated water resources management (IWRM) is a vital, no-regrets strategy where poor water management exacerbates climate vulnerabilities, particularly in developing countries or where there is severe degradation of land and water resources. Specific vulnerabilities are addressed through application of specific strategies devised to target water-related climate risks. Finally, well-functioning natural infrastructure and adaptive governance impart characteristics of resilience needed to deal with uncertain future events.

Decision makers will increasingly confront the reality that, yes, the environment does matter in climate change. This is not only because ecosystems are themselves threatened by climate change impacts but because the tools for management of the natural infrastructure of river basins are also tools for adaptation. What strategies will make these tools most effective?

3.3 Ecosystem-Based Adaptation

An 'ecosystems approach' to development is advocated in many strategies for conservation and sustainable development (Shepherd, 2004). It is built on policies and practices that succeed in addressing the needs of people and the environment through participation in negotiated decisions and through adaptive management. Application of an ecosystems approach to water management has been tested in river basins in different regions and climatic settings around the world. Results have demonstrated the benefits for reducing climate vulnerabilities and strengthening resilience. The lessons from these demonstrations show how tools from ecosystem-based approaches can be used in strategies for climate change adaptation (Bergkamp et al., 2003).

For example, in the Pangani River Basin in Tanzania, over-allocation of water is making water scarcity worse. The 3.4 million people of the basin are vulnerable to projected drying of the climate. With identification of this vulnerability, and backed by a national water policy based on the principles of IWRM, efforts are underway to implement 'environmental flows'. This is an ecosystem-based method for allocating water within the limits of availability, based on negotiation among stakeholders of allocations to different uses and to sustaining ecosystem services (Dyson et al., 2003). Implementation entails developing and coordinating decision-making over water allocation at local to basin scales. Institutional strengthening is thus key, as a means of enabling diverse stakeholders to participate in the discovery of options, in learning and in joint action. Both reduced vulnerability to water scarcity and resilience emerge from this process. Allocation of water to sustain natural infrastructure, such as wetlands and estuary habitats, and adaptive governance provide capacity to deal with uncertain future events.

A second example is from Guatemala, in the high-altitude upper watersheds of the Coatán and Suchiate rivers, which flow off the slopes of the Tacaná volcano to the Pacific Ocean. These watersheds have been deforested and are badly degraded in many places, with severe erosion of formerly deep soils reducing capacity for water retention. Population is high in the upper watersheds and degradation in the environment has led to a narrowing of livelihood options. Communities in the upper and lower watersheds are vulnerable to flooding caused by storms that bring high rainfall intensity, especially tropical storms and hurricanes. Flooding risk is exacerbated by the lost water-storage capacity of the eroded soils which leads to increases in the volume and rate of runoff. Disaster preparedness is a high priority for authorities in strategies for managing climatic variability and climate change adaptation. In addition, communities have formed multi-stakeholder 'micro-watershed councils' that coordinate watershed management among small groups of villages. Driven by the need to expand livelihood options to reduce poverty, these new institutions have led to diversification of farming systems, including terracing of degraded slopes and afforestation through the introduction of agroforestry. Communities are investing their labour and capital in restoration of natural infrastructure. As self-organisation expands, communities are becoming more resilient, with more adaptive capacity and – as new enterprises emerge out of diversification of livelihoods – less sensitive to specific climatic vulnerabilities such as severe storms.

Examples of ecosystem-based adaptation in river basins demonstrate important distinctions between investments in natural and engineered infrastructure. Engineered infrastructure such as dams and reservoirs, or irrigation and inter-basin transfers, lowers exposure, for example, to water scarcity, flood and food insecurity. Such schemes use top-down approaches; and capacities to cope with uncertain future events depend upon the technical tolerances incorporated into infrastructure design and operation. Investing in natural infrastructure can also be climate justified by targeting specific vulnerabilities and may require access to and adoption of new technologies. However, rather than top down, it is system-based. It benefits from vulnerability assessment and may require technologies and financing, but these are combined with capacity building and development of governance that is multi-stakeholder, flexible and adaptive. The quality of institutions complements the quality of technology. Multiple benefits can then emerge, with vulnerabilities reduced as exposure and sensitivity are lowered. Capacity to cope with future uncertainties then improves as system-based resilience rises.

3.4 Avoiding Maladaptation That Degrades Natural Infrastructure

Recognition of the critical role of natural infrastructure in adaptation to climate change impacts on water and resilience brings focus to the importance of preventing maladaptation. These are adaptations that, while addressing a specific vulnerability, end up lowering overall capacities to cope and eroding resilience. Maladaptation thus includes actions that cause natural infrastructure to degrade and weaken ecosystem services needed to lower exposure and sensitivities to climatic variability and change.

The story of the Komadugu Yobe river provides a warning of the dangers of maladaptation associated with infrastructure development that damages resilience. Capacity of communities to cope with stresses, shocks and future change fell after dams and irrigation development caused damage to the river and loss of ecosystem services. Such mistakes are liable to be repeated if the benefits of ecosystem services are not recognized in strategies for climate change adaptation. Any rush to engineer infrastructure for adaptation such as dams, levees, dikes and sea-walls needs to be reconsidered. Instead, comprehensive and resilience-based strategies for infrastructure development are needed which combine sustainable and appropriate investment in portfolios of both engineered and natural infrastructure.

4 Conclusions

Why does the environment matter in climate change adaptation? As water dominates the impacts of climate change, it matters because of the ecosystem services provided by the natural infrastructure of river basins. Healthy rivers, lakes and wetlands, functional floodplains, natural estuarine and coastal structures and groundwater recharge all reduce exposure to climatic hazards. They support livelihoods and economic development that reduce sensitivity to hazards, especially for the most vulnerable. In the hot spots of vulnerability, populations will cope better with climate change impacts on water where natural infrastructure is intact or restored than where it is degraded.

Where management and restoration of river basins and their natural infrastructure is based on multi-stakeholder governance and learning, it builds adaptive capacity. Investing in the institutions needed for flexible, participatory and adaptive management of the environment gives communities – and nations – the means to negotiate and mobilise the decisions needed to reduce vulnerability to climate change.

River basins are more resilient where natural infrastructure provides a diversity of ecosystem services and where institutions empower self-organisation and learning among multiple stakeholders. Such resilience extends to biodiversity because – by reinforcing ecosystem structure and function – ecosystem-based adaptation helps to reduce or delay threats to biodiversity from climate change. Climate change adaptation within a resilience framework will strengthen capacities to cope with uncertain future events. This is vital in a changing climate, when the past is no longer a reliable guide to future climate or hydrology and there is thus a severe lack of adequate information at the scales needed to support decision-making.

There is no claim that natural infrastructure is the sole answer to climate change adaptation. What is needed are portfolios of local actions which include engineered infrastructure (where appropriate and justified) and investments in natural infrastructure. However, dangers arise when adaptation policies fail to incorporate natural infrastructure. Without attention to natural infrastructure and appropriate investments, unforeseen impacts of engineered infrastructure development can increase vulnerabilities and weaken resilience through maladaptation.

In practical terms, policy makers need to be encouraged to ask some critical questions about the environment when developing policy on climate change adaptation:

- how can adaptation ensure economic and social resilience?
- what is the critical national natural infrastructure for climate change adaptation?
- what is the full range of infrastructure options for adaptation – including both engineered and natural infrastructure?
- what investment is needed in natural infrastructure – in term of restoration and management as well as adaptive institutions?
- what infrastructure options are most cost effective – whether natural or engineered – in terms of short-term benefits and long-term resilience?
- what packages of local actions, natural infrastructure and engineered infrastructure will be the best choice and need to be encouraged?

Such questions need to be part of the analysis of policies on climate change adaptation. They need to be asked while placing climate change and adaptation in the context of the economic, security and social priorities that dominate the global political agenda. With climate change weakening capacity to cope with shocks and stresses and thus to address these priorities, a key is for climate change adaptation to increase resilience. With resilience as a goal, the natural infrastructure and the ecosystem services it provides must form the heart of effective strategies for climate change adaptation.

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World Water Council
World Water Forum

co-operative programme on water and climate

IUCN

IWA International Water Association

Perspectives on water and climate change adaptation

Adapting to climate change in water resources and water services in Caribbean and Pacific small island countries

SOPAC

IWCAM Integrating Watershed and Coastal Areas Management in Caribbean Small Island Developing States

GEF

CEHI CARICOM

UNEP

UNDP

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

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

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

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

Participants were invited to contribute perspectives from three categories:

1. **Hot spots** – These papers are mainly concerned with specific locations where climate change effects are felt or will be felt within the next years and where urgent action is needed within the water sector. The hotspots selected are: Mountains (number 1), Small islands (3), Arid regions (9) and 'Deltas and coastal cities' (13).

2. **Sub-sectoral perspectives** – Specific papers were prepared from a water-user perspective taking into account the impacts on the sub-sector and describing how the sub-sector can deal with the issues. The sectors selected are: Environment (2), Food (5), 'Water supply and sanitation: the urban poor' (7), Business (8), Water industry (10), Energy (12) and 'Water supply and sanitation' (14).

3. **Enabling mechanisms** – These documents provide an overview of enabling mechanisms that make adaptation possible. The mechanisms selected are: Planning (4), Governance (6), Finance (11), Engineering (15) and 'Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA)' (16).

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

3 Adapting to climate change in water resources and water services in Caribbean and Pacific small island countries

This document serves as a contribution to the 5th World Water Forum (Istanbul, 2009) from a small island countries' perspective on Topic 1.1 of the Forum: "Adapting to climate change in water resources and water services: understanding the impact of climate change, vulnerability assessment and adaptation measures".

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Adapting to climate change in water resources and water services in Caribbean and Pacific small island countries

Since the 3rd World Water Forum (Kyoto, 2003) the Caribbean and Pacific region have been collaborating as part of the global Dialogue on Water and Climate (DWC) initiative, which works »to improve the capacity in water resources management to cope with the impacts of increasing variability of the world's climate, by establishing a platform through which policymakers and water resources managers have better access to, and make better use of, information generated by climatologists and meteorologists« (www.waterandclimate.org).

Respective dialogues held in each region in preparation for the 3rd World Water Forum resulted in a Joint Programme for Action on Water and Climate (JPfA) which guided the implementation of various coping and adaptation strategies over the past years in Small Island Developing States (SIDS) of the Caribbean and the Pacific (Annex 1).

At the review of the United Nations Barbados Programme of Action for the Sustainable Development of Small Island Developing States (Mauritius, 2005) the Caribbean and Pacific nations reiterated their commitment to SIDS – SIDS cooperation with the Joint Programme for Action for Water and Climate and the international community was invited to support the implementation of the JPfA and broaden it to all Small Island Developing States regions including the Atlantic and Indian Ocean (Annex 2).

The Mauritius strategy highlighted the importance of both water resources and climate change and requested the international community to provide assistance to Small Island Developing States for the implementation of priority actions as submitted to the 3rd World Water Forum Portfolio of Water Actions for small island countries through, amongst others, the Global Environment Facility (GEF), the World Water Assessment Programme (WWAP), the Global Programme of Action (GPA) and the EU 'Water for Life Initiative'.

The results from the Caribbean and Pacific dialogues on water and climate have been documented in the respective synthesis reports.[1] They closely examine the issues to better understand and plan for the impacts of climate change and climate vulnerability on water resources in SIDS, thus providing a solid background for this perspective document for the 5th World Water Forum.

SOPAC[2] and CEHI[3] as lead coordinating agencies for water and sanitation in respectively the Pacific and Caribbean region have formalized their collaboration through a MOU between both organizations signed at Kyoto and have since been working together on a variety of issues related to integrated water resource management and related adaptation to climate change.

Since Kyoto, SOPAC and CEHI have mobilized funding for the implementation of the 3rd World Water Forum's SIDS portfolio of water actions including: Integrated Water Resources Management; Hydrological Cycle Observing System; water demand management; water quality capacity-building; water governance; regional water partnerships; and inter-SIDS water partnerships.

As coordinator for the Pacific & Oceania subregion under the Asia Pacific Water Forum, SOPAC facilitated a review of the Pacific Partnership Initiative on Sustainable Water Management[4] under which the above priority actions were financed in the Pacific and the 3rd progress report of the partnership is guiding the region's contribution to the 5th World Water Forum.

1 Springer (2002) and Scott et al (2002).

2 Pacific Islands Applied Geoscience Commission, www.pacificwater.org.

3 Caribbean Environmental Health Institute, www.cehi.org.lc.

4 The 3rd Partnership Steering Committee Meeting, September 2008, Apia, Samoa.

View from Pigeon Island in Saint Lucia (Donna Spencer).

CEHI in turn is coordinating the Caribbean's position at the 5th World Water Forum through the Americas Regional Process leading to the 5th World Water Forum, with the formulation of a position paper prepared with support from the Inter-American Development Bank (IADB) and the World Bank. Additionally, CEHI continues to strengthen its mandate of integrating watershed and coastal areas management (IWCAM) in the Caribbean region under its programme portfolio and, as such, has undertaken many related activities.

This perspective document will:

1 provide examples of 'no regrets' approaches, applied in small island countries to cope with current climate variability and adapt to future climate change, at different levels ranging from communities, local administrations and national governments.
2 demonstrate the need for a sound knowledge base and information system, as well as a better understanding of the relation between water resources, water and health, and climatic extremes.
3 discuss the need for integrated approaches such as offered by integrated water resources management and drinking water safety planning, and how these concepts can mainstream climate adaptation and should be linked to disaster risk reduction and disaster management.
4 influence policy and decision-makers of small island countries, and mobilize increased efforts to take funding for adaptation in the water sector up in the broader development finance discussions.

In general the perspective document aims to provide further guidance to the efforts in SIDS regions in coping and adaptation related to water resources management and provision of water services.

The first chapter deals with general water and climate issues in small island countries. Chapter Two examines the coping and adaptation strategies adopted by SIDS and the advances made in implementation and the need to mainstream climate adaptation into water resources management and disaster risk reduction. The final chapter deals with the political will and need for additional financing to the water and sanitation sector.

1 Water and climate in small island countries

Small island countries are no different from other countries in that freshwater is essential to human existence and a major requirement in agricultural and other commercial production systems. However, the ability of the island countries to effectively manage the water sector differs in Small Island Developing States (SIDS), as they are constrained by their small size, isolation, fragility, natural vulnerability, and a limited human, financial and natural resource base.

Increasingly variable rainfall, cyclones / hurricanes, accelerating storm water runoff, floods, droughts, decreasing water quality and increasing demand for water are so significant in many small island countries that they threaten the economic development and the health of their peoples.

Flooding in Fiji's Rewa Delta (Photo by Marc Overmars).

The Intergovernmental Panel on Climate Change (IPCC) continues to report that expected climatic changes will stimulate an increase in extreme weather events that include higher maximum temperatures, increased number of hot days, more intense rainfall over some areas, increased droughts in others, and an increased frequency and severity of tropical cyclones / hurricanes. Although global climate predictions are being made through advanced models the uncertainty over the expected climate changes for small island countries is hampering an adequate response. Low skill levels of climate forecasts are preventing reliable predictions exceeding a period of 3 months. However, the expected increase in climatic extremes should provide sufficient incentives to 'no regrets' approaches dealing with both floods and droughts.

Although the contribution of small island countries to greenhouse gas emissions is globally insignificant and rank amongst the lowest in the world, the islands face arguably the heaviest and most immediate burden of climate change such as sea storm surges and sea level rise affecting the low lying atoll islands in the Pacific and in the Caribbean as well.

Unless something is done soon, the severe water problems across both the Pacific and Caribbean regions will considerably worsen under the influence of climate change. This message was conveyed by several Pacific leaders attending the 1st Asia Pacific Water Summit[5] hosted by Japan in December 2007, and shared by high-level delegates at the October 2007 launch of the initiative for the development of a

Accessible technology solutions, such as this wetlands filtration system, are being constructed in Saint Lucia as part of an overall approach to managing wastewater in a changing climate. (Photo by Donna Spencer).

Glacial melt, water and SIDS

The impacts of glacial melt on SIDS are predicted to be especially destructive, both in the short and long-term, including changes in water temperature, salinity, and sea level rise. The GEF-Funded Mainstreaming Adaptation to Climate Change (MACC) project highlighted some of these impacts as:

- Beach erosion: As the sea level rises, more of the Caribbean SIDS beaches will be reclaimed by the Atlantic Ocean and Caribbean Sea.
- Salinisation of soil, aquifers, and estuaries: Sea level rise will bring salt and brackish waters into the soil, aquifers and estuaries, thus threatening drinking water supplies, agriculture, and important coastal ecosystems.
- Degradation of mangroves, seagrass beds and coral reefs: The degradation would be caused by the salinisation and beach erosion, as mentioned above. Additionally, the sea level rise will translate into a diminished amount of light reaching coral reefs and sea grass beds. The consequence of their destruction is far reaching, including decreased fish stocks that live and feed in and around the reefs; elimination of natural protection from storm surges; decreased tourism activities on the reefs, such as snorkeling, scuba diving, and fishing; and a decrease in valuable biological diversity.
- Enhanced storm surges: To further complicate the matter of diminished protection from storm surges, as mentioned above, the higher sea level, combined with other climatic changes, will bring about enhanced storm surges, wrecking more havoc on coastal ecosystems and communities than before.
- Coastal inundation: With over 90% of populations and economic activities located in the coastal zones of Caribbean SIDS, flooding will have a negative impact on economic livelihoods and human life.

[5] Message from Beppu, 1st Asia Pacific Water Summit, December 2007, Beppu.

Caribbean Regional Climate Change Strategy at the CARICOM Secretariat in Guyana.

1.1 Challenges and constraints

The challenges and constraints of sustainable water resources management in Pacific and Caribbean island countries and territories were categorized into three broad thematic areas at the regional consultation on Water in Small Island Countries held in preparation for the 3rd World Water Forum in Kyoto 2003 . These are:

1 Pacific and Caribbean island countries and territories have uniquely fragile water resources due to their small size, lack of natural storage. Competing land use and vulnerability to natural and anthropogenic hazards, including drought, cyclones and urban pollution. This requires detailed water resources monitoring and management and improving collaboration with meteorological forecasting services;
2 Water service providers face challenging constraints to sustaining water and wastewater provision due to the lack of both human and financial resource bases, which restrict the availability of experienced staff and investment, and effectiveness of cost recovery. Future action is required in human resources development, water demand management and improving cost recovery;
3 Water governance is highly complex due to the specific socio-political and cultural structures relating to traditional community, tribal and inter-island practices, rights and interests. These are all interwoven with past colonial and 'modern' practices and instruments. These require programmes to develop awareness, advocacy, and political will at all levels to create a framework for integrated water resources management.

Water Utilities in SIDS, such as these technicians from St. Kitts, are working to address increasing demand and the challenges of climate change. (Photo by Halla Sahley)

1.2 Joint programme for action on water & climate

In March 2003, ADB and SOPAC facilitated the Water in Small Island Countries sessions at the 3rd World Water Forum. The global SIDS position that resulted from these sessions was mainly the result of the Dialogue on Water & Climate (DWC) session which linked the Pacific and Caribbean regions together on water and climate issues.

The close collaboration between the Caribbean and Pacific regions during preparatory work for the 3rd World Water Forum resulted in the formation of the Joint Caribbean-Pacific Programme for Action on Water & Climate (JPfA).

The JPfA comprises 22 action elements, common to both the Pacific and Caribbean regional consultation outcomes, covering four collaborative areas: research, advocacy and awareness, capacity-building and governance. From this immediate priority, actions were identified in six areas. The JPfA takes an Integrated Water Resources Management approach to addressing water and climate issues in SIDS, as demonstrated by the Integrating Watershed and Coastal Area Management (IWCAM) in the Caribbean, under CEHI and now accompanied by the Pacific Sustainable Integrated Water Resources and Wastewater Management Programme (Pacific IWRM) under SOPAC. The JPfA promotes the transfer of knowledge, expertise, positional statements and personnel between the two regions to the benefit of the 34 countries involved.

Raised limestone island of Nauru which is depending on rain-water harvesting and desalination. (Photo by Marc Overmars)

At the 3rd World Water Forum global SIDS agreed to six priority actions, referred to as the Small Island Countries Portfolio of Water Actions namely:

- Water resources management through the Hydrological Cycle Observing System (HYCOS);
- Water demand management programme;
- Drinking water quality monitoring;
- Improving water governance;
- Regional Type II Water Partnership support;
- Interregional SIDS water partnership support through the JPfA.

2 Vulnerability and adaptation assessments

As reported in the Pacific Synthesis Report on Water and Climate (Scott et al, 2002) vulnerability and adaptation assessments in relation to climate change are required of signatory countries to the United Nations Framework Convention on Climate Change (UNFCCC). The Pacific Islands Climate Change Assistance Programme (PICCAP) was developed to assist with the reporting, training and capacity-building required under the Convention. Climate Change Country Teams established under PICCAP undertook to:

- prepare inventories of greenhouse gas sources and sinks;
- identify and evaluate emission reduction strategies;
- assess vulnerability to climate change;
- develop adaptation options;
- develop a national implementation strategy for mitigating and adapting to climate change in the long term.

In a synthesis of Pacific preliminary national vulnerability assessments, Hay and Sem (2000) note the following adaptations with relevance to water resources, which are also applicable to Caribbean SIDS:

- Improved management and maintenance of existing water supply systems has been identified as a high priority response, due to the relatively low costs associated with reducing system losses and improving water quality;
- Centralized water treatment to improve water quality is considered viable for most urban centres, but at the village level it is argued that more cost-effective measures need to be developed;
- User-pay systems may have to be more widespread;
- Catchment protection and conservation are also considered to be relatively low cost measures that would help ensure that supplies are maintained during adverse conditions. Such measures would have wider environmental benefits, such as reduced erosion and soil loss and maintenance of biodiversity and land productivity.
- Drought and flood preparedness strategies should be developed, as appropriate, including identification of responsibilities for pre-defined actions;
- While increasing water storage capacity through the increased use of water tanks and/or the construction of small-scale dams is acknowledged to be expensive, the added security in the supply of water may well justify such expenditure;

Jamaicans crossing the Hope River following flooding from Hurricane Gustav. (Photo by Franklin McDonald)

Poor, unregulated settlements on the river's edge in Haiti are highly prone to flooding. (Photo by Vincent Sweeney)

- Development of runways and other impermeable surfaces such as water catchments is seen as possible, but an extreme measure in most instances. Priority should be given to collecting water from the roofs of buildings;
- Measures to protect groundwater resources need to be evaluated and adopted, including those that limit pollution and the potential for saltwater intrusion;
- The limited groundwater resources that are as yet unutilized in the outer islands of many countries could be investigated and, where appropriate, measures implemented for their protection, enhancement and sustainable use;
- The development of desalination facilities is considered to be an option for supplementing water supplies during times of drought, but in most instances the high costs are seen as preventing this being considered as a widespread adaptation option.

Amongst the many assessment findings summarized by Hay (2000) the following are most relevant to water and climate:

- climate variability, development, social change and the rapid population growth being experienced by most small island countries are already placing pressure on sensitive environmental and human systems, and these impacts would be exacerbated if the anticipated changes in climate and sea level (including extreme events) did materialize;
- land use changes, including settlement and use of marginal lands for agriculture, are decreasing the natural resilience of environmental systems and hence their ability to accommodate the added stresses arising from changes in climate and sea level;
- given the limited area and low elevation of the inhabitable lands, the most direct and severe effects of climate and sea level changes will be increasing risks of coastal erosion, flooding and inundation; these effects are exacerbated by the combination of seasonal storms, high tides and storm surges;
- other direct consequences of anticipated climate and sea level changes will likely include: reduction in subsistence and commercial agricultural production of such crops as taro, bananas and coconut; decreased security of potable and other water supplies; increased risk of dengue fever, malaria, cholera and diarrhoeal diseases; and decreased human comfort, especially in houses constructed in western style and materials (especially in the Pacific);
- groundwater resources of the lowlands of high islands and atolls may be affected by flooding and inundation from sea level rise; water catchments of smaller, low-lying islands will be at risk from any changes in frequency of extreme events;
- the overall impact of changes in climate and sea level will likely be cumulative and determined by the interactions and synergies between the stresses and their effects; and
- the current lack of detailed regional and national information on climate and sea level changes, including changes in variability and extremes have resulted in most assessments being limited to using current knowledge to answer 'what if' questions regarding environmental and human responses to possible stresses.

The first of these findings is particularly significant since it implies that, in most parts of the Pacific and Caribbean regions, present problems resulting from increasing demand for water and increasing pollution of water may be much more significant that the anticipated affects of climate change.

The final finding is also significant in that it refers to climate variability. In reporting obligations, The UNFCCC referred specifically to climate change (rather than to climate variability and change), possibly reflecting the perspective of climate change science existing at the time the Convention was drafted. A greater appreciation of the role of variability has developed and it is now generally recognized that the impacts of climate change are likely to be experienced through changes in variability. These considerations suggest that managing water resources for variability and extremes is fundamental to the issue of adapting to climate change in the longer term.

That conclusion is also supported by the vulnerability and adaptation assessments completed for Fiji and Kiribati (World Bank, 2000) which provide examples of climate change impacts on water resources in high and low islands and reach the conclusions that:

- Pacific Island countries are already experiencing severe impacts from climate events;
- island vulnerability to climate events is growing independently of climate change;
- climate change is likely to impose major incremental social and economic costs on Pacific Island countries; and
- acting now to reduce present day vulnerability could go a long way toward diminishing the effects of future climate change.

In the Caribbean region the impacts of rising temperatures are being linked to the recent and very active hurricane seasons which have spawned several intense hurricanes resulting in billions of dollars in damage and thousands of deaths caused mainly by flooding. Of the Caribbean countries, Haiti has suffered the extreme consequences on account of the severe degradation of its forests with great loss to life and property.

Some key recommendations derived from these conclusions include:

- the adoption of a 'no regrets' adaptation policy;
- development of a broad consultative process for implementing adaptation;
- require adaptation screening for major development projects;
- strengthen socio-economic analysis of adaptation options.

These recommendations reflect the need for the mainstreaming of climate change adaptation policies into water resources management.

The guidebook on 'Surviving Climate Change in Small Islands' provides an overview for the assessment of vulnerability of water resources to climate changes (Emma L. Tompkins et al, 2005).

Table1: Assessment of vulnerability.

Climate change	Exposure	Who or what affected
Sea level rise and saltwater intrusion	Salinisation of water lenses	Human consumption and health
	Less fresh water available	Water suppliers
		Plant nurseries and parks
		Biodiversity, protected areas
Reduced average rainfall	Less fresh water available	Aquifer recharge rates
	Droughts	Cisterns and reservoirs
		Biodiversity
Increased evaporation rates	Soil erosion	Farming community; crop yields
		Biodiversity
Increased rainfall intensity	Runoff and soil erosion	Reduction in crop production
		Sedimentation of water bodies
		Blocked storm water wells

Adapted from: Hurlston (2004).

The table above shows that climate change is likely to increase the exposure of small islands to water shortages for various reasons. Specific groups are likely to be sensitive, for example, those who rely on subsistence agricultural production and families who rely on cisterns may have to consider other means of accessing water.

3 Coping and adaptation

The Global Water Partnership states in their latest policy brief that the best approach to manage the impact of climate change on water is that guided by the philosophy and methodology of Integrated Water Resources Management (GWP, 2007). It also states that the best way for countries to build the capacity to adapt to climate change will be to improve their ability to cope with today's climate variability.

For small islands, climate change is just one of many serious challenges with which they are confronted. Adaptation to climate change impacts certainly requires integration of appropriate risk reduction strategies within other sectoral policy initiatives such as in water resources management (Emma L. Tompkins et al, 2005).

In the Pacific region, concentration on the potential impacts of climate change on small island communities has even deflected attention and resources away from the immediate and serious day-to-day problems faced by small island nations, particularly in water resources (White I. et al, 2007). The above obviously does not preclude the application of coping strategies and adaptation measures to climate variability and change, which, on the contrary, is essential for the sustainable management of water resources in small island countries and territories.

Regarding the vulnerability of small island countries and territories to climate variability and change as well as anthropogenic influences, the required coping and adaptation strategies have been articulated under a specific theme of 'Island Vulnerability' in the Pacific Regional Action Plan on Sustainable Water Management (SOPAC, 2002) as follows:

Raised limestone island of Niue also known as the 'Rock of Polynesia'. (Photo by Marc Overmars)

Many islanders rely on coastal resources. (Photo by Marc Overmars)

- **Key Message 1:** Strengthen the capacity of small island countries to conduct water resources assessment and monitoring as a key component of sustainable water resources management.
- **Key Message 2:** There is a need for capacity development to enhance the application of climate information to cope with climate variability and change.
- **Key Message 3:** Change the paradigm for dealing with Island Vulnerability from disaster response to hazard assessment and risk management, particularly in Integrated Water Resource Management (IWRM).

Actions have been undertaken to address each of the key messages not only in the Pacific but also in other SIDS regions.

3.1 Water resources monitoring and assessment

There is a need to invest in adequate water resources monitoring and assessments in order to cope with climatic extremes, both droughts (often related to ENSO events) and flooding (often linked to the occurrence of cyclones/hurricanes).

Insufficient understanding and knowledge on how rivers respond to extreme rainfall or how resilient aquifers are in prolonged periods of drought will compromise the provision of freshwater supplies. This requires the increased capacity of National Hydrological Services in flood and drought forecasting as well as a stronger collaboration between them, water resources managers and water utilities.

Awareness of the effects of floods and droughts on drinking water quality needs to be increased through closer engagement between water users and water suppliers. Increased health surveillance and water quality monitoring should be encouraged especially in times of disasters.

As examples, the Pacific and Caribbean Hydrological Cycle Observing Systems are now being established through support from the European Union Water Facility and the French Government respectively. Water quality monitoring is being supported through NZAID in the Pacific, and the Institut de recherche pour le développement (France), the Caribbean Environmental Health Institute and the Caribbean Institute for Meteorology and Hydrology in the Caribbean region.

The Pacific HYCOS programme is providing support to National Hydrological Services in the region and is building their capacity in flood and drought forecasting as well as in basic monitoring of water resources. This information is essential for any climate adaptation initiative whether they focus on domestic (water supply), agricultural (irrigation) or industrial (hydropower) use of water. The need for thorough analysis of hydro(geo)logical information and water quality, as well as water quantity data, is frequently overlooked by adaptation programmes which sometimes make assumptions on the impacts of climate on water resources without adequate research. If we do not know how aquifers respond to droughts or how rivers respond to floods it will be impossible to make sensible decisions on adaptation measures which are aiming to deal with the increase of climatic extremes.

The Carib-HYCOS project seeks to enhance natural disaster mitigation capabilities by the use of modern flood forecasting and warning systems; strengthen water management capabilities by improving the knowledge base of water resources concerning quantity, quality and use; increase exchange of information and experience, particularly during natural disasters; and develop technological capabilities (including training and technology transfer) appropriate to the circumstances and realities of each country. It is expected that the project implementation will result in: (a) better understanding of the regional hydrological phenomena and trends in order to rationalize the use of water resources; (b) modernization of the region's water resources agencies and their response capability to extreme phenomena; (c) integration of these agencies into the region's development decision-making; and (d) improved cooperation among the region's national water agencies, including the real-time circulation of water and environment data.

Water resources on atoll islands like South Tarawa in Kiribati are being affected by climate variability and change. (Photo by Marc Overmars)

Water Quality Monitoring in Dominica. (Photo by Sasha Beth Gottlieb)

Hydrological monitoring, such as on the island of Espirito Santo, Vanuatu, is essential for water resources management in small island countries. (Photo by Marc Overmars)

3.2 Using climate information

There is a need to make use of climate forecasts to support decision-makers in the water sector. Research into the interaction of the ocean and atmosphere over the last two decades has resulted in an impressive ability to observe and account for many of the factors governing climatic variability at the seasonal and inter-annual time scale.

National Meteorological Services are being strengthened in their capacity to develop techniques that are able to produce climate forecasts of modest skill, but this information is not easily accessible and available for interpretation by water resources and water supply managers. Particularly for the rainfall dependent low lying atoll islands, strategies to cope with extended periods of drought will largely depend on their ability to make interpretations of three-monthly rainfall forecasts.

Strategic storage of rainwater and the introduction of water saving or water conservation measures adopted by both the utility and the general public, will enhance the ability of Pacific and Caribbean island countries and territories to overcome droughts and maintain sufficient standards of drinking water quality.

The Pacific Island Climate Update (ICU) supported by NZAID provides such information to end-users in the Pacific in a regional overview, whereas the strengthening of NMSs is being undertaken under an AusAID-funded climate prediction programme. Both are linked to climate centres in the Pacific islands, the United States, France, Australia and New Zealand.

In the Caribbean, a joint collaboration between the Caribbean Community Climate Change Centre (CCCCC), the Caribbean Institute for Meteorology and Hydrology (CIMH) and the Brace Center for Water Resources Management of McGill University will see the development of a Caribbean Drought and Precipitation Monitoring Network for the region that will be hosted at the CIMH.

Through the analyses of rainfall data and use of GIS in Tuvalu, under the Pacific HYCOS programme, support is provided to an AusAID and EU-funded initiative, Vulnerability and Adaptation, to provide all households on the main atoll of Funafuti with a rainwater harvesting tank in order to provide a strategic water storage to overcome extended periods of droughts which are often linked to ENSO episodes. The UNEP, through CEHI, is supporting similar efforts in Caribbean SIDS by using GIS-assisted mapping methods of rainfall capture potential and water availability to promote the practice of rainwater harvesting in water stressed parts of the region.

Outer islands in the Pacific are depending on increasingly variable rainfall (Photo by Marc Overmars)

Rainwater harvesting such as on Banaba, Kiribati (l) and Mabouya Valley, Saint Lucia (r) has been under utilised in many small island countries. (Photos by Marc Overmars and Donna Spencer)

3.3 Mainstreaming risk management

There is a need to mainstream risk management into water supply and water resources management, building on the integrated approaches adopted by Pacific and Caribbean island countries and territories such as Drinking Water Safety Planning (DWSP) and Integrated Water Resources Management.

Drinking Water Safety Planning is defined as "a comprehensive risk assessment and risk management approach that encompasses all steps in the water supply from 'catchment to consumer' to consistently ensure the safety of water supplies" (WHO, 2004). It addresses all aspects of drinking water supply through an integrated approach focusing on the control of abstraction, treatment and delivery of drinking water in combination with attention for awareness and behaviour change.

This requires close collaboration between the water supplier, the water quality and health regulator and the water resources managers in conjunction with a strong participation of communities living in catchments of high volcanic islands, on top of water reserves, low lying atolls or raised limestone islands. Improved hygiene behaviour and awareness of the linkages between drinking water and health are essential, and participatory approaches and community-based monitoring are needed for urban as well as rural communities.

Pollution of vulnerable groundwater lenses are a major concern for many small island countries. (Photo by Marc Overmars)

The introduction of DWSP is promoted in the Pacific through an AusAID-funded programme by SOPAC in collaboration with WHO, whereas the U.S. Centers for Disease Control and Prevention (CDC) is promoting this new concept together with CEHI in the Caribbean.

Children are particularly vulnerable to the adverse impacts of climate change, felt in the lower reaches of watersheds, such as the Haina Watershed in the Dominican Republic. (Photo by Donna Spencer)

An example of an appropriate adaptation strategy for water is provided by Tonga where the nationally-developed Drinking Water Safety Plan by the Tonga Water Board and the Ministry of Health guided the scoping of an EU-funded drought resilience building project valued at 1.1 million euros focused on risk prevention instead of response. In the Caribbean, the Spanish Town water supply system in Jamaica was the first pilot of a DWSP approach through the joint collaboration between the local National Water Commission and the CDC. The approach is presently being replicated in Guyana (part of the Caribbean yet on the South American mainland), again in partnership with the CDC and CEHI. The collective experiences of both countries will be applied when introducing the process to the other Caribbean SIDS.

The concept and the approaches which IWRM embodies - namely, the need to take a holistic approach to ensure the socio-cultural, technical, economic and environmental factors are taken into account in the development and management of water resources - has been practiced at a traditional level for centuries in some islands.

For small island countries and territories these IWRM plans would need to include drought and disaster preparedness plans. Pollution on land from inadequate wastewater disposal, increased sediment erosion and industrial discharges are impacting upon coastal water quality and fisheries stock which sustain entire island populations. This requires small island countries and territories to look at managing water resources not only within the watershed but also the receiving coastal waters.

The introduction of IWRM in SIDS is being promoted through the GEF-IWCAM Programme by CEHI and the Pacific IWRM Programme by SOPAC under the Global Environment Facility and EU Water Facility.

Through close alignment of climate adaptation programmes also funded through the GEF in the Caribbean (CPACC, MACC, and SPACC) and the Pacific (PACC) the opportunity arises to ensure that flood and drought management is being addressed in the countries concerned within an IWRM framework. Use can be made of the established APEX bodies that can function as National Water and Climate Committees and steering committees for both adaptation and integration of water resources management.

At present there is still a disconnect between risk management, climate adaptation and water resources management with receiving small island countries, donors and supporting agencies working in different silos foregoing the principles of mainstreaming in ongoing natural resources management processes.

This needs to be changed through interventions at the highest levels such as through the Prime Minister's Office, Ministries of Planning or Finance and guided by a sound information base on water and climate.

4 Political will and financing

It is generally recognized that improving the way we use and manage our water today will make it easier to address the challenges of tomorrow. With respect to climate change it is evident that SIDS will have to deal with the current challenges and constraints including climate variability before they can adapt to future climate changes.

A recent WHO/SOPAC report revealed that the annual incidence of diarrhoeal diseases in the Pacific still nearly matches the numbers of its inhabitants with 6.7 million cases of acute diarrhoea each year, responsible for the annual death of 2,800 people, most of them children less than 5 years old. Country statistics on access to improved sanitation and improved drinking water indicate that on average approximately only half of the total population of the Pacific island countries are served with any form of improved sanitation or drinking water (WHO/SOPAC, 2008).

Providing safe drinking water to communities is posing increasing challenges to small island countries. (Photo by Marc Overmars)

In the Caribbean, flood events associated with successive tropical storms and hurricanes in recent years have prompted stepped-up surveillance and monitoring by national public health agencies in terms of control of outbreaks of dengue fever and diarrhoeal diseases. Although in most countries of the Caribbean access to potable drinking water is upwards of 80% (with the exception of Haiti), interruptions to water supply following storms is a significant risk factor in terms of maintaining health and sanitation.

The 1st Asia-Pacific Water Summit held in December 2007 in Beppu, Japan, was attended by six Pacific Island Leaders from the Federated States of Micronesia, Palau, Tuvalu, Nauru, Niue and Kiribati, as well as Ministers from Fiji, the Cook Islands and Papua New Guinea. SOPAC, as focal point for the Oceania component of the Asia-Pacific Water Forum, provided support to countries participating in the

Summit and facilitated a special session on water and climate in small island countries.

The large participation by Pacific Heads of State at this Summit was a testament of their strong political commitment to meeting future water challenges and their efforts to cope with an increasingly variable climate, and adapt to the future effects of global climate change.

The Pacific leaders attending the summit in Beppu reaffirmed their commitment to give the highest priority to water and sanitation in economic and development plans; improve governance, efficiency, transparency and equity in all aspects related to the management of water, particularly as it impacts on poor communities; take urgent and effective action to prevent and reduce the risks of flood, drought and other water-related disasters; and support the region's vulnerable small island states in their efforts to protect lives and livelihoods from the impacts of climate change (APWF, 2007).

The Summit specifically raised attention to the opportunity that presents itself at this moment: to mainstream Climate Adaptation, Disaster Risk Reduction and Water Safety Planning into Integrated Water Resources Management.

The commitment shown at Beppu still needs to be converted into action but signs of countries linking national priorities such as improving access to safe drinking water and sanitation to climate adaptation efforts and risk reduction are promising, such as in Tuvalu, Kiribati, Tonga, the Marshall Islands and Nauru.

Commitments from donors to increase funding for both climate adaptation and water and sanitation are promising as demonstrated by AusAID, EU, GEF, World Bank and other donor agencies. Rather than implementing 'quick fixes' focused on infrastructural improvements, adequate attention should be paid to the building of local capacity to improve the management of water services and resources in order to achieve a degree of sustainability of interventions.

Climate change issues are addressed at the regional level by the Council for Trade and Economic (COTED) of the Caribbean Community (CARICOM). Additionally, Caribbean Heads of Government have included climate change as a specific item on the agenda of their meetings. Currently, the Prime Minister of Saint Lucia has the responsibility within the CARICOM Cabinet for climate change and sustainable development issues. At the last Caribbean Heads of Government meeting (July 2008), a Regional Task Force on Climate Change was established to provide technical advice to participants, specifically focusing on COPS negotiations.

Improving access to water and sanitation requires political will (Photo by Marc Overmars)

Combined with adequate priority given to water and sanitation in national development plans and strategies, these actions will provide the best approaches to achieve the MDG target of halving the proportion of people without access to safe drinking water and basic sanitation by 2015 and to be prepared for the future. Harmonization of donor agency programmes are in this respect key to maximizing the impact of actions, and this would need to be supported by a regional framework for monitoring investments and results.

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Annex 1

JOINT CARIBBEAN AND PACIFIC PROGRAMME FOR ACTION ON WATER AND CLIMATE

A. RESEARCH (11 Action Elements)

1) Strengthen the application of climate information and strengthen the links between meteorological and hydrological services;
2) Strengthen institutional capacity for data generation;
3) Develop rainfall and drought prediction schemes based on existing models;
4) Enable regional support to develop water application of climate information and prediction;
5) Implement a programme of climate analysis for assessment of extreme weather events; develop minimum standards for risk assessments;
6) Implement actions to strengthen national capacity (equipment, training, etc.) using the model outlined in the Pacific Hydrological Cycle Observation System (HYCOS) proposal and recommendations regarding water quality;
7) Implement a programme of targeted applied research projects to address knowledge gaps in line with recommendations and priorities presented;
8) Develop and/or implement minimum standards for conducting island water resources assessment and monitoring;
9) Implement appropriate water quality testing capability and associated training at local, national and regional levels;
10) Strengthen and enhance communication and information exchange between national agencies involved with meteorological, hydrological and water quality data collection programmes (including water supply agencies and health departments);
11) Utilize the research capabilities at regional science institutions;

B. PUBLIC EDUCATION, AWARENESS AND OUTREACH (4 Action Elements)

1) Provide high level briefings on the value of hazard assessment and risk management tools;
2) Support community participation in appropriate water quality testing programmes targeted at environmental education and awareness of communities, using existing and proposed programmes as models;
3) Recognize the value of informal community groups;
4) Include the media as a specific institution.

C. EDUCATION AND TRAINING (2 Action Elements)

1) Enhance education and career development opportunities in the water sector;
2) Implement hydrological training for technicians in line with the recommendations presented in a proposal to meet training needs;

D. POLICY AND INSTITUTIONAL DEVELOPMENT (5 Action Elements)

1) Build environment to facilitate the emergence of an IWRM framework;
2) Incorporate the community in policy development at the ground level;
3) Build capacity in the use of a risk management approach to integrated resource management, in EIAs;
4) Develop appropriate policy/legislative instruments;
5) Harmonize legislation, regulations and policy.

Annex 2

Mauritius Strategy for the Further Implementation of the Programme of Action for the Sustainable Development of Small Island Developing States

Port Louis, Mauritius, 15 January 2005

V. Freshwater resources

27. Small Island Developing States continue to face water management and water access challenges, caused in part by deficiencies in water availability, water catchment and storage, pollution of water resources, saline intrusion (which may be exacerbated, *inter alia*, by sea-level rise, unsustainable management of water resources, and climate variability and climate change) and leakage in the delivery system. Sustained urban water supply and sanitation systems are constrained by a lack of human, institutional and financial resources. The access to safe drinking water, the provision of sanitation and the promotion of hygiene are the foundations of human dignity, public health and economic and social development and are among the priorities for Small Island Developing States.

28. Small Island Developing States in the Caribbean and the Pacific regions have demonstrated their commitment to SIDS – SIDS cooperation with the Joint Programme for Action for Water and Climate. The international community is invited to support the implementation of this programme, and the proposal to broaden it to all Small Island Developing States regions.

29. Further action is required by Small Island Developing States, with the necessary support from the international community, to meet the Millennium Development Goals and World Summit on Sustainable Development 2015 targets on sustainable access to safe drinking water and sanitation, hygiene, and the production of integrated water resources management and efficiency plans by 2005.

30. The international community is requested to provide assistance to Small Island Developing States for capacity-building for the development and further implementation of freshwater and sanitation programmes, and the promotion of integrated water resources management, including through the Global Environment Facility focal areas, where appropriate, the World Water Assessment Programme, and through support to the Global Programme of Action Coordination Office and the EU "Water for Life Initiative".

31. The Fourth World Water Forum, to be held in Mexico City in March 2006, and its preparatory process will be an opportunity for the Small Island Developing States to continue to seek international support to build self-reliance and implement their agreed priority actions as submitted to the Third World Water Forum Portfolio of Water Action, namely: integrated water resources management (including using the Hydrological Cycle Observing System); water demand management; water quality capacity-building; water governance; regional water partnerships; and inter-small island developing State water partnerships.

World Water Council
World Water Forum

co-operative programme on water and climate

IUCN

IWA International Water Association

Perspectives on water and climate change adaptation

Better water resources management – Greater resilience today, more effective adaptation tomorrow

Global Water Partnership

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

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

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

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

Participants were invited to contribute perspectives from three categories:

1 **Hot spots** – These papers are mainly concerned with specific locations where climate change effects are felt or will be felt within the next years and where urgent action is needed within the water sector. The hotspots selected are: Mountains (number 1), Small islands (3), Arid regions (9) and 'Deltas and coastal cities' (13).

2 **Sub-sectoral perspectives** – Specific papers were prepared from a water-user perspective taking into account the impacts on the sub-sector and describing how the sub-sector can deal with the issues. The sectors selected are: Environment (2), Food (5), 'Water supply and sanitation: the urban poor' (7), Business (8), Water industry (10), Energy (12) and 'Water supply and sanitation' (14).

3 **Enabling mechanisms** – These documents provide an overview of enabling mechanisms that make adaptation possible. The mechanisms selected are: Planning (4), Governance (6), Finance (11), Engineering (15) and 'Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA)' (16).

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

4 Better water resources management – Greater resilience today, more effective adaptation tomorrow

A Perspective Paper contributed by the Global Water Partnership through its Technical Committee.

This perspective paper was prepared under the direction of the Technical Committee of the Global Water Partnership. TEC members Claudia Sadoff and Mike Muller served as lead authors, with additional inputs and commentary from the TEC Chair, other TEC colleagues and a GWP-wide working group on climate change adaptation.

The paper is the second contribution of a GWP programme of work to review different aspects of water use and management relating to climate change. It builds on Policy Brief 5, "Climate Change Adaptation and Integrated Water Resource Management – An Initial Overview", released in 2007, which has benefited from CPWC's publication «Climate Changes the Water Rules», and is intended as a preliminary articulation of the framework that GWP will utilize for its work on climate change adaptation under its new strategy for the period 2009–2013. The preliminary ideas and concepts outlined in this perspective paper will be further developed in a full TEC background paper on the subject to be published during 2009. The background paper will also provide examples and identify, through the GWP partnership network, some of the region-specific dimensions of the challenge and the particular interventions that are required at each level.

The paper complements a series of background papers and policy and technical briefs prepared by the Global Water Partnership through its Technical Committee. These publications can be downloaded from www.gwpforum.org or hard copies can be requested from gwp@gwpforum.org.

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Water is a primary medium through which climate change will have an impact on people, ecosystems and economies. Water resources management should therefore be an early focus for adaptation to climate change. Water resources management does not hold all of the answers to adaptation, a broad range of responses will be needed. But water is both a key part of the problem, and an important part of the solution. It is a good place to start.

Improved understanding of the dynamics of climate change as it affects water supply and demand and the broader impacts on all water-using sectors will guide better water resources management. This will in turn build resilience to current climate variability, while building capacity to adapt to future climate change. Water is recognized to be key to the achievement of many of the Millennium Development Goals. So better water resource management is a cost-effective strategy; delivering immediate benefits to vulnerable and underserved populations, while strengthening systems and capacity for longer-term climate risk management.

Achieving and sustaining water security – broadly defined as harnessing water's social and productive potential and limiting its destructive potential – provides a focus for adaptation strategies and a framework for action. For countries that have not achieved a reasonable level of water security, climate change will make it harder. For those who have enjoyed significant levels of water security, it may prove hard to sustain. All are likely to need to channel additional resources to water resource management.

A water secure world will need better information and stronger institutions, as well as investment in infrastructure – small and large scale – to store and transport water. It will require balancing equity, environmental and economic priorities; and 'soft' (institutional and capacity) as well as 'hard' (infrastructure) responses. It will need appropriate attention to both natural and man-made storage options. It will require actions and innovations at all levels: in projects, communities, nations, river basins and globally. Integrated water resources management offers an approach to manage these dynamics, and a thread that runs up and down these levels of engagement.

Financial resources are needed to build a water secure world. Sound water management, which is a key to adaptation, is weakest in the poorest countries, those with the greatest climate variability today, and those predicted to face the greatest negative impacts of climate change. Investment in national water resources management capacity, institutions and infrastructure should therefore be a priority for mainstream aid, as well as for sustainable development financing that delivers adaptation benefits.

In some transboundary basins the best adaption investments for any individual country may lay outside its borders, for example in basin-wide monitoring systems or investments in joint infrastructure and/or operating systems in a neighbouring country. To the extent that specialized adaptation funds are made available, they should go beyond single-country solutions to generate public goods and to promote cooperative transboundary river basin solutions.

1 Water resources and adaptation: Framing the issue

Many of the anticipated impacts of climate change will operate through water. Changing rainfall and river flow patterns will affect all water users; shifting rainfall patterns will affect cropping systems and the prevalence of vector-borne diseases such as malaria; increased uncertainty and shifting crop water requirements will threaten poor rainfed farmers in particular; intensification of droughts, floods, typhoons and monsoons will make many more people more vulnerable; while risks and uncertainties are growing around water-borne disease incidence, glacier melt, glacier lake outburst flood risks and sea level rise.

These impacts are the consequence of the way in which the hydrological cycle is expected to be affected by climate change. While in many cases, the impact cannot yet be proven, the long-term nature of water resource management means that responses need to start now. This will require enhanced understanding of water resources to inform well-directed management and investment interventions. The benefit will be that these interventions will also help to manage current climate variability and shocks, particularly in the world's poorest countries.

1.1 Water is a primary medium for climate change impacts

The Ministerial Declaration of the Second World Climate Conference states "...that among the most important impacts of climate change were its effects on the hydrologic cycle and on water management systems and, through these, on socio-economic systems." (Second World Climate Conference, 1990)

A 'leverage' effect could see relatively small temperature changes leading to a 10 – 40% increase in average river flows in some regions and a 10 – 30% decrease in others. This could have a major impact on water supplies to a rapidly urbanising world as well as on shelter and transport infrastructures. It may render many of the industries and much of the agriculture that supplies and feeds them highly vulnerable, if not unsustainable.

1.2 Proactive water management is proactive adaptation

Just as climate change mitigation is being addressed through a series of fundamental changes in the way that societies produce and use their energy, adaptation will be addressed in part through a series of fundamental changes in the way societies manage and use their water resources.

In pursuing these changes, we suggest the end goal should be to achieve 'water security': the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water-related risks (Grey and Sadoff, 2007).[1]

To achieve water security, investments will be needed in infrastructure to store and transport water, as well as to build institutions that are armed with the information and capacity to predict, plan for and cope with climate variability. Such investments will help adapt to long-term climate change and manage current climate variability and shocks – thus offering water security to the world's poorest countries.

The art will lie in finding the right balance between the different kinds of intervention.

1.3 The role of Integrated Water Resources Management

Neither the challenges that climate change poses for development nor many of the potential responses are particularly new. Many of them were first articulated on an international platform in 1992 at the Rio Earth Summit, which warned of the dangers and outlined a programme of action that sought to address them in a manner that balanced the twin goals of addressing environmental protection and the development needs of poor countries. To help achieve these goals, the principles of the integrated water resource management (IWRM) approach were also agreed upon.

Agenda 21, the final resolution from Rio (United Nations Conference on Environment and Development, 1992), provides a valuable historical perspective as well as evidence of the difficulty of moving from problem identification to effective action. It highlighted that:

> *"The widespread scarcity, gradual destruction and aggravated pollution of freshwater resources in many world regions, along with the progressive encroachment of incompatible activities, demand integrated water resources planning and management. Such integration must cover all types of interrelated fresh-*

[1] It is worth noting that this definition does not focus on security as relating to threats of violence or war, although some related concerns, such as the intentional contamination of water supplies, could be addressed as water-related risks. Nor, for the purpose of this paper, does it focus only on arrangements for the security of household level water services, though it does include those services.

water bodies, including both surface water and groundwater, and duly consider water quantity and quality aspects. The multisectoral nature of water resources development in the context of socio-economic development must be recognized, as well as the multi-interest utilization of water resources for water supply and sanitation, agriculture, industry, urban development, hydropower generation, inland fisheries, transportation, recreation, low and flatlands management and other activities. Rational water utilization schemes for the development of surface and underwater supply sources and other potential sources have to be supported by concurrent waste conservation and wastage minimization measures."

These dimensions become even more important as we seek to understand how climate change factors into this already complex mix.

Two key attributes of IWRM commend it as an approach to the challenges of climate change. The first is that it integrates the activities of a range of sectors that use, impact or are impacted by water thus ensuring that activities in one sector do not undermine those in another. The second is that it recognizes that effective institutions will be needed to manage the trade-offs between different activities and interests (Global Water Partnership Technical Advisory Committee, 2000 and 2007).

2 Climate change challenges for water resource management

2.1 The physical science

While some regions may benefit from climate change, overall the IPCC predicts that the effects of climate change on water resources will have negative implications. The IPCC Technical Paper on Climate Change and Water (IPCC, 2008) states that:

"Globally, the negative impacts of future climate change on freshwater systems are expected to outweigh the benefits *(high confidence). By the 2050s, the area of land subject to increasing water stress due to climate change is projected to be more than double that with decreasing water stress. Areas in which runoff is projected to decline face a clear reduction in the value of the services provided by water resources. Increased annual runoff in some areas is projected to lead to increased total water supply. However, in many regions this benefit is likely to be counterbalanced by the negative effects of increased precipitation variability and seasonal runoff shifts on water supply, water quality and flood risks. (high confidence)" [3.2.5]*

It is against this technical background that the challenges of the future have to be addressed, although it should be remembered that existing climates are already highly variable and climate change simply adds to the complexity and scale of the challenge of managing this variability.

While there is growing confidence about model predictions of changing temperatures and rainfall, the impact of these changes on water availability from rivers, lakes and underground sources is poorly understood. As an example, one effect of temperature increases is to increase evaporation rates. Since the balance between evaporation and rainfall determines whether a climate is humid or arid, aridity will tend to increase where rising temperatures are not matched by rising rainfalls. Changes in aridity will have a substantial impact on both surface water runoff and groundwater recharge as will changes in the timing and intensity of rainfall.

The impact of global warming on snow fields and glaciers will also impact water resources, since they currently act as natural reservoirs, storing water in winter and releasing it gradually as melt-water in summer. Under global warming scenarios, the melting of snow and glaciers will first increase and then reduce river flows, causing first floods, then droughts. The phenomenon is particularly important in the Andean region of South America and the Himalayan region of South Asia.

Further complicating the picture will be the impact of climate change on vegetation cover which will in turn significantly change both runoff and evaporation. All these factors will affect the water resources available for use by societies.

Water quality effects are also important. Reductions in river flows will reduce their capacity to dilute wastes and require additional investments to achieve the same standards of environmental protection. Changing runoff patterns and temperatures may result in water quality effects that either render water unusable (as in agriculture, where salinity is a major determinant of viability) or impose additional treatment costs on users (as in the case of the eutrophication of waters used for domestic supplies). The intrusion of seawater into coastal freshwater systems is a further quality challenge.

The ability to monitor and predict such climate change impacts at a scale that is helpful to users is still extremely limited, leading the technical team of the IPCC working on water and climate (IPCC, 2008) to conclude that:

> *"There is a need to improve understanding and modelling of changes in climate related to the hydrological cycle at scales relevant to decision making."*

Although the importance of hydrological monitoring has been highlighted at all United Nations conferences on water and sustainable development since the 1977 Mar del Plata conference, the quality of the hydrological data, which is needed to monitor the impact of climate change and to guide future planning, has generally deteriorated since then.

Much of the data on streamflows that is held by the Global Runoff Data Centre in Germany is more than 30 years old, and in 2008 support was terminated for the Global Environmental Monitoring System (GEMS), a worldwide repository of water quality data.

In many poorer countries, hydrological information systems decayed when scarce resources were allocated to more immediate needs, and even in the rich world, monitoring targets have often not been met. As a result, in many countries there is limited information to support the planning, development and management of water resources, a situation which cannot be reversed overnight.

2.2 The broader dynamics

Changes in the availability, timing and reliability of rainfall and the water resources that flow from it will have impacts on all water-using sectors. These impacts in turn will affect the broader dynamics of national economies as well as environmental and social needs, particularly in poorer societies. Specifically, since effective water management is important for the achievement of many of the Millennium Development Goals, these impacts could also threaten their achievement and their sustainability once achieved.

While the overall availability of water will not necessarily decrease with climate change, the distribution and timing of rainfall will change. This will change patterns of access to water, creating new surpluses in some areas and increased competition in others. Managing these evolving hydrologies will impose significant demands on water management.

The variability of rainfall will also increase with climate change, and this will impact growth potential and the costs of achieving adequate levels of water security. In Ethiopia, the economic cost of hydrological variability is estimated at over one third of the nation's average annual growth potential (Grey and Sadoff, 2007).[2] Variability, in fact, can be a greater management challenge than scarcity in that both sides of the equation (too little water and too much water) need to be managed, and managed under greater uncertainty.

As climate variability increases, so too does the cost of the infrastructure, information and systems needed to cope with it. The major impact of climate change in many sectors may be an increase in the cost of water services, and the cost of reliability in service delivery. This will not only be the case for drinking water, but also for agriculture, power production, services and industry. Ecosystem water use will be put under extreme pressure as the costs of water rise. Few countries have effective mechanisms to assure adequate water for ecosystems, so ecosystem water use is routinely the first use foregone.

Climate change will increase the incidence of catastrophic events such as flood and drought. This will impact lives, livelihoods, land values and investment incentives in vulnerable areas. While readiness and insurance schemes as well as water management interventions will be instrumental in addressing these risks, the prospects for these increasingly vulnerable areas will change. In general, more vulnerable areas are inhabited by poorer populations.

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[2] This estimate is based on the results of a stochastic, economy wide multi-market model that captures the impacts of both deficit and excess rainfall on agricultural and non-agricultural sectors. The results show growth projections dropping 38% when historical levels of hydrological variability are assumed, relative to the same model's results when average annual rainfall is assumed in all years (which is the standard modelling assumption) (Grey and Sadoff, 2007).

Those with options move away from hazards or uncertainties. As vulnerable areas become more vulnerable – to floods, sea level rise, groundwater intrusion, loss of arable land – the poor are likely to be disproportionately hurt.

Changing water security conditions will drive changes in the spatial location of economic activities, and even the structure of economies. On balance, economic activity will be driven toward water secure areas and away from insecure areas. Over time, changing water security conditions may also affect the structure of an economy – its sectoral mix and the rules by which it operates – as water affects sectoral economic returns.

Globally, trade in water-intensive products ('virtual water') may increase as patterns of water security shift. In the absence of confounding incentives, trade should promote greater water-intensive export production in water rich areas, and greater imports of water-intensive products in water scarce areas.

2.3 Timeframes, sequencing and uncertainty

The uncertainty which pervades every aspect of climate change adaptation planning is seen by some as good reason to postpone action. Most impacts are expected decades in the future, and the scale of impacts could vary widely with a range of factors – the success and scope of mitigation efforts, the accuracy of today's models, the potential for non-linear tipping points that cannot be modelled, and so on.

However, implementing any new approaches to water resources management responses will also be a long-term process. Institutions take time to design and establish. Major water resources infrastructure, such as large reservoirs and canals, routinely take over a decade to plan and construct.

While sequencing and prioritizing specific medium-term priorities is surely complex, it is timely and wise to focus now on opportunities for enhancing management capacities, for strengthening information systems, and for building infrastructure to enhance resilience at both small and large scales.

3 Climate change responses through water resources management

Given the impending challenges, it is crucial for policy makers to recognize the role of water as a primary medium through which climate change will have an impact on development and to incorporate these considerations in overall development planning and management. Likewise, it is important for water managers and water users alike to adapt to the unfolding future. An approach to water resource management is needed that can identify and address the challenges – and uncertainties.

The challenge is analogous to the way that the mitigation challenge is being addressed, through a series of fundamental changes in the way that societies produce and use their energy. These start from the resources societies use to fuel their activities, the way that these are used and combined to generate power, through to the settlement patterns that societies adopt for their cities and the public transport systems. It extends to patterns of production, consumption and trade, all with a view to reducing the production of carbon dioxide and other greenhouse gases.

A similar approach is required in the use of water, although arguably water provides a greater challenge since, in many cases, it is sourced directly from the natural environment of which it forms part. Unlike energy, water is difficult to transport over large distances and patterns of its use are very localized, varying dramatically between and within countries. Apparently different sources of water are often related to each other through the water cycle. Plantation forests on hillsides may deplete groundwater in the valleys; overenthusiastic pumping of groundwater in one area may dry up streams nearby; harnessing river for hydropower may affect fish populations and fisherfolks' livelihoods in estuaries downstream.

So water resources must be managed, and water used, in a manner that reflects water's variability, uncertainty, scarcity and abundance. That management also has to reflect the interconnectedness between its users at different scales locally, regionally and globally.

3.1 Adaptation through better water resources management

If water security is to be achieved and sustained, it will require approaches that reflect the particular challenges of the water cycle, aggravated as they will be by drivers including, but not limited to, climate change. Such approaches should reflect the integrated nature of the water cycle by incorporating the different users, uses, threats and the threatened.

IWRM is an approach to water management that explicitly recognizes the need to structure and manage the trade-offs required, recognizing that one use affects others and that all depend upon the integrity of the resource base.

Better water management will be essential if communities are to adapt successfully to climate induced changes in their water resources. The strategies adopted will have to use a combination of 'hard', infrastructural, and 'soft', institutional, measures and to go well beyond what is normally considered as 'water business'. Critically, they will require major changes in the way agriculture, industry and human settlements in general are managed. The future resilience (or vulnerability) of human communities to climate change related impacts will depend, in large measure, on their success.

The patterns of water use as well as the nature of the water resource itself are dynamic and ever-changing. Changes in consumption patterns and production technologies, changing patterns of trade or political and social preferences and priorities all have an impact on the way water is used and the impacts human activities have upon it. Similarly, changes in the resource, including the impacts of anthropogenic climate change cannot be projected with any degree of precision, and institutions must be able to respond flexibly to the changes as they emerge.

A further important advantage of the IWRM approach is that it is itself adaptive. Properly applied, IWRM establishes institutions and processes that can identify and respond to changes in the economic and social environment as well as in the natural environment.

3.1.1 Institutionalizing adaptation in water management

The principles of IWRM clearly align with the challenges to water management that climate change will exacerbate. But what does this mean in practice? How can water management policies and practices align to help communities, ecosystems and environments adapt to climate change?

Water policies and practices must aim to build institutions, information and capacity to predict, plan for and cope with seasonal and inter-annual climate variability, as a strategy to adapt to long-term climate change. And these institutions must be able to facilitate processes of social and economic change that involve significant tradeoffs.

In this context, institutions are not only formal organizations; indeed, it may be preferable if formal organizations emerge only once the key challenges and the key functions that have to be undertaken are known. 'Soft' institutions – which include informal coordination activities, information gathering and collation, setting of rules through legislation or cooperation, and the monitoring and regulation of compliance -- are equally important. Good management practices that are inculcated in user communities are more likely to be sustainable than rules imposed by formal organizations.

To achieve the goals of water security and development, water challenges need to be addressed within broader climate change and development strategies and users and resource managers must be engaged in an interactive way that enhances their ability to cope with uncertainty and respond to challenges as they emerge. In part, this means ensuring that all levels of decision-makers – from policy makers to water managers to users – have the information they need to develop and continuously update adaptation strategies.

While information and the capacity to understand it is essential, in many countries, the ability of core management institutions to address current let alone future challenges is limited and needs to be strengthened.

The same applies to another key function of water resources management, the facilitation of tradeoffs between different water users and uses to cope with both variability and long-term climate change. These tradeoffs need to balance the 'three Es' of economic

Efficiency, social Equity and Environmental sustainability.

Given the role of water in almost all dimensions of social and economic life and its fundamental role in the environment, any change in the pattern of water use and management will affect a variety of stakeholders. While the goal will always be to find win-win synergies, there will usually be trade-offs of some sort to be made and the processes by which these are made (and the way negative impacts are mitigated) need to be institutionalized.

Thus tradeoffs have to be made between the security offered by dams, which increase water storage capacity to manage low flows and floods, and the impact of construction on people living in the project area. While the societal benefit from increased storage is huge, the impact in terms of livelihoods and social structures can be devastating.

There are also tradeoffs between different uses; in many countries the needs of farmers and hydropower generators are not aligned and assuring security of water supply to urban residents may reduce power generation income. Devising mechanisms to determine who should get what share in times of plenty and in times of scarcity is at its root a political issue which requires robust institutions to achieve outcomes that are accepted by all those involved.

And, as the demand for water grows and reaches the limits that can be provided, there are decisions to be made about the balance between the protection of the natural environment of which water forms part and the requirements of social and economic activity. While the decisions themselves will reflect domestic political processes, water management institutions must help to frame and facilitate them.

3.1.2 Actions will need to take place at all levels (projects, villages, economy-wide, global)

At the project level, water investments should be designed for resilience to climate change. At the village level, interventions should seek to diminish social, economic and environmental vulnerabilities to climate. Economy-wide planning should take into account climate shifts and the implications this might have for specific sectors or spatial areas. Globally, promotion of trade in water intensive products (virtual water trade) and targeted technology transfers could promote adaptation.

The impacts of variability, aggravated by climate change, are felt at different levels and have to be addressed at all levels. Individual farmers have to take decisions – and need information to do so. Power companies need to know where their supplies are likely to come from and plan accordingly. And urban residents need to know that reliable water supplies for domestic and commercial purposes will be maintained. Ideally, decision-making processes will be 'built in' to the institutions that are established to manage water.

3.1.3 Actions will need guidance by science and best practices from both water and climate fields

While many of the responses to water management challenges are as old as civilization, new circumstances create many opportunities – and many needs – for innovation and fresh thinking.

In many regions, rainfall and river flows are already extremely variable in both timing and amount, and it has been suggested that climate change will simply mean 'more of the same' variability.

To some extent this is correct. Variability is the stock in trade of hydrologists and water engineers who use well understood statistical techniques to estimate the variability of rainfall and streamflow. This is then applied to the design of infrastructure such as storage dams, flood protection dykes and even the culverts which ensure that roads are not washed away. The future may not however be amenable to being predicted in the same way.

Practitioners and publics alike will need to have access to the best possible information as well as to different approaches taken in different communities to ensure that they choose the most appropriate alternatives and are not trapped by their pasts into a dead-end future. In particular, it will be important to improve access to climate information and to develop stronger linkages with climate scientists, in order to take on board the significant recent improvement in the science community's ability to predict, with some degree of accuracy, climate variability at seasonal and inter-annual scales (Kabat et al, 2002). Incorporating this information effectively as part of water resource management could be a crucial tool for coping more effectively with climate variability and building capacity for adapting to climate change.

3.1.4 Actions must balance software (intelligent and robust institutions) and hardware (adequate infrastructure)

An important element of the approaches to water resource management that have evolved over the past few decades has been the recognition that engineering solutions, while vitally important and an integral part of any future approach, will not by themselves solve the world's water problems. There is a range of social, economic and political challenges that have to be addressed and a variety of 'soft' institutional instruments that can be deployed to complement 'hard' infrastructural solutions. The art is in finding the right balance.

'Hard' Options

One way to manage the impacts of climate variability on water resources is through 'hard options' to capture and control river flows. Storage dams are built to retain and store flows that are in excess of user requirements and to release them during periods when low flows are not sufficient to meet user needs, a practice that can also serve to maintain aquatic ecosystems. Alternatively, during floods, peak flows can be stored for later release, avoiding flood damage by reducing maximum flows. Both functions are important to sustain urban settlements and to avert disasters caused by floods and droughts.

Dams also harness water as a form of potential energy to generate electricity, without which healthy urban life is difficult to sustain as settlements increase in size. Nineteen per cent of the world's electricity is currently generated from hydropower and there is substantial potential to expand this, particularly in low- and middle-income countries. A specific benefit of hydropower is that it does not usually generate significant quantities of greenhouse gases and thus allows economic and social development to occur without aggravating global warming.

Other important waterworks include canals, tunnels and pipelines, which not only supply human demands directly but, less obviously, create linked systems that, by virtue of their multiple sources, suffer less variability and therefore offer enhanced supply security. Equally, wastewater disposal and stormwater drainage systems contribute to the ability of communities to maintain their activities and protect public health.

'Soft' Options

The armoury available to water managers for addressing variability and extreme events is not restricted to infrastructural means. As important are the institutional mechanisms that help deal with climate variability and achieve goals such as water supply for people, industries and farms, flood protection and ecosystem maintenance. These 'soft' tools manage demand as well as increase supply, through water allocation, conservation, efficiency, and land use planning.

These soft tools are often cheaper, and may be more effective, than their infrastructural equivalents and can certainly complement infrastructure to ensure that it works effectively. Thus, in addressing potential water shortages, as much attention should be given to managing demand as to increasing supply, by introducing more efficient technologies as well as simply promoting a culture of conservation. This will be particularly important in areas where overall water availability declines.

In many countries, this is already done in a rudimentary way. For instance, organized drought restrictions in agriculture and 'hosepipe bans' for domestic users should be seen as institutional mechanisms used to manage variability by prioritizing different water uses at times of supply stress. Targeted technical interventions such as leak reduction programmes in municipal distribution networks can not only pay for themselves through water savings but provide direct energy savings, which help to mitigate climate change.

Demand management to encourage efficient use also has huge potential. Well-off households can substantially reduce their consumption and farmers can usually get far more 'crop per drop'; industrialists often achieve more production per unit water when put under regulatory pressure and can also locate water intensive processes in areas where water is plentiful. Incentives for water users to exchange their current water allocations, either through administrative systems or 'trading', can help to achieve more efficient water use, although the social impacts need to be carefully managed.

At a larger scale, the global trade system has a substantial impact – positive and negative - on water use, which needs to be understood and engaged. In this context, the promotion of biofuels as a source of energy could greatly aggravate the challenges of water scarcity if not carefully planned and regulated.

Beyond direct water management, institutional instruments such as land use planning can substantially reduce the vulnerability of communities to water based natural disasters if they are informed by reliable flood data. Thus resilience against floods can be achieved by building protective infrastructure or through planning which restricts settlement in vulnerable areas. This demonstrates that there is often a choice from a suite of hard and soft instruments that can be applied to enhance resilience.

Urban planning can also contribute in other ways. Although rapid urbanization is often perceived as an environmental problem, it also brings environmental benefits. One of these is that household water demand is usually less in dense urban areas than in more thinly populated areas, for obvious reasons. Planning and building compact cities may indeed prove to be one of the more effective ways of curbing domestic use of water.

In all this, it is important to recognize that many of these challenges are not new and are certainly not the product of climate change alone. Thus, aside from urbanization, the changing lifestyles and dietary patterns associated with growing affluence in countries like China and India will, arguably, have an even greater and more immediate impact on the water environment. This is why it is important to address the impact of climate change on water resources as part of a broader programme of better water management.

Mixing 'Hard' and 'Soft'

In virtually all circumstances, water security will require a mix of investments in both hard (infrastructure) and soft (institutions) options. The right mix will be a function of many hydrological, economic, socio-political and environmental factors. Historically, when stocks of hydraulic infrastructure are low, investment in infrastructure have provided relatively higher returns. Investment in management capacity, and infrastructure operations and institutions become increasingly important as larger and more sophisticated infrastructure stocks are built (Grey and Sadoff, 2006) (see Figure 1).

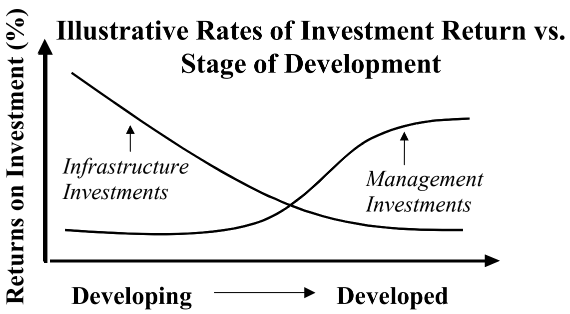

Figure 1: Water infrastructure and management. Source: World Bank (2002)

The increased intensity of extreme flood and drought events suggests that climate change will enhance returns to infrastructure investments that allow water managers to control, store and deliver water under more variable conditions. On the other hand increasing variability and hydrological uncertainty suggest that the value of information and flexible, adaptive management institutions will be significantly enhanced. The right balance will be driven by specific circumstances, but returns to investments in both can be anticipated to rise.

3.1.5 Balancing the Three Es

In choosing between different strategies to address water challenges and in their implementation, it is clear that important political choices have to be made between different economic and social interests as well as about the impacts on the environment.

The approach adopted needs to ensure that these choices are made explicit and that the process followed achieves an appropriate balance between conflicting interests.

In the countries most threatened by climate change, particular attention will have to be given to ensuring that the voices of the poorer and more marginalized communities are heard since they will usually be the group most at risk, whether from hunger due to drought and crop failure or from the impact of floods and related disasters, which usually have their greatest impact along the river banks and ravines of crowded cities where the poor are more likely to live.

3.2 What's new in all of this for water resources management?

Climate change is going to require a re-examination of current approaches in water management, as well as in the design of many components of urban settlements and economic and social infrastructure generally. In this context, lessons from the past and from areas that currently suffer from extreme conditions may be valuable. While water management is always driven by local contexts, there are several areas of effort that will clearly require renewed and increasing attention in all countries.

3.2.1 Disaster risk management

Intelligent and adaptive responses will depend on a systematic understanding of the potential risks and impacts of climate change and their application to specific situations.

In this area, the expertise of hydrologists and engineers will need to be brought more closely together with that of risk managers in the insurance industry, disaster management specialists and regional planners. While this has begun to happen in some areas, countries and specialized agencies will need to promote such interaction in a systematic manner with the aim of identifying new and changing risks, prioritizing them in terms of likely impact and occurrence, and devising strategies to reduce them.

A special case of the institutional challenge is the integration of disaster management systems with the broader institutions of water management. Much knowledge about managing extremes already resides in specialized disaster management institutions. The challenge is to extract this wisdom about dealing with extreme events and apply it more generally, on the assumption that once rare events will occur more frequently.

In this process, it will be recognized that many of the challenges are social as well as technical and institutional. Politicians need to be convinced of the nature of future problems before they are willing to devote time and resources to them. Behaviours need to be modified at community level if risks that have been identified are to be averted. Recent experience in the management of severe flood events has highlighted that the pre-emptive engagement of disaster management works before an extreme event, to ensure that communities are informed about risks and aware of how to respond to extreme events, has proved to be the difference between the loss of property and infrastructure only and the loss of lives.

3.2.2 Information and cooperation

Managing increasing uncertainty and system-wide hydrological variability will increase returns to information and cooperation in water management at all scales.

In this context, the need for information must be emphasized. As emphasized earlier, it will be particularly important to improve access to climate information and to develop stronger cooperation with climate scientists and take advantage of techniques to predict climate variability at seasonal and inter-annual scales. However, while theoretical estimates of likely events and patterns of occurrence can be made, it will be increasingly important to monitor trends in order to decrease uncertainty and achieve greater efficiency in interventions.

For this to occur, far greater investment will be required in both the physical (and remote) monitoring and the institutions needed to interpret the data and translate it into relevant information for policy and practice.

3.2.3 Water quality

The IPCC reports with high confidence that higher water temperatures and intensified floods and droughts will affect water quality and exacerbate many forms of water pollution. In part this will be a consequence of the simple fact that rivers with less flow are less able to dilute and remove pollutants. Floods will move water across landscapes, picking up additional sediments, pathogens and pesticides. Salt water intrusion is another water quality challenge that will rise with climate change.

Understanding these dynamics will be critical to avoid harm to ecosystems, human health, and water system reliability and operating costs. This is another dimension in which the capacity of water resource managers will have to be strengthened.

3.2.4 Water rights and allocation mechanisms

With increasing extremes and unpredictability, water rights and allocation mechanisms are an area that will require serious review by policy makers and water managers. Water rights and allocations are generally premised upon historical water availability. As climate change causes future water availability to diverge from the past, past rights and mechanisms may no longer be viable. Systems of water rights, allocation and conflict resolution mechanisms will need to be put in place or strengthened to deal with these new realities. Flexible systems will need to be developed to respond to extremes of water availability and unpredictability.

3.2.5 Rethinking water storage

Since hydrological variability will increase with climate change, greater storage will be needed to capture peak flows and augment low flows. This is essentially an investment in greater water security and reliability.

Climate change will impact not only the volume of water storage that is appropriate, but also the appropriate type of storage (natural, man-made, small, and large.) Discussions of storage tend to focus on large-scale, man-made storage dams but there is a range of storage options, which includes natural storage, such as groundwater (naturally or artificially recharged), wetlands and lakes; and man-made storage at all scales, which includes household rainwater harvesting, traditional community tanks, storage dams (from small to large), and large-scale reservoirs.

In addition to natural and man-made storage of water, 'virtual' and 'financial' mechanisms can be constructed to 'store' the benefits of water. Water storage is essentially a hedge against the loss of benefits incurred when water is unavailable. Strategic grain reserves can be seen as stores of embedded water, amassed during high production years and redistributed during low production periods. Weather and crop insurance schemes can be seen as financial storage mechanisms that insure agricultural incomes by financial means, rather than insuring agricultural outputs through the enhanced reliability of irrigation (i.e. greater volumes of irrigation water under command). Where water storage is desired to enhance the reliable delivery of water-intensive goods (agricultural or manufactured), trade in water-intensive products or 'virtual water' can be seen as important alternatives to actual water storage.

The comparative advantages and disadvantages of different types of storage will change as climates change. Options that were once undesirable or unnecessary could soon become good options. What were good options in the past may not be in the future. New storage may be needed; some existing storage may no longer be viable. In some cases infrastructure could be modified to adapt to changing conditions, e.g. by providing additional intakes at lower reservoir levels in hydropower dams or changing the way in the infrastructure is operated. In other cases decommissioning might be the rational alternative.

It is essential to revisit the range of storage options in this new context and reassess relative benefits and harms.

3.2.6 Adaptive management

Given the great uncertainty and the challenges of collective action, flexibility and continuous strategic updating will be more crucial than ever before.

There are multiple challenges confronting communities and countries that seek to 'climate-proof' themselves, by managing their water resources more intelligently to increase their resilience to climate variability and thus to reduce their vulnerability to the effects of climate change. As always, poorer countries will face the greatest challenges. Addressing these challenges will require strong and well-informed leadership as well as effective strategies.

A key challenge is to orient water managers, as well as their partners in key water use sectors, to the potential impact of the emerging new climates. Intelligent institutions are needed at all levels – institutions that can go beyond managing water on a day to day basis to identify water use trends, areas vulnerable to climate change and opportunities to respond as well as possible to the emerging challenges.

This cannot be a one-off project. It is about building dynamic organizations that have the tools and the ability to respond strategically and effectively to changing circumstances. To achieve this, key water use sectors as well as policy makers must be engaged and share a common understanding of the challenges so that appropriate responses can be identified and supported, and trade-offs made.

3.3 Financing adaptive water resource management

The current global focus on water is on the short-term – immediate poverty priorities such as basic water supply and sanitation and 'bankable' activities such as hydropower and industrial water supply. Yet there is a real likelihood that without effective long-term water management these current activities will prove to be unsustainable. Hydropower plants are already failing to produce the amount of electricity expected; basic water supplies are failing for lack of adequate water sources; agriculture in many regions is making unsustainable demands on groundwater resources.

In many poorer countries, capacity to manage water resources suffered during years of structural adjustment in which public sector expenditures were reduced. Often, it was the water resource management and hydrology functions that suffered most since the short-term priority was water supply and sanitation. One consequence of this is that many countries cannot even manage their current climate variability, not because the strategies needed are unclear but because the means to implement them are lacking. They rightly ask why they should address tomorrow's climate change if they cannot afford to manage today's drought?

To date, discussions in the global processes to develop effective responses to climate change have been heavily weighted towards the challenge of mitigation. This reflects the strong sense that the immediate priority is to take action to reduce the extent of human induced change. As it becomes obvious that substantial change is very likely to occur, more attention is being given to adaptation.

However, it is important to address the burden of financing adaptation processes which will fall more heavily on poor countries which are less resilient to start with. Africa and South Asia in particular will see some of the most extreme changes and have some of the world's weakest capacity to deal with these changes. Even in cases where the extent and scope of climate changes are similar, countries and communities with the institutions and capabilities to manage water resources will suffer less impact than those who do not.

For this reason, resources need to be mobilized to finance adaptation action. This is increasingly accepted and serious negotiations are ongoing, addressing a range of issues. In fact the adaptation financing landscape is so rapidly changing that any specific recommendations would likely be outdated before they went to print.

Whatever the final arrangements, however, there are certain principles that should guide their development. The Paris Agreement on Aid Effectiveness should serve as a guide for funding adaptation in poor countries, avoiding special purpose, special interest instruments wherever possible. A recurring theme through much of the early work on both managing water and managing the impact of climate change has been about the need to 'mainstream' the activity into overall development planning and management.

The provision of sustainable ongoing funding of national water resources management capacity, institutions and infrastructure should therefore be seen as a priority for mainstream assistance. The aim should be to ensure that long term capacity is built and retained in the institutions that are going to have to cope with the unfolding changes.

Water resources management investments should also be viewed as sustainable development financing that delivers adaptation benefits. Similarly multipurpose hydropower development (with flood and drought benefits) provides opportunities to deploy mitigation financing with adaptation benefits. These sorts of multiple bottom line investments are being explored and should be promoted in the adaptation finance architecture.

To the extent that specialized adaptation funds are made available, they should look beyond single-country solutions to generate public goods and to promote cooperative transboundary river basin solutions. Adaptation financing should not promote single-country interventions where multi-country cooperative interventions may be more effective.

Thus in some transboundary basins, the best climate change adaption interventions for any individual country might lie in basin-wide information and monitoring systems, or in upstream infrastructure investments and/or reoperations in a neighbouring riparian country for joint management of shared water resources. While international finance for adaptation should be mainstreamed in countries in terms of current aid effectiveness agreements, mechanisms should also be developed to encourage countries to explore cooperative options, and to promote cooperative water management solutions between countries where appropriate.

4 Conclusions

Just as energy use is the focus for mitigation efforts, water is arguably the primary medium through which climate change impacts will be felt and water management will inevitably become a focus for adaptation.

However, many countries have not yet achieved a reasonable level of water security. Efforts to achieve and sustain water security are thus not just an essential response to climate change, but also an immediately beneficial investment that will help to buffer economies, societies and ecosystems from today's climate variability.

A mix of both 'soft solutions', such as enhanced information, warning systems and stronger management institutions, and 'hard solutions,' such as infrastructure, will be needed to minimize the uncertainty and disruptions that climate change will bring through the hydrological cycle.

A coherent approach to promote this drive for water security, that will address both current climate variability as well as the challenges of climate change, is that of integrated water resources management. The foundation for this has already been laid by the decision at the Rio Summit in 1992 that an integrated approach to water resource management and development was essential to address emerging challenges.

Properly implemented, an IWRM approach is inherently adaptive as it should both inform water users about water challenges and provide a framework through which such challenges can be addressed. Since many countries are already promoting and implementing IWRM, this framework can and should also be used to address the challenges of climate change. This will obviate the need for new institutions and activities and should help to mainstream adaptation or 'climate-proofing' into national development plans.

There is, however, evidence that the resources currently made available for water resource management are inadequate for the task. Therefore, it is important to ensure that reliable core funding for this ongoing activity is provided even as specific adaptation funding initiatives are launched.

This will help to avoid disconnected adaptation initiatives related to the water environment. Advancing and sustaining water security is an important goal today, and a 'stretch' goal for tomorrow's climate change adaptation. Today's investments in water security should be seen as an explicit part of a coherent longer term strategy for adaptation that will build a more resilient world in the future.

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Perspectives on water and climate change adaptation

The Water Variable – Producing enough food in a climate insecure world

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

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

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

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

Participants were invited to contribute perspectives from three categories:

1 **Hot spots** – These papers are mainly concerned with specific locations where climate change effects are felt or will be felt within the next years and where urgent action is needed within the water sector. The hotspots selected are: Mountains (number 1), Small islands (3), Arid regions (9) and 'Deltas and coastal cities' (13).

2 **Sub-sectoral perspectives** – Specific papers were prepared from a water-user perspective taking into account the impacts on the sub-sector and describing how the sub-sector can deal with the issues. The sectors selected are: Environment (2), Food (5), 'Water supply and sanitation: the urban poor' (7), Business (8), Water industry (10), Energy (12) and 'Water supply and sanitation' (14).

3 **Enabling mechanisms** – These documents provide an overview of enabling mechanisms that make adaptation possible. The mechanisms selected are: Planning (4), Governance (6), Finance (11), Engineering (15) and 'Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA)' (16).

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

5 The Water Variable – Producing enough food in a climate insecure world

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The Water Variable – Producing enough food in a climate insecure world

This paper serves as an input for the thematic, regional and political processes of the 5th World Water Forum and focuses on the challenges related to water, climate change and food security. Recent publications related to the anticipated impacts of climate change on water and agriculture are comprehensive, but a global analysis of specific impacts remains limited. The paper summarizes recent food production and food security trends and provides an overview of how climate change, through impacts on global hydrology, could impact food production, and consequently food security, in some key farming systems. However, as climate change is but one of many drivers of agriculture, climate change impacts need to be appreciated in relation to specific farming systems in order to identify appropriate adaptation measures. The paper highlights key drivers and presents possible responses, emphasizing that the scope of policy response will need to be broad if water institutions are to be effective in coping with climate change.

Preface

"*Adapt or Die*". This dramatic headline introduced an article in the Economist last September (2008), addressing the imminent need to focus more on adaptation to climate change, not least on the capacity of poor farmers in developing countries. The article presents data, which estimates that African farmers relying on rain-fed agriculture may loose on average $28 per hectare per year for each 1 °C rise in global temperatures. Although such estimates are speculative they point to the potential economic impacts of climate change at the level of an individual small holder.

Approximately 60% of global food production is derived from rainfed farming systems. The remaining 40% is derived from irrigated agriculture practised on 20% of the world's arable land. This split between rainfed and irrigated production sets the scene for a deeper consideration of the possible impacts of future climates on global food production and possible adaptation strategies. The annual variability in temperature and precipitation are fundamental aspects for agricultural production, but they are just one sub-set of inputs for food production. Fertilisers, pesticides, labour, mechanisation, storage and marketing systems all influence food production and availability to a lesser or greater degree depending upon the farming system (FAO, 2002). Nonetheless, soil moisture deficits and weather related crop damage (physical and biological) still remain the most prevalent constraints to primary agricultural productivity.

Any view of the anticipated impacts of climate change on food production needs to maintain a measured perspective of the relative importance of climatic factors in plant growth and plant/animal disease. It should also be stressed that farming systems are inherently adaptive. They have never been technically or socially rigid and fixed. Rather, they have been opportunistic, using available natural resources, technologies, institutions and market mechanisms to respond to changing human demands and environmental changes. Hence, a consideration of the implications of food production in relation to agricultural water management requires a systemic appreciation of precisely where water is instrumental in maintaining agricultural productivity.

Introduction

This paper is intended to contribute to the 5th World Water Forum as an input for the thematic, regional and political processes and is intended to provoke some discussions within the Forum on the relative significance of agricultural water management. It will briefly discuss some of the challenges related to water, climate change and food security[1], and present some examples of possible policy and management options/areas that merit further consideration. It does not attempt to provide a comprehensive overview of this vast subject area[2].

Numerous recent publications point to the anticipated impacts of climate change on water and agriculture (World Bank, 2007; IPCC, 2007; FAO, 2008a; Bates et al., 2008). However, global analysis of specific impacts on agricultural growth remains limited. Tubiello and Fischer (2007) couple an agro-ecological zone model to a global food trade model for a non-mitigated and a mitigated scenario to examine the impacts on rainfed agriculture. Fisher et al. (2007) deploy the same modelling approach to examine the possible impacts on irrigation water requirements. The resulting projections of agricultural growth, food insecurity and irrigation water requirements under mitigation assumptions are highly mixed with regional 'winners' and 'losers'. However, even with temperature and CO_2 forcing effects taken into account at global scale, the distinction between rainfed and irrigated production and their relative contribution to agricultural production has to be made. Soil moisture deficits in rainfed systems cannot be negotiated, and the production risk is a direct function of rainfall. As soon as irrigation technology is applied, the production risk is buffered by the availability of water withdrawn from store or from flows. Under these circumstances, crop yields are raised and cropping intensities can be doubled or tripled.

It is important to emphasize that climate change impacts on rainfed agricultural production are transmitted through soil moisture deficits and temperature increases. However, for irrigated production the primary impacts are transmitted through the overall availability of water resources. Even if the two production systems are subject to the same set of demand drivers (population growth, income growth), the factors of supply and the points of competition over water resources tend to be quite different. Rainfed agriculture does not have to compete for rainfall. Irrigated production, on the other hand, will continue to compete with other productive sectors and will have to account for its use not just in economic terms, but increasingly in social and environmental domains.

Food production trends

Over the last century, global food production has managed to match population growth. Despite a three-fold global population increase since the turn of the 1900s, global production is still enough to sustain 6.5 billion people even if such indicators as the ratio of global cereal stocks to utilization are declining. Indeed, FAO's latest figures indicate that global cereal production in 2008, estimated at 2,245 million tonnes, enough to cover the projected needs for 2008/09, estimated at 2,198 million tonnes, and to allow a modest replenishment of world stocks. But with only 431 million tonnes, the cereal stocks-to-utilization ratio, at 19.6 percent, is at its lowest level in 30 years.

It is also important to point out that the increase in cereal production in 2008 was accomplished by the developed countries who were able to respond rapidly to more attractive prices. Because of a greater elasticity of their supply relative to demand, they increased their cereal output by 11 percent. The developing countries, by contrast, only recorded an increase of 1.1 percent and if China, India and Brazil are excluded from this group, production in the rest of the developing world actually fell by 0.8 percent. Not surprisingly cereal imports bills for developing countries are estimated at 78 billion dollars in 2007/08 against 34 billion in 2005/06 reflecting a 127 percent increase over a period of two years.

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1 The FAO (2002) definition of food security is: "A situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and health life". FAO (2008a) also states: "To achieve food security, all four of its components must be adequate. These are: availability, stability, accessibility and utilization." According to Schmidhuber and Tubiello (2007), only the first of these four factors is routinely addressed in climate change simulation studies.

2 or example, it does not include climate change aspects related to fisheries or forestry. There are many interesting, and challenging, perspectives, which a more comprehensive approach to climate change and food security would need to address.

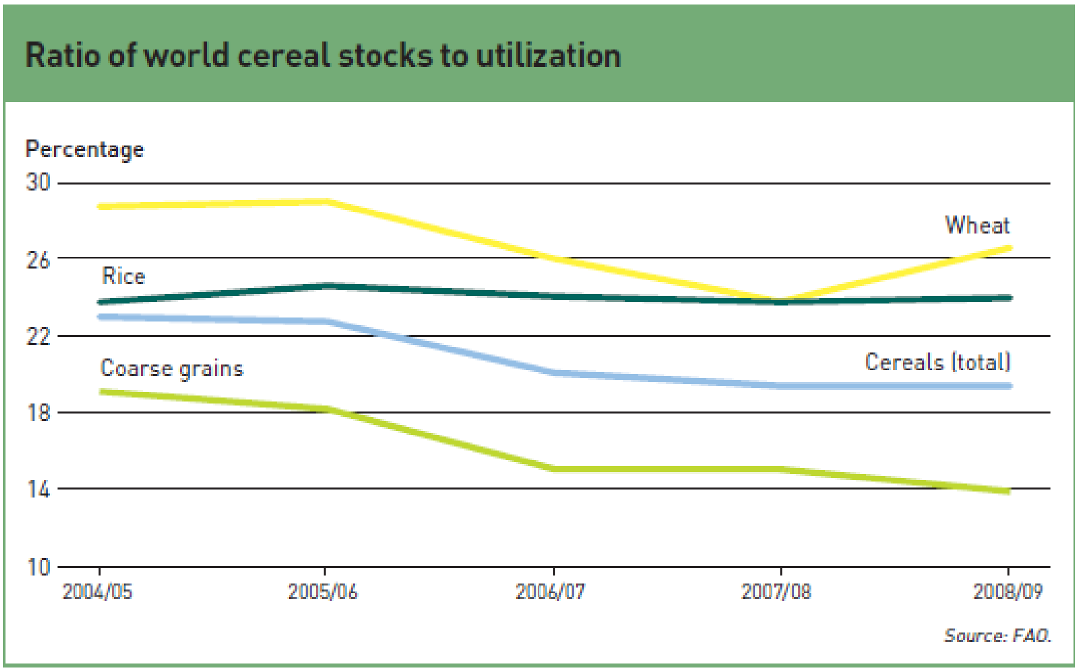

Figure 1: Ratio of world Cereal stocks to utilization. Source: FAO

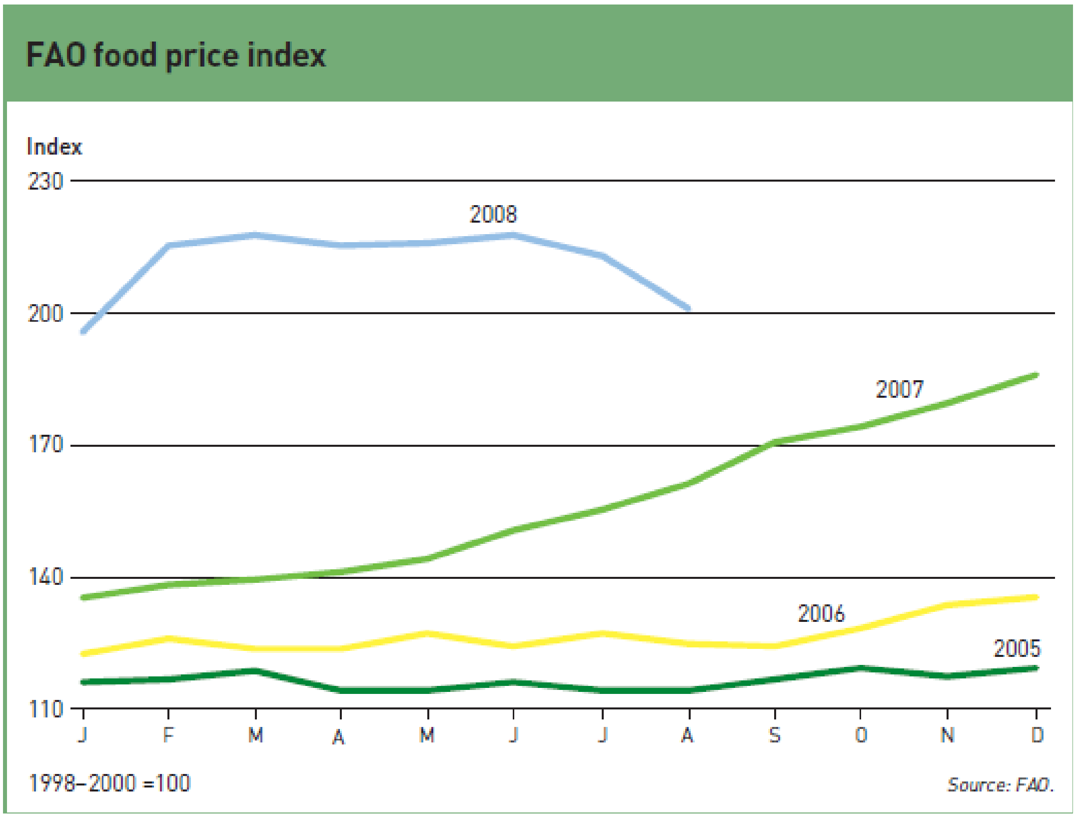

Figure 2: FAO Food Price Index. Source: FAO

The recent volatility in food commodity prices is a strong warning that the globe's food supply systems are not infinitely elastic. Against known trends in demand, disruptions to food supply through adverse weather or the unintended consequences of bio-fuel policies illustrate how sensitive both subsistence and intensive farming systems can be to external shocks (FAO, 2008c).

The increases in agricultural output in the 20th century can be attributed to horizontal expansion of arable land and the capacity to intensify production through the application of seed, fertiliser and pesticide technologies and the ability to store, divert and pump surface and groundwater. Such factors were largely behind the 'green revolution', a period characterized by significant increases in agricultural output in most parts of the world, and notably in countries such as India and China. Dams, diversions and other infrastructure harnessed water (lake, river and groundwater) resources for farming and energy production. In addition, increasing trade enabled food to be transported from surplus countries and regions to countries and regions which did not have enough food production capacity and/or chose to allocate land and water resources to other productive uses. Given the current volatility in global food production, the continued performance of the large contiguous areas of irrigated land needs and their related water infrastructure to be examined.

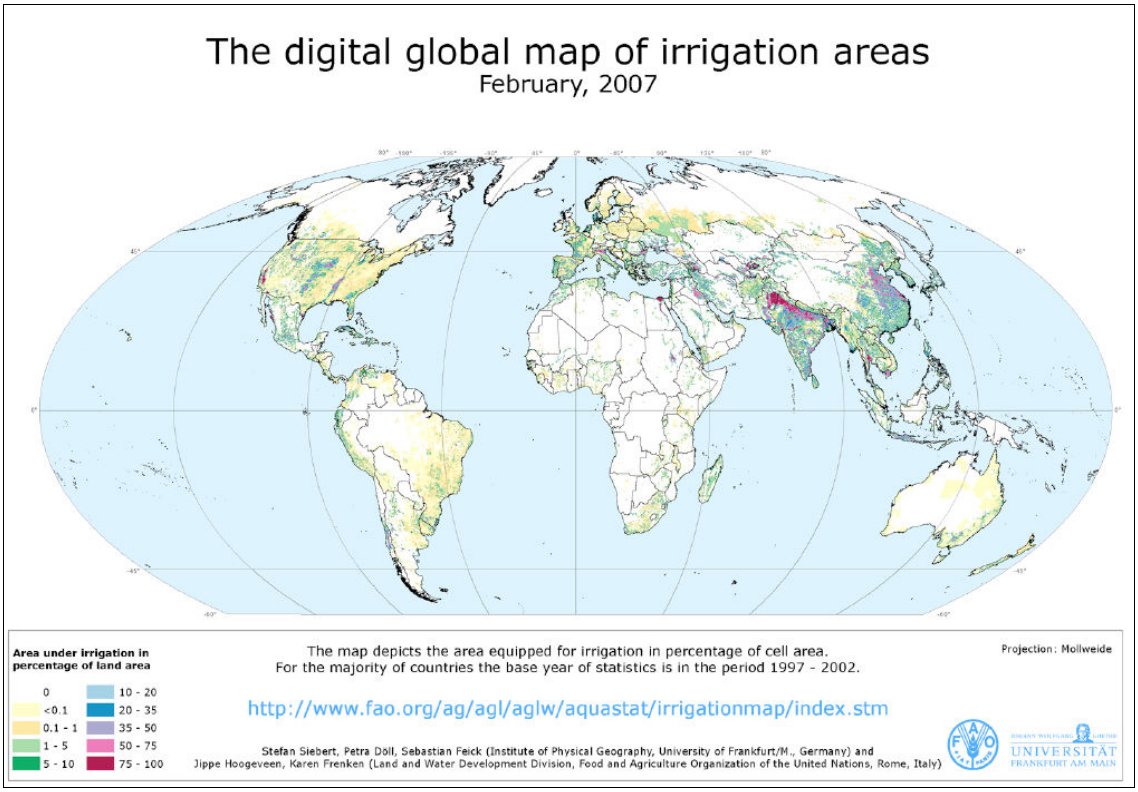

Figure 3: The digital global map of irrigation areas. Source: FAO and Universität Frankfurt am Main.

Food Security Trends

FAO recently presented a framework document on the interrelationships between climate change and food security (FAO, 2008a). This document clearly highlights the significant importance of climate change, but also makes it very clear that food security "*is the outcome of food system performance at global, national and local levels.*" It requires a systems approach, as it is "*directly or indirectly dependent on agricultural and forest ecosystem services, e.g., soil and water conservation, watershed management, combating land degradation, protection of coastal areas and mangroves, and biodiversity conservation*".

Despite overall growth, global food security has not been achieved. The number of chronically hungry people in developing countries as a whole started to increase from the late 1990s, and by 2001–2003 the total number of undernourished people worldwide had increased to 854 million FAO 2008b). The recent rise in malnutrition (estimated at 40 million in 2008) to some 963 million people can, at least partly, be attributed to rising food prices[3].

[3] http://www.fao.org/news/story/en/item/8836/icode.

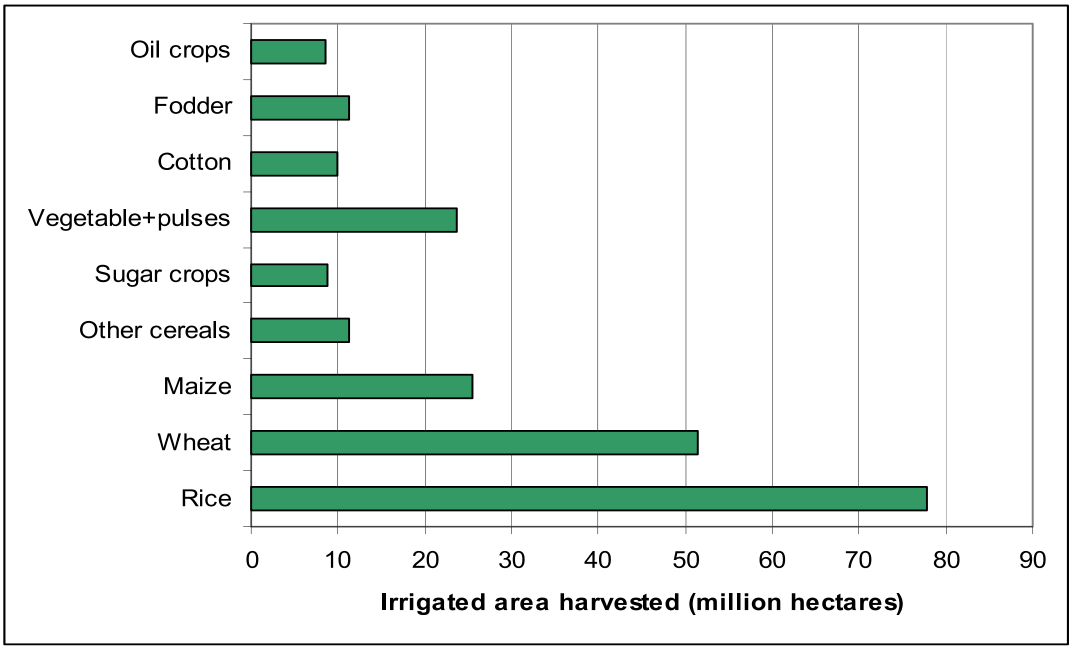

Figure 4: Distribution of crops under irrigation in the world (million ha). Source: FAO estimates based on data and information for 230 million hectares in 100 countries.

This increase has emerged despite political calls to halve the number of undernourished by 2015, made at the Global Food Summit in 1996 and later reiterated in the Millennium Development Goals in 2000. Notwithstanding such increases in absolute numbers, the total percentage of hungry people continues to decrease, but lately improvements have not managed to keep pace with the total population growth. In some regions, the negative trend has been steady over a longer time period. In southern and eastern Africa, the population of food-insecure people has more or less doubled over the last 25 years while per-capita cropped area has declined by 33% (FAO, 2006a).

A range of factors or drivers needs to be considered when looking more carefully at statistics. Population growth continues to be highest in regions with, generally, the least capacity to increase their food production. Insufficient infrastructure (for irrigation, storage, transport) prevails in many countries and regions. Poverty, civil strife, the lack of capacity to implement necessary management changes or investments and lack of human and financial resources are other factors. The impact of higher food prices, which can lead to increased hunger even if food is available, is evident now. But such price increases can be driven by higher costs for energy and other input resources, increased competition, market and trade failure or even market speculations.

FAO projects that a combination of future population growth and economic growth will push food requirements to double current levels by the 2050 (FAO, 2006a), including an increase of grain production from 2 billion to more than 4 billion tons. Current food production consumes more than 2500 billion m^3 of water annually, or 75% of total freshwater consumption (FAO, Aquastat database 2008). This level of demand will have far reaching consequences for the allocation of water resources between all productive economic sectors.

The fact that more than 900 million people in developing countries currently remain undernourished can be attributed to lack of access to food rather than a lack of global capacity to produce enough food. Even though global food stocks are falling and recent agricultural growth has been very sluggish, the global capacity to produce (and waste) food has not been cited as a direct cause of malnutrition. Nonetheless, a combination of limited food stocks and volatile energy costs clearly played an important role to push up consumer prices during 2008 (FAO, 2008b). Given that rising population and incomes drive demand for food in a predictable pattern, will climate change amplify further food supply shocks and will these shocks lead to shortfalls in production that impact global food security?

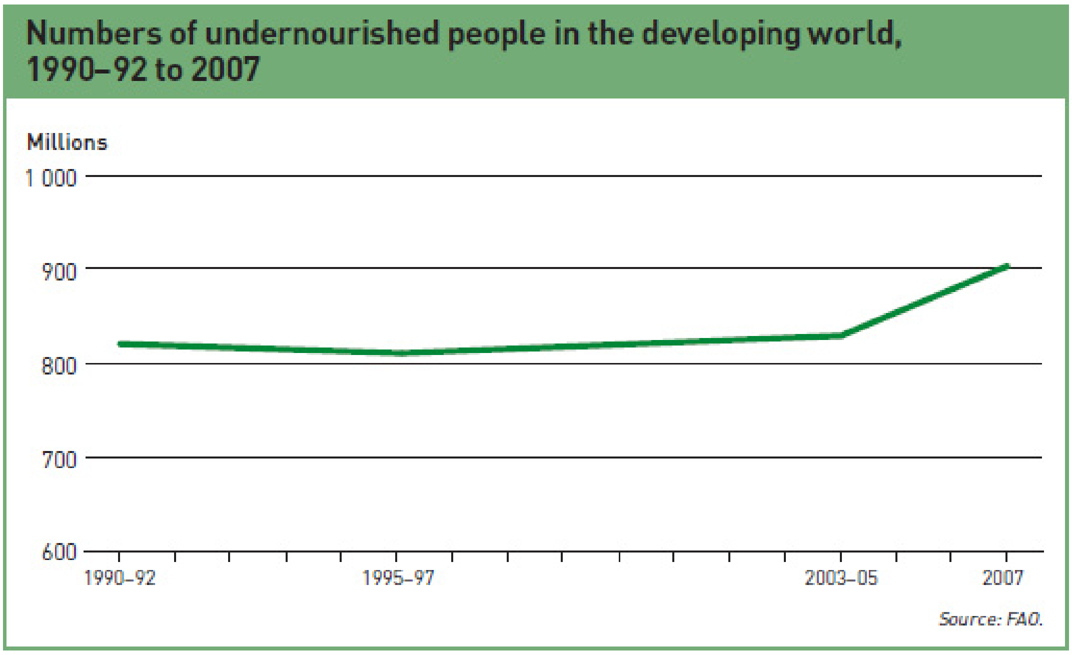

Figure 5: Numbers of undernourished people in the developing world, 1990–92 to 2007.

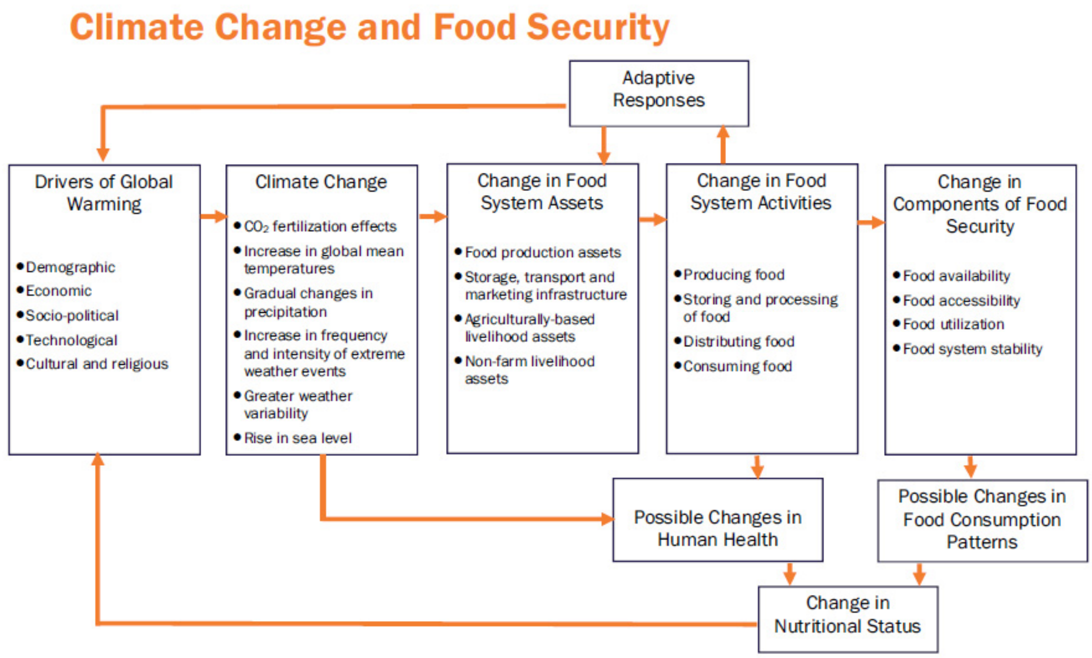

Figure 6: The interrelationships between climate change and food security. Source: FAO.

Anticipated impacts of climate change on global hydrology – transmission of impacts to agriculture

The Fourth Intergovernmental Panel on Climate Change Assessment Report (IPCC AR4), published in 2007, presents the state of the art knowledge, including important references to the modelled climate change impacts on water resources. A more detailed technical paper on climate change and water has been prepared by the IPCC (Bates et al., 2008) and provides a comprehensive synthesis. Since agriculture is practiced in most parts of the world, with the exception of interior deserts and the Polar Regions, all hydrological impacts are of significance to agricultural practice and production.

According to the IPCC AR4 "*warming of the climate system is unequivocal*" with considerable impacts on air and ocean temperatures, snow and glacier melting and a rising sea-level. Both IPCC (2007) and Bates et al. (2008) stress with high confidence that a number of hydrological systems have started to change following changes in climate, for example through increased runoff and earlier peak discharge in snow and glacier-fed river systems.

There is a globally increasing trend in precipitation over land areas of about 3.5 mm/year per decade but this is based on very short observational record (1986–2000) (Wild et al., 2008). Regional scales are more important than global averages. Increasing precipitation trends are evident from the eastern part of the Americas, northern Europe, and northern and central Asia since the beginning of the last century. Decreases have been observed in the Sahel region (from the mid 20th century), the Mediterranean, southern Africa and parts of southern Asia (e.g. IPCC, 2007 and Bates et al., 2008). Changes in precipitation and evaporation have more or less direct impacts on both river and groundwater systems. Already semi-arid areas are vulnerable to small changes, and many such areas are expected to see decreasing rainfall combined with increasing evaporation (from higher temperatures). Certainly, in terms of managing the shallow renewable groundwater circulation, the prospect of climate change should prompt a sharpened appreciation of recharge processes, storage changes and socio-economic response. In addition, for those aquifer systems decoupled from contemporary recharge, the planned depletion may need to be re-evaluated if those aquifers are going to become the lender of last resort.

Ocean temperatures are an important factor to determine changes in precipitation. Events such as the El Niño and La Niña in the Pacific Ocean clearly have strong impacts on regional (and maybe even global) climate, not least precipitation patterns. Recent decreases in precipitation over part of Africa have been attributed to the warming of the Indian Ocean sea-surface temperatures (Funk et al., 2008). The understanding of the coupling of such events to atmospheric circulation (such as El Niño – Southern Oscillation (ENSO),the North Atlantic Oscillation (NAO), and climate change is essential. ENSO, as an example, and the associated cycles of drought and flooding events, could explain as much as 15–35% of global yield variations in wheat, oilseeds and coarse grains harvests (Ferris, 1999).

Increased precipitation (in total or as more intense events within a confined time period) will augment the risks for floods, in particular in flood plains and other low-lying areas. Deltas are particularly vulnerable to changes. Increases in precipitation, with more intense run-off, in combination with higher sea-levels could cause increasing flood risks. Less precipitation (combined with increasing water diversions and use) could, also in combination with higher sea-levels, lead to more intense coastal erosion.

Most mountain glaciers are currently retreating (Lemke et al., 2007, UNDP and UNEP, 2007, 2008, Bates et al., 2008), which at least partly explains changes in annual net flow as well as temporal changes in some rivers. In the Hindu Kush range, changes in the river ecosystem resulting from decline in the glaciers and perennial snow have already been observed. Historically, high-level discharge in these rivers lasted throughout the cropping season, from April–September. It has now shifted into shorter, more intense run off in April and May, leaving increasing periods of the cropping season relatively dry (Eriksson and Jianchu, 2008).

Although total river basin discharges will normally first increase through increased melting, the long term effect will be less run-off as increasingly smaller glaciers and reduced snow-pack reduce storage of precipitation as snow and ice (Jansson et al., 2003). When (or if) a glacier eventually disappears, the effects on the seasonal availability of water in downstream regions can be dramatic. Such changes represent a serious challenge to the one-sixth of the global population that relies on melt-water from glaciers and permanent snow-packs for part of the year (IPCC, 2007), notably in China and India for example.

Extreme events transmitted through the hydrological cycle, can have severe direct impacts on agriculture. From 1992 to 2001, nearly 90 percent of all natural disasters were of meteorological or hydrological origin (e.g. WWDR, 2006). However, it is still difficult to detect trends in small-scale events such as dust storms, hail and tornados and there are no obvious long-term trends in relation to the annual number of tropical cyclones (IPCC, 2007). Although a substantial increase is evident in the Atlantic since the early 1970s, periods of equally high number have occurred earlier in the 20^{th} century.

However, measured effects from extreme events are dubious. In part, this is in because the interactions are complicated and not linear, but also because a range of non-climate factors governs the observed effects. Modified landscapes and infrastructure development as well as changes in hydrological systems (river modification) strongly influence the effects of the climate signal. Flooding may increase in one area, but it remains a challenge for a planner to determine how much of the increase is due to climate change exacerbating precipitation and run-off and how much results form non-climate factors such as land use changes, river modifications etc. A drought may appear more straight forward, but the effects can be amplified by factors such as poor land management, land use changes and increased water use.

Regional rainfall projections and runoff are particularly interesting. Possible changes in runoff over the 21st century, based on results from 12 rainfall-runoff models, were presented in a paper by Milly et al. (2005). They show that there is a strong agreement between models on increases (10–40% by 2050) in the high latitudes of North America and Eurasia, in the La Plata basin of South America, in eastern equatorial Africa and in some major islands of the equatorial eastern Pacific Ocean. Similarly, decreasing average annual runoff (typically 10–30%) could be expected in southern Europe, the Middle East, mid-latitude western North America, and southern Africa. In other regions, there is less agreement between the models. An interesting and more detailed case also showing such challenges is the effort to predict rainfall changes over the Amazons (Li et al., 2006). Eleven models were used in the IPCC AR4 to predict rainfall. Out of these, five predicted an increase of annual rainfall, three predicted a decrease, and the other three models predicted no significant changes in rainfall. This is the planning reality many policy makers and managers will have to work from.

Precipitation patterns may also be affected by other factors. In a recent article in Nature, Cox et al. (2008) focuses on the increasing risk of Amazonian drought due to decreasing aerosol pollution. The correlations between such factors in this region can be difficult, as drought is a recurring phenomenon during El Niño – Southern Oscillation (ENSO) events. However, the drought occurring in 2005 did not correspond to such an ENSO event and it was therefore possible to look at other potential parameters affecting precipitation. This serves as an illustration of how difficult it is to find straightforward correlations and cause-effects. If there has been a significant cooling effect from relatively high atmospheric aerosol content, future warming could actually become even higher if we are successful in reducing the atmospheric content of such particles (see for instance Andreae et al., 2005).

Anticipated impacts on food production – how significant is the water variable?

The links between climate, water and food production may be complex, but the equation between temperature, water and plant physiology is essentially fixed. For any C3 (e.g. wheat) or C4 plant (e.g. maize), a fixed amount of evapotranspiration and carbon dioxide is required to assimilate carbon (Steduto et al., 2007). Put simply, more food or fibre production requires more soil water – whether it is derived from rainfall or from surface and groundwater sources through irrigation. While 'more crop per drop' may be an objective for overall management of irrigation and delivery of water to the soil horizon, any increase in biomass can only be attained through increased water availability in the soil horizon. While climate already determines what can be grown at any particular location, it is the range of hydrological changes that are anticipated under the various emissions scenarios that gives cause for concern. Impacts on crop production systems can be anticipated, from failure of rainfed crops in highland areas to inundation of irrigated crops in coastal deltas.

From a water management perspective, the first question to ask is how any climate change impact will translate to higher or lower temperatures and more or less water availability in the root zones of the staple crops upon which humans and animals depend. If this can be established with an adequate degree of precision for specific farming systems (Tubiello and Fischer, 2007; Fischer et al., 2007), the second question to ask is whether water management can facilitate the adaptation of farming systems to mitigate climate risk or exploit climatic opportunities. The levels of confidence attributed to the modelling of climatic impacts under the SRES emission scenarios notwithstanding, at the global level it is not a simple case of agriculture systems coping with higher temperature and less water. Purely in terms of climatic variables, the regional contrasts are significant. When super-imposed upon the mosaic of socio-economic development, the actual impact of climate on soil moisture availability and water supply to agriculture will be felt in terms of global food security as a second or third order effect. To the extent that water serves as the transmitter of climate changes to society, decisions over how water is allocated to meet basic human needs and the demands of productive sectors will constitute the primary adaptation measure.

Rainfed systems will be impacted by the first order effects of climate change – temperature, relative humidity and rainfall. Once soil moisture deficits in the root zone falls below the wilting point of staple crops, the assimilation of carbon and biomass is attenuated and yields fall off. Zero rainfall or lower than expected rainfall equates to zero or reduced crop yields and cannot be negotiated. Improvements to soil structure and moisture holding capacities can be made by agricultural practice, but if soils do not reach field capacity in any year, production will be zero or sub-optimal. Because of these first order effects, the productivity of rainfed systems under climate change assumptions can be modelled in terms of agro-ecological response (Fischer et al., 2007), but this does not detract from the fact that production from rainfed systems will continue to be inherently volatile. Under climate change projections, amplification of this volatility is expected.

Irrigated systems of all kinds, from village gardens to the large irrigation schemes associated with river valleys and coastal deltas are designed to buffer soil moisture deficits and remove the agricultural production risk both in subsistence and commercial farming systems. In this sense they have already adapted to climates with no or limited annual replenishment of soil moisture and will be impacted by second order effects of climate change – runoff and groundwater recharge. High temperatures and high insolation encourage growth of key staples such as rice, and low relative humidity keeps down pests and disease. Unlike rainfed systems, irrigated agriculture cannot be analyzed in the same way as the rainfed systems under Agro Ecological Zones (AEZ) assumptions (Fischer et al., 2007). Indeed AEZ modelling copes with irrigated areas as a 'mask'.

Regions already struggling with complex food-related challenges (marginal areas, subsistence farming, poverty, management challenges etc.) will clearly be more sensitive. The larger agricultural systems, such as the areas of continuous irrigation in Asia, may be more buffered in terms of runoff sources and recharge and the ability to apply technology, but basin-wide shifts in temperature, evapotranspiration and water availability would have greater impacts on global food supply. Assessing the scale impacts of climate change, hydrology and global food production is, therefore, a key challenge to modellers and statisticians. While there are a range of adaptation options already available, many of which are frequently used to cope with current climate variability, such options may only be suited to cope with moderate climate changes, but limited in dealing with more severe changes (Howden et al., 2007).

Thus, climate influences agriculture in various direct and indirect ways. Maximum, minimum and average temperatures set boundary conditions for crop growth, and changes in any of these parameters, therefore, have direct or indirect positive or negative effects on the food production potential of a specific crop and region. Temperature changes may eventually shift entire climate zones. Observations from many regions show that several natural systems are affected by regional climate changes (IPCC, 2007), but it remains a challenge to isolate the climate signal from other drivers of change occurring simultaneously. Direct effects from temperature changes on agriculture have been noted with 'medium confidence' in Northern Europe (IPCC, 2007) but are harder to detect in other parts of the world. Less extreme cold temperatures but more heat-waves are becoming increasingly likely (IPCC, 2007).

There is strong consensus that continued greenhouse gas emissions will cause further warming. In the shorter term, a range of emission scenarios points toward a 0,2 °C warming per decade. On longer time-scales (over the next century), scenarios indicate an increase between 1.1 and 6.4 °C (IPCC, 2007). Clearly, uncertainty remains high. As these are global averages, regional differences are likely to be substantial. Temperature increases are generally expected to be higher both at high latitudes and altitudes. For instance, the measured temperature increase at 3000 meters in the Himalayan region is three times higher than at sea-level over the last 100 years (Eriksson and Jianchu, 2008).

As argued above, the direct climate impacts on the hydrological systems are essential to agriculture. According to IPCC (2007) and Bates et al. (2008) climate change is in general expected to exacerbate water stress. This may have severe impacts, in particular in regions already under sever stress from population growth, rapid economic development, land-use changes, pollution and urbanization. The combined changes in both precipitation and temperature also affect groundwater recharge and run-off, and may therefore strengthen (warmer/less rain) or counteract (warmer/more rain) each other. IPCC points out that there is a high level of confidence that the negative impacts from climate change on freshwater systems will outweigh the potential benefits. As there will also be an intensification of the hydrological cycle, there are increasing risks of more heavy rain-falls, increasing direct crop damage and/or causing flash-floods and floods.

The direct impacts on food production depends on region and time scale. Although crop productivity is projected to increase some at mid- to high latitudes when mean temperature increases 1–3 °C, it is expected to decrease as the temperature increase becomes higher. In the seasonally dry and tropical regions, sensitivity to even small shifts in temperature is higher, and it is expected that productivity will decrease. In total (global scale), food production is projected to first increase but later decrease following continuously higher average temperatures. It is also important to consider other effects. The effects of CO_2 on plant growth present a good example. Although CO_2 acts as a fertilizer, it is the combination with the temperature changes and availability of nutrients which will give a net effect (Melillo et al., 1993 and Tubiello et al., 2007). CO_2 fertilization is, therefore, most profound in tropical wet climates and less so in cold climates. Other important aspects to consider are the changing patterns of weeds, pests and (pollinating) insects following changes in temperature and precipitation.

Although uncertain, IPCC also provides some disturbing examples of the effects that could be expected if not appropriately managed. In Africa alone, 75–250 million people are projected to be exposed to increased water stress, and yields from agriculture are expected to decrease as much as 50% in some countries. The area of semi-arid and arid land will increase. Land areas classified as very dry have already doubled since the 1970s (Bates et al., 2008). In Asia, freshwater availability in many large rivers may decrease and changes in water availability from glacier and snow melting will have extensive effects on water availability and thus indirectly on agriculture. In the Middle East, an increase in average temperature of 1 °C is likely to increase agricultural water demand by 10%. The costs can be significant and scenarios projecting a high significant temperature increase suggest costs equal to a 3,5% loss in GDP due to loss of arable land and threats to coastal cities (FAO, 2008d). In Latin America, there could be gradual replacement of tropical forests by savannah and productivity of some important crops is projected to decrease. Lobell et al., (2008) points out that South Asia and Southern Africa are two regions with food production based on crops that are likely to be negatively affected by climate change. However, the effects are in the end strongly dependent upon changes in other socio-economic parameters and the projected range of increasing numbers of hungry people in the future is very wide (Schmidhuber and Tubiello, 2007).

Climate change impacts are not only confined to developing countries. Agriculture and forestry is expected to become increasingly difficult in eastern Australia as aridity intensifies. In Europe, the already significant regional differences in water availability will increase and drought will be even more common in the Mediterranean region. North America will experience potential increases in rain-fed agriculture in the eastern and northern parts while decreasing snow and ice will reduce summer flows in already water scarce western regions. An article presenting potential hot-spots in North America represents an interesting overview (Kerr, 2008) of such challenges. In addition, there could also be severe effects on water quality, which, in turn, could have adverse effects on agriculture (e.g. Bates et al., 2008).

System	Current status	Climate change drivers	Vulnerability	Adaptability	Response options
1 Snow Melt Systems					
Indus System	Highly developed, water scarcity emerging.Sediment and salinity constraints	20 year increasing flows followed by substantial reductions in surface water and groundwater recharge. Changed seasonality of runoff and peak flows. More rainfall in place of snow. Increased peak flows and flooding. Increased salinity. Declining productivity in places	Very high (run of river): medium high (dams)	Limited room for manoeuvre (all infrastructure already built)	Water supply management: Increased water storage and Drainage; Improved reservoir operation; Change in crop and land use; Improved soil management; Water demand management including groundwater management and salinity control
Ganges Brahamaputra	High potential for groundwater, established water quality problems. Low productivity		High (falling groundwater tables)	Medium (still possibilities for groundwater development)	
North Western China	Extreme water scarcity and high productivity		High (global implications, high food demand with great influence on prices)	Medium (adaptability is increasing due to increasing wealth)	
Red and Mekong	High productivity, high flood risk, water quality		Medium	Medium	
Colorado	Water scarcity, salinity		Low	Medium: excessive pressure on resources	
2 Deltas					
Ganges Brahmaputra	Densely populated. Shallow groundwater, extensively used. Flood adaptation possible; low productivity	Rising sea level. Storm surges, and infrastructure damage. Higher frequency of cyclones (E/SE Asia); Saline intrusion in groundwater and rivers; Increased flood frequency. Potential increase in groundwater recharge.	Very high (flood, cyclones)	Poor except salinity	Minimise infrastructure development; Conjunctive use of surface water and groundwater; Manage coastal areas.
Nile river	Delta highly dependent on runoff and Aswan Storage – possibly to upstream development		High (population pressure)	Medium	
Yellow river	Severe water scarcity		High	Low	
Red River	Currently adapted but expensive pumped irrigation and drainage		Medium	High except salinity	
Mekong	Adapted groundwater use in delta - sensitive to upstream development		High	Medium	
3 Semi-arid / arid tropics: limited snow melt / limited gw					
Monsoonal: Indian sub continent	Low productivity. Overdeveloped basin (surface water and groundwater)	Increased rainfall. Increased rainfall variability. Increase drought and flooding. Higher temperature.	High	Low (surface irrigation); Medium (groundwater irrigation)	Storage dilemma; Increase groundwater recharge and use; higher value agriculture (Australia)
Non monsoonal: sub-Saharan Africa	Poor soils; Flashy systems; over-allocation of water and population pressure in places. Widespread food insecurity	Increased rainfall variability. Increase frequency of droughts and flooding. Lower rainfall, higher temperature. Decreasing runoff	Very high. Declining yields in rainfed systems. Increased volatility of production.	Low	
Non monsoonal: Southern and Western Australia	Flashy systems; overallocation of water; competition from other sectors		High	Low	
4 Humid Tropics					
Rice: Southeastern Asia	Surface irrigation. High productivity but stagnating	Increased rainfall. Marginally increased temperatures. Increased rainfall variability and occurrence of droughts and floods	High	Medium	Increased storage for second and third season; Drought and flood insurances; crop diversification
Rice: Southern China	Conjounctive use of surface water and groundwater. Low output compared to northern China		High	Medium	
Rice: Northern Australia	fragile ecology		Low	High	
Non-rice - surface irrigation			low	Medium	
Non-rice - groundwater irrigation			Medium	Medium	
5 Temperate (supplementary irrigation)					
Northern Europe	High value agriculture and pasture	Increased rainfall; Longer growing seasons; Increased productivity	Surface irrigation: medium; groundwater irrigation: low	Surface irrigation: low; groundwater irrigation: high	Potential for new development. Storage development; Drainage
Northern America	Cereal cropping; groundwater irrigation		Medium	Medium	Increased productivity and outputs; Limited optyions for storage
6 Mediterranean					
Southern Europe	Italy, Spain,Greece	Significantly lower rainfall and higher temperatures, increased water stress, decreased runoff	Medium	Low	Localised irrigation, transfer to other sectors
Northern Africa	Morocco,Tunisia: High water scarcity		High	Low	Localised irrigation, supplementary irrigation
West asia	Fertile crescent	Loss of groundwater reserves	Low	Low	
7 Small islands					
Small islands	Fragile ecosystems; groundwater depletion	Sea water rise; saltwater intrusion;increased frequency of cyclones and hurricanes	High	Variable	Groundwater depletion control; Water demand management

Table1: Climate change impacts and response options for agricultural water management, (FAO, 2008c).

Socio-Economic Drivers of Change

That climate change will determine shifting patterns of plant growth and present challenges and opportunities to current agricultural practice is not in dispute. But the rate at which any climate change will apply has to be considered against rates of change in the socio-economic systems upon which they are superimposed. Future socio-economic development will strongly influence the impacts of climate change on food security (Schmidhuber and Tubiello, 2007). The interaction with socio-economic drivers such as population and income growth has the potential to exacerbate and counteract the direct impacts of climate change. Management responses to environmental variability and socio-economic change are themselves varied, and have exhibited varying degrees of success and failure. For example, the Millennium Ecosystem Assessment (2005) finds that humans have changed ecosystems more rapidly and extensively than ever before in the last 50 years in order to meet our growing demands for food, freshwater, timber, fibre and fuel.

Below are presented a number of key drivers that will interact with climate change.

Population growth – Although the population growth rate has started to decrease, it is estimated that the global population will only level out at 8–11 billion around 2050. The best current guess is just above 9 billion, which means the global population will increase by almost 50% in 50 years. Regional differences will be dramatic and most of the population increase will coincide with countries already facing severe development and management problems or scarcity of resources (not least related to land and water).

Population distribution and dynamics – Populations will not only increase but also move. Urbanization will continue to drive development patterns. In 2007 humans became more urban than rural for the first time (United Nations, 2005). At the same time, 900 million people were confined to urban slums (WWDR, 2006). Urbanisation can exacerbate climate change impact on water by changing physical properties (run-off, soil water and groundwater recharge, evaporation, etc.), thus influencing the capacity for agriculture in the vicinity of the city, but growing cities are also a competitor for water. In addition, urbanization has a general impact on consumption patterns. The urbanization trend will continue and by 2050, the urban population is expected to have doubled.

Overall Economic development – Economic development can be both a negative and positive driver. There is, for example, a direct relationship between Gross Domestic Product (GDP) and diet, and as global economy is expected to grow at a rate far exceeding population growth, this is clearly a factor that needs to be considered. Economic growth tends also, in more general terms, to lead to increasing competition over natural resources, including land and water. At the same time, economic development also generates resources that can be reinvested in agriculture, for example to implement mitigation and adaptation measures to deal with climate change.

Consumption patterns – According to a recent report, the livestock sector generates more greenhouse gas emissions as measured in CO_2 equivalent – 18 percent – than the transport sector. It is also a major driver of land and water degradation (FAO, 2006b). This is one example of how trends in consumption patterns can shape future resource use and impacts. With increased prosperity, people are consuming more meat and dairy products every year. Global meat production is projected to more than double from 229 million tonnes in 1999/2001 to 465 million tonnes in 2050, while milk output is set to climb from 580 to 1043 million tonnes. Understanding the effect of consumption patterns is also essential from a wider climate change mitigation perspective.

Natural resource constraints and competition – Development related drivers, such as economic growth, would increase pressure on natural resources. Resource constraints and increased competition are in themselves drivers that could have potentially serious effects on food production capacities – competition over land, water, energy, and fertilizers, just to mention a few. Constraints may be a result of the lack of adaptation to the physical limitation of the resource, weak distribution systems and lack of relevant infrastructure, capacity (management and economic) problems, or a combination of these factors. Economic development, urbanization and population growth will also require more resources for other 'sectors' – such as energy, industry etc.

Although there are economic activities that will 'compete' with agriculture, the energy sector is likely the single most important. Water and energy is intrinsically correlated, and it is through the shared requirements of abundant water resources that agriculture and energy are so closely linked. Climate change, making less water available in some regions, can entail increased competition (e.g. hydropower versus irrigation).

Energy production requires water resources in the production phase (hydropower, bio-energy, geothermal energy, wave and tidal energy) or for cooling purposes. Although not always a consumptive user of water, there are direct water related challenges, for example increased evaporation from reservoirs, water use for bio-energy production or water quality degradation. If current policies are maintained, global energy demands are expected to grow by as much as 55% until 2030 according to the International Energy Agency (IEA) 2007 World Energy Outlook. Developing countries are expected to account for 74% of the total increase. Although the statistics from the same agency stress that oil, coal and gas will continue to dominate, other sources of energy will also need to expand. Renewable energy production (including biomass and hydro-power) is expected to increase by 60% until 2030 but will, nonetheless, still only cover a very small portion of total energy demand.

Bio-energy – Bio-energy is a special case. Increases in bio-fuel production have direct impacts on water consumption and food availability. Although biofuels could be a potential for many poor countries, areas already or on the brink of experiencing water stress could see reduced water availability for more basic needs of people as well as for vital ecosystems. As Varghese (2007) states, "*the indiscriminate promotion of bio-fuel development as a 'cheap and green' energy option may interfere with optimal water allocation, and/or the pursuit of appropriate public water policies that will help address the water crisis*". Although bio-fuel feedstock currently accounts for only 1 percent of the total area under tillage, and a similar percent of crop water use, production is likely to grow rapidly. Impacts are still poorly understood. Demand for biofuels based on agricultural feed-stocks will be a significant factor over the next decades and it has already contributed to higher food prices (FAO, 2008c).

Dealing with uncertainty

It is important to stress that uncertainty, or simply the lack of data or information, should not be a reason for inaction. Investments are already needed to better cope with ongoing climate variability and changes, be they natural or human induced. Such investments, in hardware (infrastructure) or software (human capacity), are critical adaptation measures under current levels of uncertainty about the future. If adequately implemented on a 'no regrets' basis, they have the potential to make society better prepared for and less vulnerable to future climate change.

The need for more precise understanding of biophysical and social processes remains just as pressing, climate change or not. The wish-list could be extensive, but Bates et al. (2008) provide an interesting overview on some major gaps related to climate change and water. They note that the "*ability to quantify future changes in hydrological variables, and their impacts on systems and sectors, is limited by uncertainty at all stages of the assessment process*". There are observational needs, needs to better understand what the climate projections are really depicting and what the impacts would be and, not least, what the appropriate adaptation and mitigation options are. There is also a range of other complex changes and interrelationships that must be further addressed. How will sea-surface temperatures change due to climate change? How will the content of aerosols change? What are the effects of changing albedo due to land-use changes, changes in snow and ice cover etc. What are the feed-back effects of such changes? All such factors will have a substantial effect on our capability to project changes in precipitation, among other factors. Results from current climate models, which are often contradictory in relation to rainfall changes, serve as a clear example.

In addition, there are still knowledge gaps related to CO_2 and climate responses for many crops, including many that are important for the rural poor (Tubiello et al., 2007). For water resources or agricultural planners operating at the local or even national level, the global climate models will still need further refinements: "*There is a scale mismatch* *between the large-scale climatic models and the catchment scale, which needs further resolution*" (Kundzewicz et al., 2007). Projected temperature shifts are still mainly provided as regional or global averages and regional differences will continue to be substantial. For a farmer, such global averages are not very helpful and the challenge to make projections on a more regional and even local scale will remain and need to be improved. To strengthen the capacity to 'translate' shifts in global circulation to regional and local weather conditions is therefore essential. The understanding of the impacts of natural large-scale phenomena such as the El Niño – Southern Oscillation (ENSO) (see for example Meehl and Washington, 1996 and Ferris, 1999) or the North Atlantic Oscillation (NAO) events must also be further improved, as they have substantial weather related impacts on, e.g., agriculture.

Another example of knowledge gaps is the lack of information about development impacts in other sectors. In the case of Energy, for example, the future impacts from bio-energy production more or less remain as uncertain as climate change impacts. A few years ago, bio-energy was, at most, a parenthesis in discussions, regardless of whether the focus was on energy development or land, water and food issues. Due to the necessity for climate change mitigation strategies, the whole situation has shifted in just a few years. A dramatic production increase of bio-energy could drastically alter future water and land requirements – and thereby have a substantially greater impact on food production capacities than climate change itself. With some estimating that as much additional water is needed to meet bio-energy needs in a few decades (under current projections) as to meet our food needs, this issue will only grow in importance.

As such developments are more market driven, they are likely to progress much faster than our ability to conduct necessary research based assessments on potential impacts. Some targets are already set. What will be the impacts of the US Energy Policy Act of 2005, which promotes further use of bio-fuels, considering that by 2015 bio-fuels may account for about 23% of the country's maize output? What will be the impacts of the European Union target stipulating a 5.75% market share of bio-fuels in the petrol and diesel market by 2010? There are some signs that biofuel production contributed to the 60 percent increase in the price of maize between 2005 and 2007, because of the U.S. ethanol program in combination with reduced stocks in major exporting countries (World Bank, 2007). To make informed, long-term decisions, more knowledge is clearly required in these areas – but can we get it fast enough?

Responses to water and food challenges

Climate change, water and agriculture must be priority issues for policy and decision makers in the coming decades. The 2008 World Development Report (World Bank, 2008) made this case very clearly, pointing out that 75 percent of the world's poor live in rural areas in developing countries. At the same time, only about 4 percent of official development assistance goes to agriculture, although it has been increasing over the last few years (World Bank, 2007).

If a growing population is to be fed and the volatility of rainfed systems adequately buffered to maintain global food security, only the delivery of more water into the root zone of productive land can assure the required production. Socio-economic drivers and climate change impacts will condition where this can be achieved. In this respect rainfed systems will need to become more opportunistic, harvesting soil moisture where possible, and irrigated farming systems will need to become much more flexible in their use of limited water resource. It is at this point of competition for surface and groundwater resources that agricultural agencies will have to become much smarter and responsive to a broader array of socio-economic drivers. Agriculture has always been the residual user of available water resources, but is still the largest user and the only productive user of water with a negotiable margin. Improvements in potable water supply management will still need to be made when raw water is scarce, but the volume of use will remain insignificant when compared to that of agriculture.

Policies and actions related to climate change, water and agriculture clearly need to be better incorporated into existing key development related processes. To a large degree, the drivers causing the problems, and therefore holding the potential solutions, are outside the immediate domain of the water using sectors. In the face of such uncertainty, water institutions will need to become more flexible, capable of anticipating changes in user behaviour and then implementing an intelligent mix of water resource use and regulation.

Below, some key policy and management responses are presented to prompt discussion. It is important to remember that economic sector responses to climate change many need to be extensive, ranging from specific field-level investments to major shifts in public policy support.

1 **Access to information relevant for policy and management is a strategic issue.** Having access to relevant information for policy making and for the development of management responses will be a fundamental prerequisite to better cope with and adapt to changes. Scientific data and state of art knowledge needs to be translated into policy and management relevant information that could be of direct relevance to decision making at various levels. The issue of scale will be fundamentally important. Overview maps, such as a recent example presented in Science (Kerr, 2008) showing potential hot-spots or broad-scale analysis to identify major areas of particular concern (e.g. Lobell et al., 2008) could be vitally important as tools to better communicate potential climate change challenges and impacts on regional and even local scales. Such hot-spots are not necessarily confined to regions suffering from direct climate-related challenges (low or erratic precipitation, high annual and decadal variability) but could also be represented by regions with weak adaptation capacity (e.g. many developing countries) or high impact risks (e.g. low-lying coastal areas etc). The provision of more relevant information will require:

- **An increased focus on how climate change interacts with natural climate related processes.** As an effect of direct impacts from changes in temperature or indirect effects through climate change impacts on water resources (and other parameters), other drivers may exacerbate or reduce the overall climate change impact (positive and negative feed-back effects). Climate change will interact with important natural climate related phenomenon such as El Niño – Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO). This can either strengthen or weaken the climate change signal, but our understanding is still superficial. As events such as ENSO and NAO have substantial weather related impacts of direct interest to agriculture, better understanding of climate change impacts on such events will be essential for improved regional and local projection capacities.
- **An increased focus on knowledge transfer and capacity building at the user's level.** For a farmer, urban planner or water resources manager, projected global climate change averages are not of real practical use. The capacity to make projections at regional and local scales need to be strengthened, and further investments are required to improve information disbursement and to strengthen the capacity of users to interpret and use such information, from the individual farm level to more large-scale urban planning or sector management strategies. However, as stated by FAO (2007) "*Improved access to knowledge is only theoretical for many in poor countries especially in rural areas*" as long as efficient technologies, including the internet, are not available. A range of methods to share knowledge at user level would therefore be appropriate.
- **Tools to better assess current technological solutions from a climate change adaptation perspective.** Technology and infrastructure will be essential to efforts to adapt to and mitigate climate change. They also, however, present challenges. Arguably, reliance on technological fixes has made us more vulnerable to previously climate change. If technology and investment has enabled agricultural practice to be pushed into marginal lands, then increased resource use has pushed some regions and countries close to or even beyond their natural resource limits. Hence technological progress may encourage a false sense of security and even inhibit adaptation measures. Therefore an assessment of the styles of water investment that can result in positive adaptation is an obvious first step. For example, the scope for high intensity investments such as dam storage to buffer production risk may need to be compared with economic result of dispersed low intensity investments in groundwater development and management.

2 **A focus on adaptation and mitigation strategies in agriculture that goes both deep and wide.** The integration of climate change-related challenges with other drivers is essential (Howden et al., 2007). If interacting drivers are not appropriately considered, there is a risk that investments will be made in vain or even become counter-productive. Land use

changes, large-scale water diversions, economic development, changes in consumption and production patterns (agriculture, industry), changes in population and population dynamics will all influence water resources availability and quality. In many cases these socio-economic changes may eclipse the local-regional manifestation of short to medium-term climate change. Reviewing such feedback systems needs a carefully measured application of science and economics, but a better understanding of such linkages forms the foundation for more effective policy interventions.

3 Shift the policy and management emphasis. The increasing focus on adaptation rather than risk mitigation is a positive step forward. But it is not enough. It will be essential to:

- **Increase focus on overall resilience building in all systems, particularly in the most vulnerable farming systems.** Moving from simply coping with impacts and managing risks to making well judged investments in adaptation and building long-term resilience needs sustained policy guidance. Ultimately, achieving improved resilience towards global changes, including climate change, needs to underpin more or less all planning and decision-making. In particular long-term and large-scale investments in water infrastructure and institutions need to be assessed in terms of their resilience.
- **Focus more on how the potential positive impacts of climate change can be harnessed.** Climate change will have beneficial impacts in some regions. Adaptation strategies also need to consider these implications in terms of local, national and international markets. For example, ensuring that agricultural production can increase in such regions in order to balance deficits elsewhere may require radical changes in food policy, particularly for countries that have cut back on their agricultural production capacity in recent decades.

4 Move beyond the sectors. Agricultural production and adaptation is clearly not just the mechanical application of bio-chemistry and water technology, and solutions to food-security challenges will need to be sought outside the water and agricultural disciplines. Macro-economic policies (notably those influencing social structures, market conditions and international trade), infrastructure development, and spatial planning will probably have the greatest impacts on demand for agricultural production and the capacity to adapt to changes. Thus, there are clear limitations to the adaptation measures that can be designed and implemented within the water and agriculture sectors. From a global food security perspective, influencing global trade policies on agricultural products, for example, may prove to be one of the more important climate change adaptation strategies. Climate change may increase food production imbalances and such imbalances will need to (at least partly) be dealt with through increases in regional and global trade. Such approaches to adaptation can be politically complex, as was recently demonstrated by the failure of WTO Doha 'development' round (United Nations, 2008). Given this, introducing climate change adaptation perspectives within such a process may be optimistic. However, wider market mechanisms and marked based instruments (such as the Clean Development Mechanism) can be expected to play a fundamental role in shaping adaptation and mitigation.

It will be essential to encourage more integrated or 'joined-up' policy processes to obtain appropriately scaled responses to climate change. But incorporating the varied interests of agriculture, water and energy sectors as well as policy makers influencing actors in market development, trade and infrastructure will be a challenge. Therefore a focus on the development of integrated management and decision-making tools is recommended. This may require an assessment of existing economic and legal planning instruments, including adaptation assessment frameworks (e.g. Howden et al., 2007) and more operational local/national management frameworks such as National Adaptation Programmes (NAPs).

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Perspectives on water and climate change adaptation

Adapting to climate change in transboundary water management

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

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

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

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

Participants were invited to contribute perspectives from three categories:

1 **Hot spots** – These papers are mainly concerned with specific locations where climate change effects are felt or will be felt within the next years and where urgent action is needed within the water sector. The hotspots selected are: Mountains (number 1), Small islands (3), Arid regions (9) and 'Deltas and coastal cities' (13).

2 **Sub-sectoral perspectives** – Specific papers were prepared from a water-user perspective taking into account the impacts on the sub-sector and describing how the sub-sector can deal with the issues. The sectors selected are: Environment (2), Food (5), 'Water supply and sanitation: the urban poor' (7), Business (8), Water industry (10), Energy (12) and 'Water supply and sanitation' (14).

3 **Enabling mechanisms** – These documents provide an overview of enabling mechanisms that make adaptation possible. The mechanisms selected are: Planning (4), Governance (6), Finance (11), Engineering (15) and 'Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA)' (16).

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

6 Adapting to climate change in transboundary water management

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Adapting to climate change in transboundary water management

A large part of the world's freshwater resources is contained in river basins and groundwater systems that are shared by two or more countries. As climate change is expected to raise the number of extreme situations of flooding and drought, both in frequency and in duration, transboundary management of these water resources becomes more essential to reduce the impact of these extremes.

Transboundary water management is in essence more complex than national and sub-national water management because the water management regime (the principles, rules and procedures that steer water management) usually differ more between countries then within countries. Transboundary water management therefore requires coordination over different political, legal and institutional settings as well as over different information management approaches and financial arrangements. Joint bodies are usually instrumental in achieving such coordination. Next to that, riparian countries should look for commonalities in the water management problems they face and should look for solutions that are mutually beneficial.

The UNECE Convention of the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) provides a common legal basis for countries to cooperate. The Water Convention is based on equality and reciprocity between countries. Its provisions offer the basis upon which countries can build their activities. The implementation programme under the Water Convention supplements those provisions by offering a range of guidelines for practical implementation as well as good practices. Under the Water Convention, the Protocol on Water and Health is established that aims to protect human health and well-being by improving water management, and preventing, controlling and reducing water-related disease. The Protocol on Water and Health is an important tool to address climate change impacts, in particular the impacts on human health caused by the effects of climate change on water resources and water services, such as water supply and sanitation.

In view of the expected impacts of climate change on water management, currently a Guidance on Water and Climate Adaptation is developed, to be finalised by the end of 2009. The objective of the Guidance is to support cooperation and decision-making in transboundary basins on a range of relevant or emerging issues related to climate change. For this purpose, the Guidance addresses adaptation to possible impacts of climate change on flood and drought occurrences, water quality and health related aspects as well as practical ways to cope with the transboundary impacts through, inter alia, integrated management of surface and groundwater for flood and drought mitigation and response. An important aspect of the Guidance is recognition of potential benefits of floods such as increased water availability and improved ecological status of floodplains. The Guidance illustrates steps and adaptation measures that are needed in order to develop a climate-proof water strategy, starting from the transboundary context. It focuses on the additional new challenges for water management deriving from climate change: what are the impacts of climate change on water management planning and how should this planning be modified to adapt to climate change.

The Guidance addresses the central elements of transboundary regimes; policy setting, legal setting, the institutional setting, information management, and financing systems and provides recommendations to incorporate and accommodate them. The Guidance also distinguishes 5 different types of measures to adapt water management to climate change that together form the so-called safety chain; prevention measures, measures to improve resilience, preparation measures, response measures, and recovery measures.

The Guidance aims at encourage mutual understanding between, and within, countries as well as between scientists and decision-makers. This understanding is best built through intensive cooperation. Moreover, by jointly working towards climate adaptation, riparian countries can achieve cost-effectiveness because measures can be implemented where they are most effective, irrespective of the national boundaries. The Guidance provides a structured approach towards developing such measures.

Nevertheless, in all the work towards adaptation to climate change, the major challenge for politicians is to have a vision of how to implement the ideas, as well as the courage to withstand criticism and to share power with other actors.

Introduction

Observational evidence from all continents and most oceans shows that many natural systems are being affected by anthropogenic climate changes. One of those affected systems is the hydrological cycle which encompasses water availability and water quality as well as water services (IPCC, 2007). Adaptation to climate change is, consequently, of urgent importance. The impacts will certainly vary considerably from region to region and even from basin to basin. This poses serious challenges for water resources management.

A particular challenge for water resources management is connected to the fact that many river basins and groundwater systems are transboundary; i.e. the basin is shared by two or more countries. Recent studies identify a total of 279 international river basins (Bakker, 2006), covering almost half of the world's total land surface (Wolf et al., 1999).

Similarly, there are also internationally shared groundwater resources hidden beneath the ground surface around the world. Two UNECE surveys of Europe have indicated that there are some 200 transboundary aquifers in the UNECE region alone (Almássy and Buzás, 1999) and an overview of internationally shared aquifers in Northern Africa shows that these aquifers underlie a substantial part of the land surface (Puri et al., 2001). A study done by UNESCO has identified 273 shared aquifers worldwide[1].

The amount of water resources, both surface and subsurface, shared by two or more countries is consequently substantial. This makes transboundary water resources management one of the most important water issues today.

Freshwater supplies are limited. Increasing water scarcity and depletion of natural resources, partly as a consequence of climate change, leads to a potential increase in water conflicts between countries that share transboundary waters (Yoffe et al., 2004). This water scarcity is, however, caused not only by natural processes but also by inadequate and inefficient water management and competition between water uses (Wester and Warner, 2002).

But water scarcity is not the only problem confronting neighbours who share transboundary waters. A recent study on floods in a transboundary context concluded that although only 10 percent of all river floods are transboundary, these floods represent a considerable amount of the total number of casualties, displaced/affected individuals and financial damages worldwide (Bakker, 2006). The situation is compounded by the inherent difficulties in managing floods that cross borders.

From the above it follows that where water resources management is complex, water management in a transboundary situation is even more complicated, in particular when this management has to account for the consequences of climate change. Given the abundance of water resources that are shared between countries, transboundary water management is an essential element to consider in sustainable water resources management and adaptation to climate change worldwide.

This paper addresses adaptation to climate change in transboundary water resources management. It discusses the theoretical background of transboundary water management and describes the UNECE Guidance on Water and Climate Adaptation as an important tool to guide countries in putting water adaptation to climate change into practice. The Guidance is currently under development within the framework of the UNECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention).

Water management regimes

Water management is based on certain (implicit or explicit) principles, rules and decision-making procedures that enable convergence of stakeholders'

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1 World-wide Hydrological Mapping and Assessment Programme (WHYMAP). http://typo38.unesco.org/en/about-ihp/associated-programmes/whymap.html

expectations. Such a set of principles, rules and procedures is called a regime. Transboundary water regimes usually include formal rules such as international water conventions, statutes of transboundary water commissions, cooperative agreements adopted by national governments aimed at coordinating national water management activities in transboundary water basins, and relevant national laws and procedures. Regimes also include informal rules such as, traditional ways of using natural resources (traditional ways of transport or fishing, for example) that are informally accepted in transboundary water basins but are not documented as formal norms in agreements or contracts (Roll et al., 2008). Prevention and resolution of (potential) conflicts between water uses in riparian countries, and avoidance of severe effects of floodings, droughts, accidents, etc., especially in transboundary waters, compels countries sharing a water resource to reach agreement on common rules and procedures of cooperation to jointly manage these water resources (Nilsson, 2006). This cooperation is a component of the overarching term 'water governance' which depicts a change in thinking about the nature of policies. The notion of government as the single decision making authority has thus been replaced by a more contemporary, multi-scale, polycentric governance. Governance takes into account that a large number of stakeholders in different institutional settings contribute to policy and management of a resource. Governance differs from the old hierarchical model of government in which state authorities exert sovereign control over the people and groups making up civil society. Governance includes the increasing importance of basically non-hierarchical modes of governing, where non-state actors (formal organisations like NGOs, private companies, consumer associations, etc.) participate in the formulation and implementation of public policy. Governance thus encompasses a broad range of processes related to the coordination and steering of a wide range of stakeholders by formal and informal institutions. The water management regime is consequently a pivoting point in achieving a well organised water governance system which supports adaptive management of water resources (Timmerman et al., 2008).

Where water is sometimes used as a tool and argument for conflict, shared waters can also be a source of cooperation. In fact, initiatives aiming at river basin management regimes and institutions committed to bilateral and/or multilateral cooperation regarding transboundary water resources prevail (UNEP, 2002). Such cooperation often starts with exchanging information between countries. Over time, cooperation may come to pass on different water management issues like joint projects and even joint planning (Enderlein, 1999). It should be noted, however, that while many initiatives are in place to jointly manage surface water resources, the same cannot be said about transboundary aquifers which are usually less developed. By its nature, the beneficial use of groundwater is more particularly subject to socio-economic, institutional, legal, cultural, ethical and policy considerations than surface water (Puri et al., 2001). Its national development nevertheless seems to be hampered by weak social and institutional capacity, and poor legal and policy frameworks. In a transboundary context, this can be even further amplified because of contrasting levels of knowledge, capacities and institutional frameworks on either side of many international boundaries.

Thus far, different elements of management and use of water resources have been mentioned. These elements are structured here into five central elements that describe transboundary regimes: policy setting, legal setting, the institutional setting including the actor networks, information management, and financing systems (Anonymous, 2001; Raadgever et al., 2008).

Water policies that are in place in a country can be found in the formal documents which contain current and future water management strategies. They refer to the goals of government, or other organizations and strategies to reach those goals. As policies have a strategic character, especially in view of climate change, they should have a long-term time horizon: current management should actively prepare for future changes. Policy strategies should fulfil current needs and have the ability to perform well in multiple possible futures. Because today's information is not sufficient to identify all possible futures, strategies should be flexible and keep as many options open as possible (Raadgever et al., 2006). To promote effective implementation, policies should be tailored toward the specific interests and resources of the involved parties. From the perspective of adaptation to climate change in water management, policies become hypotheses and the consequent management actions become experiments to test those hypotheses. This requires continuous monitoring of progress toward achieving policy objectives as well as learning from the results of management actions (Raadgever et al., 2008).

A major challenge in managing transboundary waters is that the waters must be managed in the context of potential inconsistency and conflict of policies when no single government has control. Transboundary water management is faced with the task of solving complicated problems dependent on the specific conditions created by the interaction of two or more political systems (Gooch et al., 2003). As transboundary water management requires dealing with different policies, learning between the stakeholders becomes even more important. Harmonisation of policies is needed to prevent situations in which management actions in one country neutralise or counteract management action in other countries. In such situations, communication and exchange of policies and plans is imperative.

The legal framework consists of the full set of national and international laws and agreements. Legal frameworks can support transboundary water management in various ways. First, law should be complete and clear and contain sufficient detail to offer guidance and support without being too restrictive. A complete water law reflects the principle of integrated water management and includes requirements for public participation and access to information. Furthermore, water laws can establish or influence formal networks, structures for information management and financial aspects of water management. Water management planning and implementation should be based on the existing legal framework and in turn may influence the legal framework. In addition, transboundary legal framework should support enforcement of management policy and include liability aspects as well as dispute settlements provisions. Finally, law should not limit management options but should provide incentives to alter management actions to changing circumstances. This can be achieved by including regulations for (periodical) review and change of laws and regulations including changes in the institutional setting, information management and financial systems (Raadgever et al., 2008).

Water management in literature is currently described in terms of complexity where problems are termed wicked (Rittel and Webber, 1973) or persistent (Van der Brugge et al., 2004). In complex water management issues, a wide range of governmental and non-governmental stakeholders should be actively involved (Ridder et al., 2005). All stakeholders in this approach should be invited to share and discuss their perspectives in the subsequent stages of the policy process and develop a process of active learning. These interactions can promote constructive conflict resolution which can result in inclusive agreements that the parties are committed to. In addition to formal networks, informal multilevel actor networks can enhance information flow, ensure collaboration across scales and provide for social memory (Raadgever et al., 2006). This participation in transboundary water management can be realised by the establishment of joint bodies responsible for the management of shared waters, either surface or subsurface. These joint bodies should support an interdisciplinary and intersectoral approach, and include stakeholders in their water management planning and implementation strategies (Raadgever et al., 2008).

As stated above, information is needed to develop understanding of the possible futures, but it is also needed to monitor policy progress. This information should be collected based on an understanding of the need for information for policymaking and policy evaluation. Decision-makers should therefore be closely involved in specifying information needs (Timmerman et al., 2000). Moreover, a broad range of governmental and non-governmental stakeholders should therefore be provided with an opportunity to express their perspectives in the decision-making process and should provide sufficient information to support their opinions. They should also be invited to articulate their information needs and influence the production of information. To be truly integrative, information should not only reflect multiple perspectives, but also consider current and future uncertainties. Furthermore, an infrastructure to exchange and discuss data, information, and viewpoints should be developed to support cooperation and participation within, but even more importantly between, countries. Only then can information production and exchange result in the use of information in policy debates, and influence water management decisions (Timmerman and Langaas, 2004). This also requires clear communication about the interpretations and assumptions used to produce the information and critical (self-)reflection by the producers (Ridder et al., 2005). Especially in the transboundary context, information management faces the challenge of exchanging comparable information of sufficient quality.

Because water management also requires involvement of local communities and local stakeholders, special attention should be given to the information channels used to inform and involve these groups. Communication on the local level often takes place through local newspapers, some of which are distributed free of charge. Next to that, local meetings are important in developing a dialogue with local authorities and inhabitants. The use of Internet is not yet commonplace in many communities but access is growing. Internet is therefore a potentially important vehicle to share information with local entities. (Roll and Timmerman, 2006).

Sufficient resources should be available to ensure sustainable water management. Transboundary river basin management faces the costs of producing a diverse set of public goods (e.g., flood protection) and market goods (e.g., hydropower), as well as the costs of the management process itself (e.g., travel costs). Resources for this should come from public as well as private sources. Financial as well as ecological sustainability can be improved by recognising water as an economic good and recovering the costs as much as possible from the users. Cost recovery from the users of the resource is an important funding source which can be directly linked to the intensity of use. This makes the users aware of the consequences of their activities and helps to avoid overexploitation. While water pricing can reduce excessive water use, access to clean water and sanitation should be offered to all humans at an affordable price (GWP-TEC, 2003). The cost of providing affordable public goods can be financed from national taxes. International donors and banks often bear the management costs of negotiating an international treaty, but they may also finance river basin commissions and projects for a longer time, and give loans for specific projects. However, too much dependence on donors and banks makes management vulnerable and not sustainable on the long term. The challenges confronting financing system for transboundary river basin management are to ensure sufficient funding, prevent perverse price incentives, and maximize learning opportunities. Moreover, the total costs should remain acceptable. Although participatory approaches, experimentation, and monitoring outcomes cost money, in the long run they may prevent costly delays and construction of unnecessary, expensive infrastructure. And financing systems are most robust when they can rely on multiple sources (Raadgever et al., 2008).

Ideally, decision making, financing, and benefiting should be in one hand. This promotes the integral assessment of measures and ensures implementation of agreed-upon measures. It also minimizes the potential for overuse when others pay the bill – literally or metaphorically. A perfect match would be impossible to attain. Consequently, river basin management should not become too complex. Authorities should be able to take loans and depreciate their assets. This facilitates making long-term investments and ensures that assets can be replaced in time (Raadgever et al., 2006).

Assets and limitations in transboundary water management

Several factors exist that will support or hinder cooperation between countries in transboundary water management. First, the characteristics of a given problem will influence the likelihood of successful cooperation; if the cooperation incentives are largely symmetric and the problem pressure is high, the prospects for effective cooperation are good. Second, cooperation between countries in collecting data and performing joint projects builds trust at the technical level and enhances cooperation on political levels. Thirdly, a clear institutional setting that is problem-oriented, flexible and equipped with a centralised organisation structure enhances cooperation. Joint bodies can be instrumental in this regard. Economic-technological capacities in the national water sectors as well as political stability are important factors for the development of joint water management. Finally, international context is essential: if bilateral relations characterised by mutual trust and cooperation, exist, effective transboundary water management will be possible (Lindemann, 2006).

Transboundary water management nevertheless heavily depends upon circumstances at the national level. Weak social and institutional capacity, poor legal and policy frameworks, and bad management practices bear great consequences in the transboundary context where they are even more amplified by differences between riparian countries. Improving transboundary cooperation is therefore enhanced by promoting development and implementation of (formal or informal) transboundary agreements, accounting for different political and cultural settings in the riparian countries, and involving major stakeholders (different national government bodies, regional and local governments, international governments and donors, the media, civic society, individual water users and/ or influential individuals) to maximise the likelihood of agreement (Mostert and Barraqué, 2006). It is clear, however, that the method of achieving this goal is context-specific – there is no single template that can be applied to all situations.

The UNECE Water Convention and its implementation

The Convention of the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) that was done at Helsinki on 17 March 1992 is intended to strengthen national measures for the protection and ecologically-sound management of transboundary surface waters and groundwaters. Even if the Water Convention does not explicitly mention climate change, it represents one of the most essential legal frameworks in the UNECE region to cooperate on the transboundary aspects of climate change and on the development of adaptation strategies. Many of its provisions provide present the basis for such cooperation. In the first place, the Water Convention obliges Parties to prevent, control and reduce transboundary impacts which includes those related to adaptation to (or mitigation of) climate change. In fact, adaptation measures, such as the construction of dams and reservoirs, should be designed and managed to avoid negative transboundary impacts and to generate the best possible benefit for the whole river basin. Therefore, their development requires consultation between the riparian countries, as demanded by the Water Convention. Moreover, water quality objectives shall be set and best available technology used. Parties are required to follow the precautionary principle which implies, in the case of climate change, that action be taken even before adverse impacts are fully scientifically proven. This principle is especially important in climate change adaptation as high uncertainties exist regarding the exact impact on water and other ecosystems.

The Convention also includes provisions for exchange of information, common research and development, and joint monitoring and assessment: thus providing a framework for riparian countries to cooperate in the development of adaptation strategies. According to article 2 of the Water Convention, riparian Parties should cooperate on the basis of equality and reciprocity, in particular through bilateral and multilateral agreements, to develop harmonized policies, programmes and strategies for transboundary basins.

In addition, Parties should establish early warning systems and mutually assist each other. Finally, one of the most important provisions of the Convention is the establishment of joint bodies, such as river commissions, to jointly manage the shared water resources. These joint bodies are the most appropriate framework where integrated adaptation strategies, addressing all main environmental, social and economic impacts of climate change, should be designed and implemented. The Water Convention thus sets the provisions to develop and implement the elements of a transboundary water management regime as described above.

Under the Water Convention, the Protocol on Water and Health aims to protect human health and well-being through improvements in water management, and through implementation of processes to prevent, control and reduce water-related disease. The Protocol is the first international agreement of its kind adopted specifically to attain an adequate supply of safe drinking water and adequate sanitation for everyone, and effectively protect water used as a source of drinking water. To meet its goals, the Parties to the Protocol are required to establish national and local targets for the quality of drinking water and the quality of discharges, as well as for the performance of water supply and waste-water treatment. The Parties are also required to reduce outbreaks and the incidence of water-related diseases. Thus, the Protocol on Water and Health is an important tool to address climate change impacts, in particular the impacts on water resources and water services, such as water supply and sanitation, which affect human health. In fact, the process of setting targets and target dates in the areas of access to water and sanitation, health protection, and environmental and water management, as required by the Protocol, will be a useful tool to account for, and adapt to, the impact of climate change on water resources and water services.

The implementation process of the Water Convention and its Protocol on Water and Health is ongoing. An extensive knowledge base is built through the development of guidelines and recommendations on several aspects of transboundary water management. These guiding documents are supported by studies and pilot projects. Important examples are the Guidelines on Sustainable Flood Prevention (UNECE, 2000), Strategies on Monitoring and Assessment of Transboundary Rivers, Lakes and Groundwaters (UNECE, 2006), as well as the Recommendations on payments for ecosystem services (UNECE, 2007b) which all describe approaches to implement policies and activities on the respective subjects. These documents aim at providing practical approaches towards implementation of the Convention's provisions on different aspects of transboundary water management. This knowledge base under the Water Convention provides countries with common approaches that do not need to be further negotiated. The focus can therefore turn to the practical implementation of the recommendations as documented.

Guidance on Water and Climate Adaptation

In 2006, the Task Force on Water and Climate was established under the Water Convention. This Task Force is entrusted with the development of a Guidance on Water and Climate Adaptation to be submitted to the Parties to the Water Convention in November 2009, for their possible adoption. The objective of the Guidance is to support cooperation and decision-making in transboundary basins on a range of relevant or emerging issues related to climate change. For this purpose, the Guidance addresses adaptation to possible impacts of climate change on flood and drought occurrences, water quality and health related aspects. It also addresses practical ways to cope with transboundary impacts through, inter alia, integrated surface and groundwater management for flood and drought mitigation and response. The Guidance acknowledges the beneficial aspects of floods including increased water availability and improved ecological status of waters (UNECE/WHO, 2008).

The Guidance utilizes the existing knowledge base as developed under the Water Convention and describes the stepwise approach towards climate proofing of transboundary water management. The work on the Guidance builds on the experiences from many national experts and experts from international organizations. It also builds on a questionnaire that was sent out in early 2008 to identify expected impacts of climate change on water resources as well as the adaptation measures planned or implemented in South-Eastern Europe, Eastern Europe, Caucasus and Central Asia. Moreover, the work on the Guidance builds on the outcomes of an international workshop that was held in Amsterdam on 1–2 July 2008 to discuss the first draft of the guidance document. Thus, the contents of the Guidance are ensured to reflect the state of the art in climate change adaptation, support the existing challenges that countries face and, through its comprehensive and integrative character, add to the existing water management practices.

The Guidance illustrates steps and adaptation measures that are needed to develop a climate-proof water strategy, starting from the transboundary context. It focuses on the additional new challenges for water management deriving from climate change: what are the impacts of climate change on water management planning and how should this planning be modified to adapt to climate change? Moreover, the Guidance promotes the integration of specific water management aspects in general national adaptation strategies.

The document begins from a transboundary context, but is intended to be relevant to national policy and planning strategies and to be based on measures developed for national purpose. The major target group for the document is decision makers and water managers, including those responsible for water management in the transboundary context. It will therefore primarily address issues relevant to the water management sector.

The Guidance is a roadmap towards climate proofing of water management which will focus on adaptation or coping options. The document follows a step-wise approach (Figure 1), which forms the basic structure of the document. The guidance thus addresses the five central elements of transboundary regimes: policy setting, legal setting, institutional setting, information management, and financing systems. The policy, legal and institutional settings form a triangle and influence each other. Their interrelationships should be such that they create an enabling environment in which adaptation to climate change can be shaped. Whereas there is a general tendency to consider climate change as a self standing issue – as was also shown by the survey questionnaire distributed by the Task Force – the Guidance promotes the integration of climate change adaptation into water management. Climate change can thus act as an important driver to improve water management strategies. In the Guidance, climate change information is the basic element upon which the vulnerability of communities in a basin is assessed. The criteria to determine vulnerability are subjective and politically sensitive. Therefore, meticulous consideration of the information needs is required because it steers the outcomes of the vulnerability assessment. Additionally, this information is needed to evaluate the effectiveness of measures as well as reflect upon the validity of the policy base under changing circumstances.

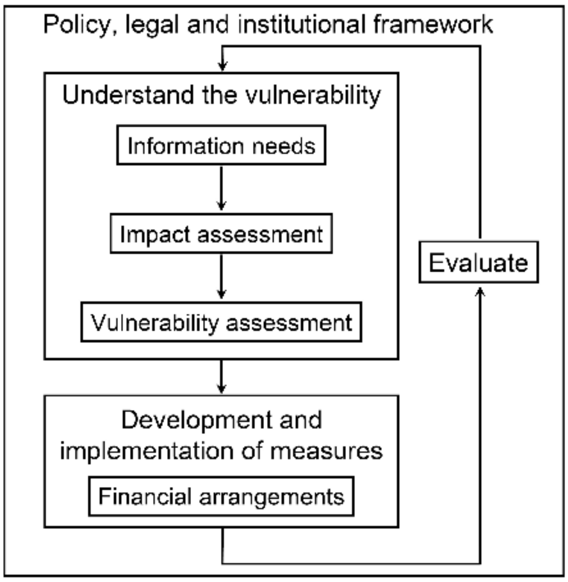

Figure 1: Development of an adaptation strategy. (UNECE/WHO, 2008)

Regarding the financial arrangements, riparian countries should focus on generating basin-wide benefits and on sharing those benefits in a manner that is agreed to be fair. A focus on sharing the benefits derived from the use of water, rather than the allocation of water itself, provides far greater scope for identifying mutually beneficial cooperative actions. Payments for benefits (or compensation for costs) might be made in the context of cooperative arrangements. Riparian countries can be compensated, for example, for land flooding as a consequence of water impoundment by another riparian. In some instances, it might be appropriate to make payments to an upstream country for management practices of the basin that bring benefits downstream (e.g. reduced flooding and sediment loads or improved water quality). This solidarity in the basin might entitle upstream countries to share some portion of the downstream benefits that their practices generate, and thus share the costs of these practices (Bernardini, 2007).

To enable climate proofing of water management, the guidance distinguishes 5 different types of measures that together form the so-called safety chain: prevention measures, measures to improve resilience, preparation measures, response measures, and recovery measures (see figure 2). All such measures are generally based on risk, hazard and vulnerability maps under different scenarios. Prevention measures are measures taken to prevent the negative effects of the climate change and climate variability on water resources management. This includes mitigation measures, designed to reduce the change in climate. Measures to improve resilience are those designed tot reduce the negative effects of climate change and climate variability on water resources management by improving the coping capacity. Preparation measures are measures designed to reduce the negative effects of extreme events on water resources management. Response measures are those designed to alleviate the direct negative effects in the aftermath of extreme events. Recovery measures aim at restoring the societal system after an extreme event has taken place. Recovery measures include, for instance, reconstruction of infrastructure.

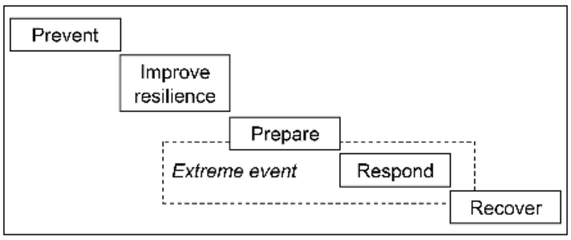

Figure 2: Different types of measures: the safety chain. (UNECE/WHO, 2008)

Application of the Guidance

The Guidance is an important building block in the implementation of the UNECE Water Convention. It is expected that the Meeting of the Parties to the Water Convention will assist countries in applying the Guidance in development of their water management regime. Also, the Meeting of the Parties will promote application of the Guidance by assisting in the establishment of pilot projects under existing programmes as well as encouraging application of the Guidance in capacity building programmes.

Pilot projects are especially important because they illustrate how transboundary cooperation can grow. In initiating a pilot project, riparian countries must show their willingness to engage in dialogue and cooperation with other riparian countries. The size of this step is limited because it concerns a pilot project supported by international regulations. Performing a pilot project enables countries to collaborate on a working level that only at a later stage feeds into decision-making. As a result, in the longer term, the Guidance will support the revision of formal cooperation arrangements (such as bilateral and multilateral agreements, mandates and actions of joint bodies) to include adaptation to climate change.

Reflection upon the key questions

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

One of the essential elements in narrowing the gap between the available knowledge and concrete decision-making is creation of mutual understanding. Scientists need to share knowledge between different areas (e.g. hydrology and climatology). They also need to connect to the problems decision-makers are facing. They should, for instance, not try to explain what the models they use are capable of doing but rather explain why their predictions give a range of possible futures. Decision-makers on the other hand should try to connect to the limitations of science. They should, for instance, not expect an unequivocal answer but rather be satisfied with a limited range of possibilities. A one-time meeting between scientists and decision-makers will not achieve mutual understanding – it will require intensive cooperation between the groups (Timmerman and Langaas, 2004).

In a transboundary context, the situation can become more complex as there may be differences between the available knowledge between countries. Countries usually use different techniques, approaches and models for their water management, which may result in different assessments of river basins and groundwater aquifers (Almássy and Buzás, 1999; UNECE, 2007a). This requires riparian countries to exchange information and come to agreements on the characteristics and forecasts of the waters they share upon which joint water management strategies can be built. All this depends on the willingness of actors to invest in improved understanding of the mutual differences as well as commonalities.

Where will climate change hit water resources and water services the hardest?

Given the differences in assessments between countries and the increased difficulty for countries to jointly manage their shared waters, impacts of climate change may hit water resources hardest in transboundary water management situations. The study of Bakker (2006) mentioned earlier showed that transboundary river floods, which only include 10% of the total number of worldwide floods in the period 1985–2005, are more severe in their magnitude and account for 32% of all casualties, almost 60% of all affected individuals and 14% of all financial damage. The study revealed that the institutional capacity in transboundary river basins is low and, even where joint bodies are in place, only few of these deal with transboundary flooding. The lack of transboundary cooperation in water resources management is consequently likely to aggravate the climate change impacts. Clearly, the need to establish joint bodies is imperative. Moreover, joint bodies should be mandated to deal with all aspects of transboundary water management.

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

Water related sectors, especially those that rely on large amounts of water, can be expected to face more severe problems as a result of climate change impacts. This will require them to reconsider their current practices and improve them. The need for reconsideration alone can be considered an opportunity to improve sectors' performance. Moreover, climate change not only poses threats to water-related sectors, but may also include tendencies that can be advantageous to sectors, like protracted growing seasons or improved weather conditions for tourism. And the development of new technologies and approaches may become unique selling points for which a potentially global market is available. Climate change thus opens the need for sectors to critically review and adapt. In the transboundary context, climate change might be an incentive to find cooperative arrangements which benefit the whole basin, such as joint water conservation projects, joint flood protection management strategies and infrastructures.

Where and when to put your money and what is required to get money committed?

The Stern report clearly declares that it is important that action should be taken as soon as possible because delay will surely result in increased costs (Stern, 2007). This not only relates to mitigation but also to adaptation. The money, however, should be wisely spent. To determine the best options for taking measures, a vulnerability assessment should be performed to identify the most vulnerable areas. Planning of measures should target these most vulnerable areas. In a transboundary context, measures that support adaptation in one country might be more effective if they are implemented in another country. Prevention of flooding, for instance, might be realized by creating retention areas upstream and such areas may be located in an upstream country. Financing should be equitably shared, where the party that gains most, pays most.

As riparian countries may have different approaches towards developing adaptation measures, a common understanding of the situation between the countries and a common approach is needed. Existing international agreements provide directions in this respect and the Guidance will be supportive in developing measures that are not only effective in one country but will also benefit others. The Guidance, for instance, states that in general, costs of implementation of adaptation measures should be borne by each country and governments should make efforts to include budgets and economic incentives in relevant bilateral and multilateral programs (UNECE/WHO, 2008). The poorest countries, that are often also most vulnerable to climate change, should be supported by more affluent countries in their development towards climate proofing of water management.

How can you identify and prioritize adaptation measures for climate change in the water sector and how can you design a portfolio of adaptation measures?

As stated above, identification and prioritisation of adaptation measures should be based on a vulnerability assessment. The Guidance provides a structure and in-depth advice on how a vulnerability assessment can be accomplished. It provides an overview of the various steps to perform to arrive at a portfolio of measures, starting from a policy, legal and institutional setting which provides an enabling environment wherein the vulnerability in a basin can be understood. The vulnerability assessment is based on the collection of relevant information and an overview of possible impacts. From this, measures can be defined in which the financial arrangements are essential. Finally, continuous evaluation is needed to ensure progress towards the objectives and to define additional measures if progress is not sufficiently realised.

Reflection upon the Political Principles

The global society is not a static one. Developments in Asia, for instance, lead to changes in demands for food and fuels. The price of oil is rocketing and the use of bio-fuels holds greater prospects, which in turn interferes with food production. Such developments have large implications for water management. The concept, for instance, of virtual water / water footprint (Hoekstra and Chapagain, 2007) tries to capture these implications by enabling comparison of such non-equivalent entities. Consequently, water management faces many challenges, among which climate change is an important one. But climate change adaptation should not be considered separately from other pressures and water management measures. Climate proofing of existing water supply systems can, for instance, be done in combination with ensuring the basic human right to water to those that do not enjoy that right at present. The adaptation responses should be considered in the context of integrated water resource management (IWRM) on the basis of the river basin. In the case of a transboundary basin, this should be done in joint agreement between the riparian countries. Adaptation measures should include aspects such as spatial planning, water quality, regulatory and operational measures, capacity-building, financial instruments, awareness building and involvement of the public. In the transboundary context this also includes solidarity between countries.

As adaptation is part of overall water management, the MDGs (Millennium Development Goals) should also be considered in the context of climate change. Climate change and climate variability can be hampering factors in achieving the MDGs. Climate change should not be used as an excuse under which hides bad water management. As stated above, improving water management should take into account climate change. The added attention to climate change can be an important element in improving water management and thereby help in achieving the MDGs. It is, nevertheless, indispensable to take into account that water management is frequently a transboundary issue and countries should be willing to join forces to achieve the MDGs.

The principles of IWRM, if well-implemented, can be very supportive in adaptation to climate change. IWRM includes the water sectors in its approach and water sectors should adopt these principles. Water sectors rely on the availability of water resources but should be aware of their responsibility for these water resources as well. As climate change and climate variability affect the availability of water resources, water management and water use can no longer be driven by the demand for water resources (Allan, 2008). On the contrary, water demand should adapt to the possibilities for supplying water. This does not exclude the necessity to improve and safeguard the availability of water resources. Adaptation measures should therefore be explored that not only cover the water sector, but also include sustainable land management, both on the national and transboundary level.

In part, water and energy are two sides of the climate change issue. Water can be an important producer of energy (for instance, hydropower) but can also be an important consumer of energy (for instance, desalinisation or pumping). Energy, on the other hand, is an important driver for climate change and thus complicates water management. Energy production and use also affects the aquatic community through infrastructure development and warming of water. Energy is nevertheless also necessary for adaptation solutions. The challenges for the water sector and the energy sector are therefore to find solutions that minimise the negative effects and maximise the possibilities.

The strategies to make water management climate-proof as developed in the political principles include: a) increase of storage space; b) increased and sustainable use of groundwater; c) revitalization of inland navigation; and d) more intensive use of hydropower potential. These strategies are generic and target many of the measures needed. They do not, however, account for additional, alternative options that may be needed at different levels. One essential strategy that is not included is management of water demand. Water use is often not efficient and is frequently wasteful, usually because the incentives to use water efficiently are not in place. In a transboundary water management situation, the upstream country often has control of the volume of water discharged to the downstream country. Using water inefficiently in the upstream country can result in water shortages in the downstream country. The strategies to make water management climate-proof should therefore also include water demand management on a basin scale.

Adaptation to climate change includes capacity building at all levels. Adaptation should be done in a participative way and this can only be achieved if all stakeholders involved have sufficient knowledge of the circumstances and the methods and tools that are used to develop possible futures. Moreover, they should have the available information at their disposal. Especially in transboundary water management situations, information is not always shared between countries. Moreover, information is sometimes collected and reported only because of the legal obligation to do so, without consideration of its actual applicability. Information can also be considered a hideout or safeguard where collecting information provides a sense of doing much useful work without actually having to implement solutions. Through this approach, information can be used to postpone decisions. Evidence of climate change occurring is, however, conclusive. Postponing adaptation measures because the information is insufficient to prove beyond a reasonable doubt that change is occurring cannot be an option. Information can also be used as a 'weapon', by using it to direct blame at other parties and to validate claims that it is the other party who is polluting the water or causing floodings. Information is, in this sense, also used to direct decision-making. Information that supports the desired outcomes will be put to the fore, while information that counters the desired outcomes will be discarded. Ideally however, information is used to support decision-making; the available information is the basis for the decision taken, it guides and supports the decisions (Timmerman and Langaas, 2004). The latter use of information is the preferred one, as this supports the necessary participative approach towards adaptation. It nonetheless requires that information collection be tailored to the needs of the stakeholders, at local, regional, national, and international levels.

Vision on the Adaptation Agenda for politicians

Adaptation of water management to climate change is not a stand alone issue that needs to be tackled: it is an integral part of integrated water resources management. Starting from this premise, politicians should be aware that in addition to the approaches towards finding solutions for climate change effects already in place, there are five main approaches that need additional attention in the overall water management.

First is that collaborative governance in water management should be strengthened. Adaptation measures should be built on a joint effort of government, society and science to ensure that measures will be effective and sustainable. This requires building of trust and social capital to ensure the problem solving process takes place. As stated before, pilot projects can be very supportive in achieving this. It will also require improving disciplinary integration, on the technical as well as the policy level (e.g., inclusion of spatial planning in water management). The development of new governance and participation models is indispensable in dealing with transboundary water management situations. This includes harmonisation of political, legal and institutional settings over administrative borders. Joint bodies are the obvious institutions to lead such changes, but often lack the mandate to implement such provisions. Improved information management is needed to support the processes on national and international levels.

Second is a paradigm shift from water supply management, where the water resources are managed in a manner designed to supply the needs for water, to water demand management, wherein the use of water is adapted to the availability of water. Use of water is often not efficient and as long as water management efforts are made to meet this use, for instance through redirection of flows, there is little need to modify existing use requirements. Measures should therefore focus more on improving efficiency of water use to ensure a sustained supply of water to the different uses in times when the resources become scarce. A specific issue in this regard is avoidance of conflict and contradiction between mitigation and adaptation strategies. Measures intended to increase water availability may also increase the use of energy (desalinization plants and pumping of groundwater, for example), thus adding to the emission of greenhouse gasses. Mitigation measures on the other hand, like development of bio-fuels, increase the need for water, thus aggravating water stress. Adaptation measures should therefore be evaluated for their energy-efficiency while mitigation measures should be evaluated for their water-efficiency.

Third is the need to look for non-structural adaptation measures. This relates to the need for demand management, where legal and policy agreements are needed to alter the use of water to improve efficiency. Also, incentives should be created to promote more sustainable use of water in not only agriculture and industry but in domestic use as well. Reduction of water use is, in this view, an essential adaptation measure. Next to that, human activities that increase vulnerability, like building settlements in flood-prone areas, should be discouraged through policy and legal actions. In all this, attention is specifically needed for subsurface water resources.

Fourthly, adaptation to climate change and other drivers of change such as energy and food prices, demographic trends, migration flows, and changing production and consumption patterns should be viewed as a long-term, continuous exercise and not a 'one-off' set of measures.

Finally, financing of measures is an important element of adaptation. An important principle here is that the use of water resources comes with a price, for instance based on the valuation of the service provided by water and the water-related ecosystems. It should, however, be noted that such an approach may lead to unexpected and unwanted effects, particularly for the most vulnerable groups. Close attention is warranted to avoid such unintended consequences.

While all this may appear obvious, implementation of these recommendations are highly demanding and will have to overcome the inertia of traditional approaches and resistance from various actors. The challenge for politicians is to have the vision of how to put the ideas into practice, as well as courage to withstand criticism and to share power with other actors.

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World Water Council
World Water Forum

co-operative programme on water and climate

IUCN

IWA International Water Association

Perspectives on water and climate change adaptation

Local government perspective on adapting water management to climate change

ICLEI
Local Governments for Sustainability

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

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

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

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

Participants were invited to contribute perspectives from three categories:

1 **Hot spots** – These papers are mainly concerned with specific locations where climate change effects are felt or will be felt within the next years and where urgent action is needed within the water sector. The hotspots selected are: Mountains (number 1), Small islands (3), Arid regions (9) and 'Deltas and coastal cities' (13).

2 **Sub-sectoral perspectives** – Specific papers were prepared from a water-user perspective taking into account the impacts on the sub-sector and describing how the sub-sector can deal with the issues. The sectors selected are: Environment (2), Food (5), 'Water supply and sanitation: the urban poor' (7), Business (8), Water industry (10), Energy (12) and 'Water supply and sanitation' (14).

3 **Enabling mechanisms** – These documents provide an overview of enabling mechanisms that make adaptation possible. The mechanisms selected are: Planning (4), Governance (6), Finance (11), Engineering (15) and 'Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA)' (16).

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

Local government perspective on adapting water management to climate change

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

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Local government perspective on adapting water management to climate change

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

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

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

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

Virtually all urban centres in high-income nations have the powers and resources to meet high standards of climate resilience, but there are still political, institutional and financial constraints on the ability of local governments to develop appropriate climate change adaptation policies, especially in low- and middle-income countries. The importance of good local governance can hardly be overstated. Where the institutional capacity to manage urbanization and provide equitable and quality public service is lacking, large populations of the urban poor will be increasingly vulnerable to climate-induced risks. *National governments and development assistance agencies need to engage with cities to help ensure that each city has the necessary competence, authority, funding and accountability.* The Adaptation Agenda must pledge these essential resources.

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

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

1 Infrastructure inadequacy

Climate Impacts and Vulnerability

Because cities support dense human development, they generally develop highly engineered systems to provide water supply, sewage disposal and storm drainage. Urban infrastructure is sized and engineered based on historic weather norms. In many cities, this existing infrastructure is under tremendous stress first, because of unprecedented urban population increases, and second, because systems are reaching the end of their 50-100 year service lifespan.

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

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

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

Strategies

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

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

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

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

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

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

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

Case 1: Durban – Merging adaptation and risk reduction[2]

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

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

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

Raise the height of shoreline stabilization measures.

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

Case 2: New York City - Incorporating climate change in infrastructure planning[3]

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

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

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

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

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

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

3 Based on: City of New York (2007).

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

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

Key questions

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

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

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

Associations of cities have now begun to address the climate adaptation process. ICLEI has published a climate resilience manual. The Istanbul Water Consensus, supported by city associations UCLG and ICLEI, engages city elected leaders in undertaking vulnerability assessments and adopting adaptation strategies. The Adaptation Agenda should recognize and support such networked capacity-building.

What is required to secure and direct investments?

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

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

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

2 Inundation risks

Climate Impacts and Vulnerability

For ease of trade and commerce, many of the world's great human settlements have been built on deltas, along coastlines or along river flood plains. Climate change makes these cities particularly vulnerable to water-related disasters. Sea-level rise and more intense storms will increase vulnerability to marine-induced disasters from tidal waves and storm surges. River flooding may be intensified by glacial melt-off and catastrophic rains. At the same time, higher sea level and lowered groundwater tables from pumping for urban use will result in salt water intrusion and compromised urban water supplies. Transportation infrastructure is at great risk – sea ports, low-lying airports, coastal highways and railroads, bridges subject to scour, subways and tunnels vulnerable to flooding. Residential development in river valleys and along sea coasts may become unsustainable. The lives and livelihoods of the urban poor are likely to be most severely impacted.

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

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

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

Strategies

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

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

Among possible adaptive measures:

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

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

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

Case 1: Mombasa – Merging adaptation and disaster reduction[4]

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

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

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

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

Case 2: Antwerp – Inundation areas and raised dikes[5]

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

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

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4 Based on: Awuor et a. (2007).

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

Case 3: Miami – Multi-agency planning[6]

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

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

Key questions

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

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

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

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

3 Water scarcity

Climate Impacts and Vulnerability

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

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

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

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

Strategies

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

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

- Building more storage;
- Conjunctive use of surface water and ground water, with ground water recharge;
- Desalination;
- Rainwater harvesting/stormwater harvesting [Singapore];
- Use of recycled water, including industrial process water and treated wastewater;
- Private vendors;
- Acquisition of water rights from agriculture;
- Matching use of water to quality (use potable water for potable purposes and use rainwater or on-site recycled water for toilets, irrigation, cooling, etc.).

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

Case 1: Seattle USA – Portfolio planning[7]

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

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

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

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

Case 2: Zaragoza – Water loss management and water demand management[8]

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

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

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

Case 3: London – Leveraging national government action through partnerships[9]

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

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

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

Key questions

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

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

8 Based on: www.switchurbanwater.eu.

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

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

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

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

4 Heightened competition for water

Climate Impacts and Vulnerability

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

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

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

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

Strategies

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

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

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

10 Based on: ICLEI (2008).

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

Case 1: Melbourne – Purchasing water efficiency savings from agriculture

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

The plan requires significant government investment. National Government dollars will

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

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

Case 2: Alexandria – Nested 'closed loop' developments[11]

At the mouth of the Nile River, the city of Alexandria faces the challenge of increased competition for river resources from the 10 nations and many cities and farm communities that use the river waters upstream. With 4 million people and an extra 2 million annual holiday visitors, Alexandria relies primarily on the Nile as its urban water source. Alexandria is engaged in a long-range strategic planning process, as part of the UNESCO/EU SWITCH programme, to develop Integrated Urban Water Management (IUWM). A key driver of the process is the city's vulnerability to competing demands on the Nile waters upstream, which are likely to increase under predicted climate change scenarios.

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

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

Key Question

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

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

11 Based on: www.switchurbanwater.eu.

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

5 Pollution

Climate Impacts and Vulnerability

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

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

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

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

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

Strategies

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

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

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

Case 1: Great Lakes and Lake Victoria – Transboundary collaboration of cities for pollution control[13]

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

[12] Based on: ICLEI (2008).

[13] Based on: www.glslcities.org.

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

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

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

Case 2: Boston – Infrastructure elevation assumes sea-level rise[14]

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

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

Key questions

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

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

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

What is required to get money to be committed?

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

6 Other Vulnerabilities – Biodiversity and Human Health

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

- Altered distribution of water-related diseases;

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

Conclusion – Political principles and local government adaptation

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

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

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

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

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

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

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

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

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

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Perspectives on water and climate change adaptation

Water, energy and climate change – A contribution from the business community

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

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

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

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

Participants were invited to contribute perspectives from three categories:

1 **Hot spots –** These papers are mainly concerned with specific locations where climate change effects are felt or will be felt within the next years and where urgent action is needed within the water sector. The hotspots selected are: Mountains (number 1), Small islands (3), Arid regions (9) and 'Deltas and coastal cities' (13).

2 **Sub-sectoral perspectives –** Specific papers were prepared from a water-user perspective taking into account the impacts on the sub-sector and describing how the sub-sector can deal with the issues. The sectors selected are: Environment (2), Food (5), 'Water supply and sanitation: the urban poor' (7), Business (8), Water industry (10), Energy (12) and 'Water supply and sanitation' (14).

3 **Enabling mechanisms –** These documents provide an overview of enabling mechanisms that make adaptation possible. The mechanisms selected are: Planning (4), Governance (6), Finance (11), Engineering (15) and 'Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA)' (16).

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

8 Water, energy and climate change — A contribution from the business community

This brochure is released by the World Business Council for Sustainable Development (WBCSD). Like other WBCSD publications, it is the result of a collaborative effort by members of the secretariat and senior executives from member companies. A wide range of members and non-business stakeholders reviewed drafts, thereby ensuring that the document broadly represents the majority view of the WBCSD membership. It does not mean, however, that every member company agrees with every word.

Water, energy and climate change — A contribution from the business community

Recently, there has been increased understanding of the links between water, energy and climate change. Research and knowledge have expanded and discussion has progressed within technical circles. Some places in the world have successfully integrated both water and energy into planning, from investment to institutional decision-making. For example, in December 2008, the US Environmental Protection Agency announced an inter-agency agreement between the offices of Air and Water to collaborate on energy and climate efforts for water utilities. Nevertheless, there is still a significant gap in communications addressing the linkages at a global scale. In particular, currently only a limited number of publications, scenarios and perspectives about energy and climate change also address water issues.

Today's financial crisis presents an opportunity for us to revisit the way we manage risk. We need to learn to consider critical issues such as water, energy, climate change, food, land, development and ecosystem services together.

This paper was initially developed for the 5th World Water Forum in Istanbul, Turkey (March 2009). Members of the World Business Council for Sustainable Development (WBCSD) have come together for this important event to provide a business contribution to this critical debate.

This document is composed of four parts:

- Key messages from business: The rationale for linking water, energy and climate change issues.
- Policy directions: Key policy directions recommended by business to policy-makers.
- Business implications in practice: Real-world implications of the linkages between water, energy and climate change for business.
- Facts in a nutshell: Quick facts on the interconnections between water, energy and climate change.

About the WBCSD

The World Business Council for Sustainable Development (WBCSD) brings together some 200 international companies in a shared commitment to sustainable development through economic growth, ecological balance and social progress. Our members are drawn from more than 37 countries and 22 major industrial sectors. We also benefit from a global network of some 55 national and regional business councils and partner organizations.

Our mission is to provide business leadership as a catalyst for change toward sustainable development, and to support the business license to operate, innovate and grow in a world increasingly shaped by sustainable development issues.

Our objectives include:

- Business Leadership – to be a leading business advocate on sustainable development;
- Policy Development – to help develop policies that create framework conditions for the business contribution to sustainable development;
- The Business Case – to develop and promote the business case for sustainable development;
- Best Practice – to demonstrate the business contribution to sustainable development and share best practices among members;
- Global Outreach – to contribute to a sustainable future for developing nations and nations in transition.

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Context

Why this issue matters now

> *"Climate change is expected to exacerbate current stresses on water resources.[...] Widespread mass losses from glaciers and reductions in snow cover over recent decades are projected to accelerate through the 21st century, reducing water availability, hydropower potential, and changing seasonality of flows [in some regions]."*
> Intergovernmental Panel on Climate Change, Climate Change 2007: Synthesis Report

Recently, there has been increased understanding of the links between water, energy and climate change. Research and knowledge have expanded and discussion progressed within technical circles. Some places in the world have successfully integrated both water and energy into planning, from investment to institutional decision-making. For example, in December 2008, the US Environmental Protection Agency announced an inter-agency agreement between the offices of Air and Water to collaborate on energy and climate efforts at water utilities. Nevertheless, there is still a significant gap in communications addressing the linkages at a global scale. In particular, only a limited number of publications, scenarios and perspectives about energy and climate change currently also address water issues.

- Global primary energy demand is projected to increase by just over 50% between now and 2030.[i]
- Water withdrawals are predicted to increase by 50% by 2025 in developing countries, and 18% in developed countries.[ii]

Today's financial crisis presents an opportunity for us to revisit the way we manage risk. We need to learn to consider critical issues such as water, energy, climate change, food, land, development and ecosystem services together.

Boosting water and energy use efficiency through investment in relevant technologies and infrastructure are critical pathways to achieving the United Nations Millennium Development Goals. It is essential that the current financial crisis not lead to a drop in this support.[iii]

Key messages from business

The rationale for linking water, energy and climate change issues

1 Water and energy are inextricably linked

- Both water and energy are essential to every aspect of life: social equity, ecosystem integrity and economic sustainability;
- Water is used to generate energy; energy is used to provide water;
- Both water and energy are used to produce crops; crops can in turn be used to generate energy through biofuels.

2 Global energy and water demand are increasing

- Energy and water demands increase with income. At low income levels, energy and water are used for basic needs such as drinking, cooking and heating. But as income increases, people use more energy and water for refrigerators, swimming pools, transport, watering and cooling that meet their new lifestyle and diet needs;
- In an increasing spiral, demand for more energy will drive demand for more water; demand for more water will drive demand for more energy;
- Business, along with all parts of society, needs to continue to improve its water and energy efficiency to enable sustainable growth.

3 Both water and energy use impact and depend on ecosystems

- Industrial, agricultural and domestic water and energy uses can have adverse impacts on ecosystems, including loss of habitat, pollution

and changes in biological processes (such as fish spawning). Such ecosystem impacts also affect the amount of water or energy supplies available;
- Maintaining environmental flows is critical to ensuring river systems can supply water to business and ecosystems;
- Water, energy and ecological footprints cannot be addressed in isolation.

4 Climate change will affect availability and use of both water and energy

- Climate change acts as an amplifier of the already-intense competition over water and energy resources;
- Mitigating climate change (i.e. reducing CO_2 emissions) as well as adapting to inevitable climate change risk (i.e. becoming better able to cope with an uncertain future) need to be considered together;
- Impacts from climate change on both regional and global hydrological systems will increase, bringing higher levels of uncertainty and risk, with some regions more impacted than others;
- There is not only one appropriate mitigation or adaptation strategy – each situation will require the appropriate and sustainable use of water and energy resources locally;
- Adaptation can come at a mitigation cost, such as building more robust infrastructure that emits more greenhouse gases.

5 Technology, innovation, a sense of shared responsibility and political will are factors that bring real solutions as we strive to keep pace with increasing needs from a growing population

- Resolving growing issues surrounding water and energy priorities will require better and integrated policy frameworks and political engagement to address them satisfactorily for all stakeholders within and across watersheds;
- Leadership from all parts of society is a condition for change to happen;
- We need:
  i – To get more energy out of each drop of water, and we need to get more water out of each unit of energy.
  ii – More renewable energy, and more renewed water.
  iii – Diversified energy mixes and alternative water supplies, e.g. industrial wastewater recycling, municipal wastewater reuse, and desalination, even though these are energy intensive.
  iv – More natural infrastructure, such as rehabilitating wetlands and mangroves to mitigate flooding, thus reducing the impacts of climate change in optimal combination with the cost of engineered infrastructure.

Policy directions

Key policy directions recommended by business to policy-makers

Water and energy policy need to be interlinked. Good governance and institutional capacity are needed, and business is willing to partner with policy-makers, legislators, researchers and others to help achieve these recommendations.

Below are five areas where business recommends policy interventions.

Please note that these policy directions *refer specifically to water, energy and climate change linkages*, rather than some of the broader key recommendations around water issues, such as water value and pricing, ownership and equitable allocation, to name but a few.

1 Provide reliable climate change risk data, models and analysis tools. In brief: Business needs reliable water, energy and climate change data, models and analysis tools in order to assess risk and make informed decisions or plans. Reliable meteorological and hydrological data should be collected at the national, sub-national and watershed levels. The tools and systems used to collect and analyse these data need to be consistent.
  Existing efforts around climate-risk data and models, such as the World Meteorological Organization's (WMO), World Hydrological Cycle Observing System (WHYCOS), United Nations Development Programme (UNDP), Climate Change Country Profiles, Water Information Systems for Europe (WISE) and the

UN-Water Task Force on Indicators, Monitoring and Reporting, have made significant progress over the years. However, gaps still remain.
– **Data**: There is a need for both in-situ (via data collection) and satellite observations. These must include a key assessment, both in the short- and long-term of the impacts of climate change, not only on water quality and quantity, but also water timing, (e.g. seasonal or monthly data, in addition to annual data).
Models: Better predictions and early warning systems about the effects of climate change at a regional scale are increasingly needed. This includes greenhouse gas (GHG) effects on the hydrological cycle and precipitation patterns, which means understanding the complexity of the water cycle and aquatic ecosystems and how these react to climate change.
Analysis tools: Interim management tools, such as scenario building, are necessary to be able to deal with the complexity of variables including climatic, economic, demographic and regional changes.

2 Integrate water and energy efficiency in measurement tools and policy. In brief: Water and energy efficiency are linked, and this needs to be expressed clearly in measurement tools and policy. A comprehensive, common approach to water and energy efficiency – or "footprint" – measurement is needed. Also, policy on water efficiency should include energy efficiency, and vice versa, because trade-offs and synergies do exist between the two.

- **System design**: The design of future water and energy systems needs to take into consideration the trade-offs and synergies between both resources. For example, a reduced water footprint (or impact) may, in one given case, result in a reduced energy footprint, but in another case may result in an increased energy footprint.
- **Measurement**: A globally accepted measurement tool that quantifies water and energy efficiency, or footprints, would enable society to make more informed decisions about trade-offs. Such a tool would need to incorporate complex variables such as type and sustainability of the water withdrawal, as well as an understanding of the cost and benefit of different options. For example, the Water Footprint Network is developing a common management practice linking water and energy footprints.
- **Policy**: Policy needs to be flexible to allow for the use of the most appropriate approach that depends on local conditions. For example, in a water abundant region it might be appropriate to reduce the energy footprint at the expense of increasing the water footprint, if this cannot be avoided. There is therefore a need for integrated river basin management that better takes into account energy and GHG emissions, as well as environmental values.

3 Ensure institutional capacities can deliver common management practices, education and awareness-raising. In brief: Institutional capacities should be built to increase awareness about water-energy linkages, leading practices for energy efficiency and water conservation, as well as the effects of climate change. This should include developing and promoting products and services that not only improve well-being, but also reduce water and energy impacts.

- **Business skills**: Businesses can contribute their experience and knowledge about these linkages, and can also share their skills in marketing, communicating, capacity-building and training.
- **Increased understanding**: Water resource managers need to better understand energy and ecosystem linkages; likewise, energy producers need to better understand water and ecosystem linkages.

4 Integrate and value ecosystem services into transboundary decision-making. In brief: The economic and social value of ecosystem services should be integrated into decision-making around water, energy and climate change issues. In order to maintain and maximize flow to all users, water should be managed at a watershed level, which requires transboundary cooperation and special care when allocating and distributing the resource.

- **Ecosystem balance**: Ecosystems, such as well-managed river basins and forests, control run-off and siltation and provide natural purification processes and regulate water flows.
- **Energy security**: There is very little (if any) information on how to ensure energy security while preserving ecosystem integrity in the face of climate change impacts.[iv]

- **Market mechanisms**: Market mechanisms, such as payments for ecosystem services, trading systems or certification standards, can be powerful complements to existing strategies for conserving ecosystems, if used in the right way.
- **Ecosystem valuation**: We are currently losing ecosystem services worth approx. 1.35-3.1 trillion (10^{12}) EUR/year. By 2050, the cumulative cost from not avoiding ecosystem losses is estimated at 33.3-95.1 trillion EUR.[v] To address this, we need further uptake and implementation of valuation tools that support decision-making that integrates the economic and social value of ecosystem services that are for now provided for free by nature. This is a key objective of The Economics of Ecosystems and Biodiversity (TEEB)[vi] project which is expected to highly influence and shape international political processes, policies and regulation around ecosystem valuation, as well as payments in the near medium-term future.

5 Encourage best practice through innovation, appropriate solutions and community engagement. In brief: Business can contribute to finding cost-effective and efficient ways of reducing water and/or energy consumption, e.g. reusing and recycling municipal and industrial wastewater by using energy-saving treatment processes. Such best-practice approaches should be encouraged and recommended by policy-makers.

- **Partnership**: Business can bring research, technology and innovation to the table. However, these efforts are only fruitful when supported by science, government, civil society and legislation.
- **Efficiency**: Significant water and energy efficiency gains can be achieved by minimizing water losses in water supply systems, due to not only wasting the water itself, but also the energy used to pump and distribute it. Energy can be recovered in water and wastewater transport and treatment systems – heat, cooling and energy production. Efficient irrigation schemes can be used to save water, e.g. by reducing losses due to evaporation and run-off through drip irrigation. New cooling systems can be designed in power plants to have an optimal trade-off between water and energy requirements and impacts (e.g. parallel condensing systems that combine wet and dry cooling systems).
- **Renewable energy**: Renewable energy use can be encouraged for water treatment processes, as well as wastewater plants.

Business implications in practice

Real-world implications of the linkages between water, energy and climate change for business

Leading companies are already tackling water, energy and climate change issues in different ways, and will increasingly do so in the future. This section highlights the challenges that companies face, and how some have responded in practice.

Please see http://www.wbcsd.org/web/casestudy.htm for complete versions of many of these case studies.

External challenges	Business implications	Case studies (Note: Can be relevant to more than one challenge or implication)
Reduced water availability *(of a certain quality and quantity, and at a given time, place or flow)* ***and increasing energy demand*** • Constraints on water withdrawals, consumption or use through: stricter regulations, limited supply • Energy supply will struggle to keep pace with increasing demand linked to increasing population and affluence • Constraints on energy efficiency and reduced emissions • Increased competition from different users • Need to consider energy and water impacts or footprints together	• Pay for increased operational costs • Save water and energy • Treat and recycle own water and wastewater (with associated energy costs) • Recover and reuse water and energy (e.g. using steam or heat, recycle other industrial and municipal wastewater) • Develop new markets for water- and energy-saving technologies and services • Use non-conventional energy sources • Measure water and energy impacts • Engage with communities to reduce potential for conflict and risks to license to operate • Identify best approach depending on local conditions, for example, in water-scarce countries	*Water and wastewater efficiency* • At **Shell**'s manufacturing sites, process effluents have to be disposed of according to increasingly stringent legislation, working towards a continuous reduction of water intensity with zero liquid discharge (ZLD) as the ultimate goal. ZLD is being applied in the Pearl Gas-to-Liquids (GTL) project in Qatar. Like any large project, Pearl GTL requires significant amounts of water, approximately 1,300 m^3 per hour, and the desalination of seawater is energy intensive. However, a GTL plant – due to the Fisher-Tropsch chemical reaction on which it is based – also produces water. At Pearl GTL, this is around 1,400 m^3 per hour. This has enabled Shell to design an integrated water management scheme based on the full reuse of wastewater. Over the full lifecycle of Pearl GTL, Shell will achieve a neutral or better balance between freshwater intake and water produced in the plant itself, meaning local water sources will not be depleted or affected. • In the past 5 years, **PepsiCo**'s water initiatives have enabled PepsiCo India to reduce water use in manufacturing plants by over 60%, and in last two years alone, it has saved over 2 billion litres of water. Over the last 3 years, PepsiCo India has conducted trials of various rice varieties in farmers' fields and used a seeding machine, which together have demonstrated water savings of 30%. • **BP** has chosen to develop biofuels that are particularly water efficient – using rain-fed sugar cane and temperate sourced crops including non-food energy grasses. BP is further investigating biodiesel from *jatropha curcas*, a shrub that tolerates periods of low rainfall. Investment planning requires environmental and social impact assessments and stimulates mapping of water basin management which otherwise may not take place. *Water efficiency and increasing production* • Water conservation has been a basic principle of good business for the **MeadWestvaco Corporation (MWV)** Mahrt paperboard mill since its startup in 1966. Exploding population growth in the southeastern US and years of acute drought continue to increase water demands on the Chattahoochee River and its associated reservoirs that stretch across the southeastern US. The mill, located on the Chattahoochee River, has proactively implemented sustainable water use reduction improvements while increasing its production over the past 40 years (Fig. 1). In recent years, MWV joined multi-state stakeholder groups to collaboratively address the area's water supply challenges. *Water, energy efficiency, CO_2 reduction* • **Dow Chemical**'s site in the Netherlands uses household wastewater that is converted into industrial water to be used as feed water for several plants. In turn, wastewater from these processes is treated and used as feed water for the cooling tower. Three million tons of water

External challenges	Business implications	Case studies (Note: Can be relevant to more than one challenge or implication)
		per year that were previously discharged into the North Sea are now used two more times, resulting in 90% less energy use and a reduction in CO_2 emissions of 1,850 tons/year. From 1994-2005, Dow reduced wastewater by 38% (per pound of production) globally. • Desalination is expected to increase about 15% per year due to the demands of a growing population. **GDFSUEZ**'s Perth, Australia desalination plant, one of the biggest in the world, produces 140,000 m^3 of drinking water every day, enough for the whole area. The electricity needed for the process is entirely produced by 35 windmills located 260 km from the plant. CO_2 emissions reductions are estimated at 200,000 tons compared to traditional desalination plants. • **TEPCO**'s high-efficiency heating and cooling system for Sony Corporation's new headquarters in Tokyo uses waste heat from a public sewage treatment plant. The result is a reduction of approximately 3,500 tons of CO_2/year and 92% less water used compared to a common office building. • **Veolia Water** has implemented a 100% energy self-sufficient wastewater treatment plant in Germany. The quality of the incoming wastewater is monitored, which guarantees the quality of the sludge produced. The quantity of sludge is then reduced through thermophilic digestion and provides 60% of plant's electricity (other energy sources include biogas from landfill). The digested sludge and treated wastewater are used as irrigation and fertilizer in nearby fields. *Providing the right technology* • One of the biggest US wastewater treatment plants, the metro plant for the twin cities of Minneapolis/St. Paul, gathers and treats, on average, 250 million gallons per day (about 950 million litres) of the municipality's wastewater. To lower energy costs and improve treatment efficiencies, the municipality replaced the existing inefficient, coarse bubble aeration system with over 320,000 ceramic and membrane fine bubble diffusers from **ITT**. Retrofitting all treatment tanks at the wastewater plant has resulted in power savings of 25%, creating annual savings of approximately US$ 1.9 million per year in energy costs. • **GHD**, working with Foster's Brewing, developed a water recycling scheme for the brewery that allowed them to augment the size of their Yatala brewery while reducing its water and energy footprint. The upgraded brewery reduced water use from 3.9 litres to 2.1 litres of water per litre of beer produced. Significant energy savings were achieved by not having to treat and transport water to the site and then treat and remove waste from the site. • At an Abbott Laboratories pharmaceutical plant in Ireland, one particular water pump was causing maintenance headaches. A life cycle cost assessment found that the pump was "over-specified" and was running at a greater speed than was required, causing poor performance and large energy bills. **ITT**'s technology both fixed the maintenance issues and created energy savings – approximately 52,000 euros per year.
Environmental & social constraints • Negative environmental or social impacts due to	 • Protect reputation and consumer trust	*Water-use planning* • **BC Hydro** spent seven years leading water-use plans on the 23 watersheds where the company has hydroelectric generating facilities. Water-use planning is a decision-making process that engages stakeholders in developing options for achieving a sustainable balance

External challenges	Business implications	Case studies (Note: Can be relevant to more than one challenge or implication)
excessive freshwater abstractions (either groundwater aquifers or surface water bodies) or greenhouse gas (GHG) emissions • Need to balance social, financial and environmental interests to maintain regulatory approval and the social license to operate.	• Remain a competitor in market • Keep licence to operate • Have long-term vision that impacts will eventually affect business • Sustainable operations yield regulatory certainty and social licence to enable continued operations	among social, financial and environmental interests. The Ministry of Environment used the water-use plans as the basis for water licence requirements that formalize the hydroelectric operations and provide for regulatory certainty. BC Hydro funds and participates in more than 200 studies (e.g. monitoring salmon populations) and physical work projects (e.g. improving salmon spawning channels) that are underway. • As an energy company, **Petro-Canada** is responsible for providing safe and reliable energy in the form of hydrocarbon products. Appropriately managing their water footprint can positively impact the energy and natural resources they require to make their products. Petro-Canada has corporate water principles that provide guidance on how they expect to manage water-related risks and opportunities consistent with their corporate policies, responsible investment and operations principles and business strategies. The principles focus on four key areas: employing responsible water practices, reducing water impacts, measuring and reporting performance, and building capacity with local communities. *Water and wastewater efficiency* • In order to reduce the sulphur content of its refined diesel fuel to 15 parts per million and be in line with new federal regulations, **Petro-Canada**'s Edmonton refinery (Alberta), needed additional hydrogen and steam. Making more hydrogen and steam would have required an additional withdrawal of up to 5 million litres of water per day from the river. Instead, Petro-Canada partnered with the municipality to install enhanced treatment capability and built a pipeline to the refinery to supply it with municipal wastewater as feed water for the plant, thus eliminating the need for additional freshwater withdrawal. *Wastewater, energy and CO_2 efficiency* • The international pulp market is increasingly competitive and demanding in terms of product quality and environmental performance. At the Richards Bay Pulp Mill, **Mondi** implemented new technologies that led to environmental improvements, including water use reductions of approximately 13,000 m^3 per day, CO_2 emissions reductions of 50% and wastewater volume reductions of over 25%. • Increasing production and disposal of water are critical issues in **Shell**'s upstream business (Fig. 2). Whenever possible, Shell looks at innovative technologies to minimize its operational water footprint. In the Middle East, Petroleum Development Oman is committed to using biofilters (reed bed technology) to clean up 45,000 m^3 of saline water (approx. 8 g/l) produced per day, by far the largest application of this technology. Instead of using deep subsurface disposal, this water is then reused for the production of biomass, reducing the overall CO_2 footprint.
Climate change • Increased risk and uncertainty regarding water and energy resources, as well as climate change impacts • Insufficient data on available resources, climate information and predictions, as well as	• Reduce vulnerability, by ensuring resilience in operations • Measure insurance costs vs. mitigation costs • Have several options for adaptation strategies that integrate the assessment of their ecological, social and economic potential, benefits and costs	*Adapting design to climate change* • The 2003 heat wave in France meant high air temperatures (leading to increased demand for cooling, including air conditioning), as well as high water temperatures in the rivers used for cooling nuclear power plants (thus leading to limited production for environmental reasons). This resulted in an estimated 300 million euros in global costs. **EDF Group** put together a climate change action plan that included cooling system design modifications, water issues (such as water flow management from hydropower), improved weather forecasting (including river water temperatures) and improved understanding of climate change impact on facilities (R&D project). Regarding hydro, **EDF Group** redesigned its sub-glacial water intake in Chamonix (Mer

External challenges	Business implications	Case studies (Note: Can be relevant to more than one challenge or implication)
toolkits for action	• Understand causal links between emissions, climate change, physical, ecological and socio-economic impacts	de Glace) due to the glacier's accelerating retreat – it has lost over 80 metres in thickness over the last 20 years. The new water intake will be located 800 metres upstream, under the glacier. *Innovative technologies for water savings* • **Eskom** uses about 1.5% of South Africa's total freshwater consumption annually while supplying more than 95% of the country's electrical energy and over half of the electricity used on the African continent. Innovative technologies (e.g., dry cooling, desalination of polluted mine water for use at the power stations) means that 200 million litres of water are saved every day compared to other, more common practices. Eskom also influences customers to get them to use electricity in the best way – for every kilowatt-hour of electricity that is saved, approximately 1.26 litres of water is also saved on average. Eskom continued to increase its energy production between 1993 and 2004 (by 43%), but with less water consumption (by 27%). • **GHD,** working with GOLD Coast Water, developed a robust scheme serving a 150,000 person urban development to adapt to climate change by integrating water supply, sewerage and storm water services. The scheme has reduced the amount of water imported to the development by more than 80% and reduced discharges to the receiving environment by more than 70%, all with a lower energy footprint than conventional schemes.
Issues related to local geographical conditions • Small islands and coastal mega cities as critical hotspots • Rapidly changing local conditions in supply and demand • Temperature rise and the impact of melting snow • Globally rising sea levels • Changes in precipitation patterns and extreme weather events	• Understand local situation • Apply integrated water and energy solutions appropriately • Deal with rising seas that penetrate aquifers and could impact physical assets (cause for increased insurance costs, supply chain interruptions) • Prepare for potential supply disruptions or infrastructure upgrade costs due to water and wastewater system flooding • Redesign facility to minimize water use and improve resilience and address contingency planning and emergency response preparedness	*Adapting to local availability* • **Rio Tinto** mining operations in northern Australia use water in a very specific way due to geographical conditions. Based on stakeholder engagement, there is a hierarchy of different water sources that the company uses – first recycled or reused water, then rainfall runoff that has been captured, and then aquifers. *Participatory activities to manage water locally* • With the objective of conserving each drop of rainwater in the region, Ambuja Cement Foundation (ACF), a division of Ambuja Cements Ltd. (**Holcim Group**) in India, addresses water and related issues through innovative and participatory activities. The network of interlinking water bodies and the creation of several structures has resulted in over 30 million m^3 of water harvested, benefiting an area of 21,000 ha containing over 8,000 wells and 10,000 farmers. *Forecasting the effects of climate change* • In the UK, **Veolia Water** studied the impact of climate change in the long run on the two main aquifers supplying water to the South-East of England, in particular the greater London area, providing 70% of the raw water treated by the company. Specialists implemented new tools allowing the Three Valleys Water company to apply the results of the Inter-governmental Panel on Climate Change's Global Climate Models, to adapt them to the regional scale, and to generate the forecasted impacts on the evolution of the groundwater resource in 25 years time.
Education and awareness of consumers	• Develop new markets for energy efficient water-saving technologies and services • Develop products and services that are more sustainable	*Consumer water and energy efficiency* • **Procter & Gamble**'s "Sustainable Innovation Products" include Ariel "Turn to 30" (wash clothes at 30°C), a line of products that saves energy and water through new formulations, product compaction and packaging innovations. Up to 85% of the energy used by laundry products is done so by the consumer to heat the water in the washing machine; only very little is used in the product's manufacturing. Efforts

External challenges	Business implications	Case studies (Note: Can be relevant to more than one challenge or implication)
	• Influence sustainable consumption • Respond to consumer demand • Contribute to development of tools or footprint methodologies	in communication and reassurance to the consumer have been successful in changing consumer behavior, getting them to reduce water temperatures. *Awareness-raising and collaboration* • **Borealis and Borouge** created *Water for the World*™ (www.waterfortheworld.net), a pioneering programme that fosters local knowledge and partnerships throughout the value chain to provide sustainable solutions for the availability of safe water and sanitation.

Facts in a nutshell

Quick facts on the interconnections between water, energy and climate change

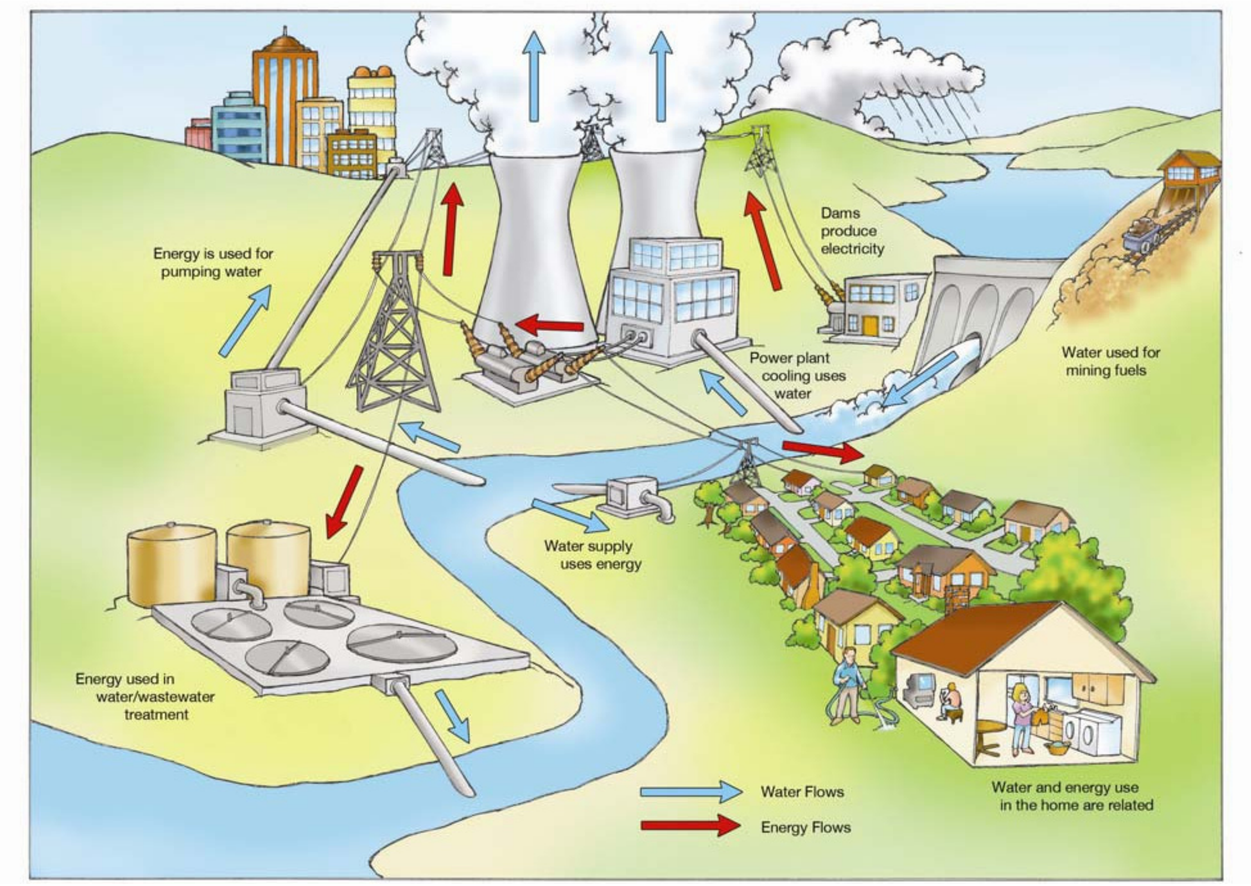

Fig. 3vii, Examples of interrelationships between water and energy. *(Source: US Department of Energy, Dec 2006)*

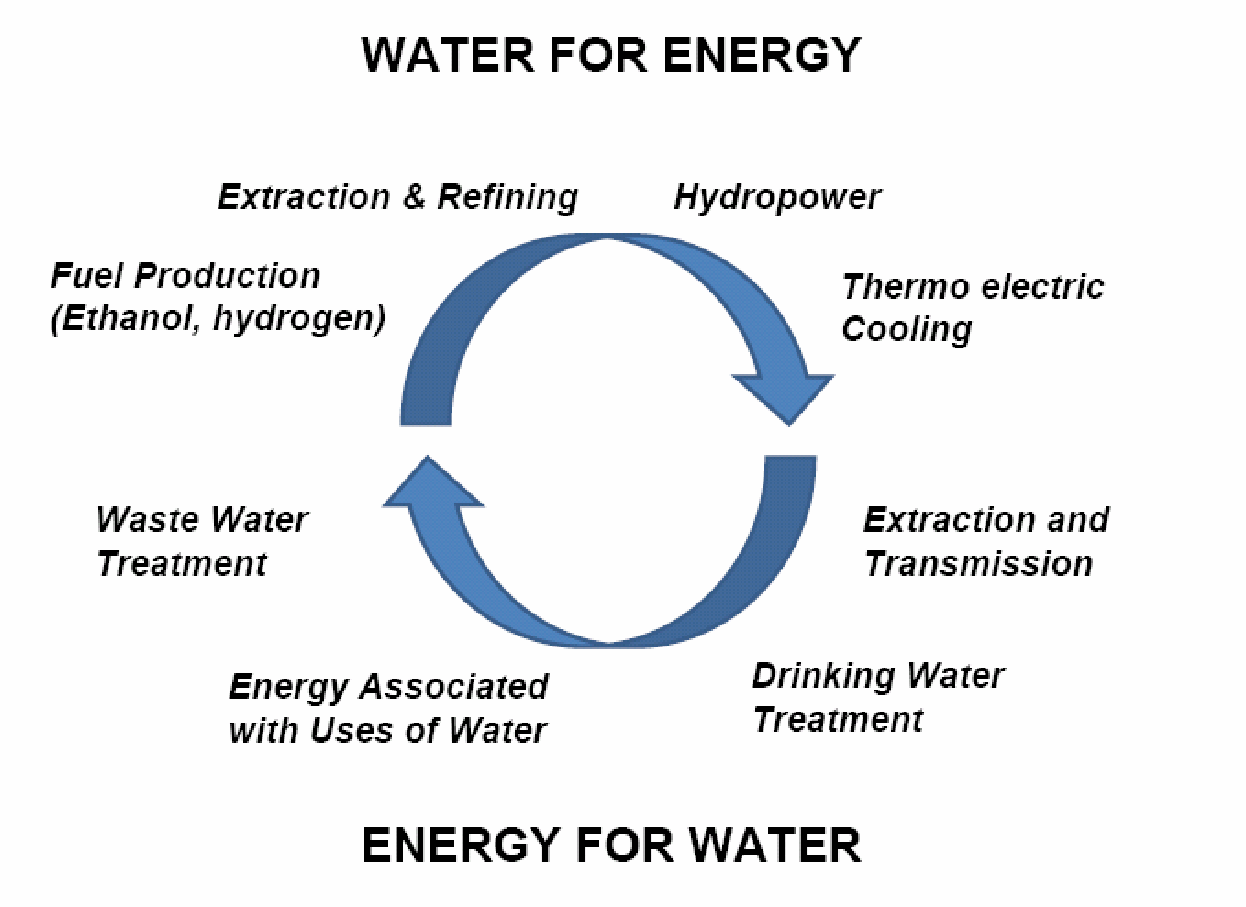

Fig. 4: Water for energy, energy for water *(Source: Paul Reiter / International Water Association)*

Warning: The diagrams below are illustrative and do not incorporate critical elements such as the distance the water/energy is transported or the level of efficiency, which vary greatly from site to site. For example, water transfer over 350 km (horizontally) uses 3.6 kWh/m3, or the same amount of energy needed to desalinate one cubic metre of seawater. The appropriate and sustainable source of water or energy depends on each situation.

How much is 1,000 GJ?

In 2005, 1,000 GJ represented the annual average energy consumption of

- 5 individuals in a developed country;
- 24 individuals in a developing country.[viii]

Energy in water

- Pumping freshwater from groundwater aquifers can have a high energy footprint;
- Estimates of energy requirements for pumping freshwater range from 540 KWh per million gallons from a depth of 35 metres (equivalent to 0.51 GJ per 1,000 m^3 of pumped water), to 2,000 KWh per million gallons from 120 metres (equivalent to about 2 GJ per 1,000 m^3 of pumped water);[ix]
- These energy needs will increase in the areas where groundwater levels are decreasing.

Water in different energy types

a Renewable energy

Hydropower

- Hydropower produced 89% of the world's renewable electricity in 2006, and 16.6% of total electricity generation worldwide. Two-thirds of worldwide economic potential remains unexploited – this resource is concentrated in the developing world;[x]

- 25% of dams worldwide are used for hydropower and only 10% have hydropower as their main use. Most of them are used for flood control or irrigation, or for multiple purposes;[xi]
- Hydropower uses and releases water instantaneously or with a delay but does not consume water. Their main loss stems from evaporation when air temperatures are high;
- Energy output from hydropower is dependent on sustainable upstream water use as well as hydrological patterns, and is therefore susceptible to climate change impacts;
- Hydropower reservoirs store both water and energy and are becoming increasingly important for the management of climate change.

Solar, wind and ocean energy

- Solar thermal power plant water consumption is about 1 m^3 of water per 10^3 kWh (electric) or 277 m^3 of water per 1,000 GJ;[xii]
- Wind energy and photovoltaic cells that produce electricity directly from sunlight are considered to have negligible water use;
- Wave energy is still a largely untapped source of renewable energy, which, like hydropower, uses water but does not consume it.

b Crude oil

- As easy oil is used up, pumping oil from reservoirs is now associated with more water production per amount of oil produced than ever before (due to aging of reservoirs and increased oil recovery operations). The volume of water produced worldwide from the oil and gas industry is still increasing at a rate of about 10% per year. Water to oil ratios ranged from <1 to up to 40 depending on maturity of the field with the lowest ratios generally observed in the Middle East;[xiii]
- Between 2 and 8 m^3 of water per 1,000 GJ have historically been required to extract oil, including water for drilling, flooding and treating.[xiv] However, when thermal steam injection or enhanced oil recovery is included in the process, this number can increase, on average, to 1,058 m^3 per 1,000 GJ.[xv]

c Oil refining and gas processing

- Consumptive water use for processing and cooling in traditional refining facilities in industrialized countries ranges from 25 to 65 m^3 per 1,000 GJ;[xvi]
- For about 800 million gallons of petroleum products refined daily in the US,[xvii] 1 to 2 billion gallons of water are consumed per day;
- CO_2 emissions per unit of electricity generation using current technologies for natural gas are approximately 50% lower than those from coal plants.[xviii]

d Biomass for conversion to biofuels (Fig. 6)

- An illustrative range of average water footprints for biomass production is 24 m^3/GJ (24,000 m^3 per 1,000 GJ) in the Netherlands to 143 m^3/GJ (143,000 m^3 per 1,000 GJ) in Zimbabwe;[xix]
- Large differences in crop water requirements exist among countries due to different climates.[xx] Also, the amount of water used does not reflect water sources and whether the crop is rain-fed or irrigated;
- Water is not only required for biomass production, but also for its conversion to biofuels.

e Coal

- More electricity is generated from coal than from any other fuel – 39% of world generation in 2002;[xxi]
- Open pit coal mining requires 2 m^3 of water per 1,000 GJ of energy in the coal, while underground mining operations require 3-20 m^3 of water per 1,000 GJ;[xxii]
- Coal power generation emitted 70% of power sector CO_2 in 2002.

f Uranium

Power generation.
There are two types of cooling systems for nuclear power plants:

- open-loop water cooling, where water is withdrawn from a river, lake or the sea, and then returned to it after cooling. The average amount of water consumed is approximately zero and the water required and then returned is approx. 160 m^3/MWh (equivalent to 44,444 m^3 per 1000 GJ).
- closed- loop water cooling, where water flows into a closed circuit and part of it is evaporated through a cooling tower into the atmosphere. The average amount of water consumed (through evaporation) is approx. 2 m^3/MWh (555 m^3 per 1000 GJ) and the water required and then returned is approx. 6 m^3/MWh (equivalent to 1, 666 m^3 per 1000 GJ).

(Figures based on average values from EDF from nuclear power plants along rivers in France.)

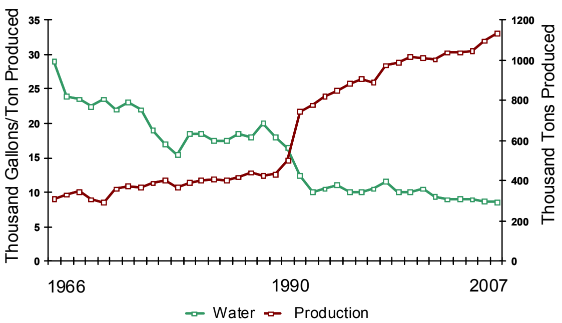

Fig. 1. Water use in paper production (MWV Mahrt mill, 1966 – 2007)

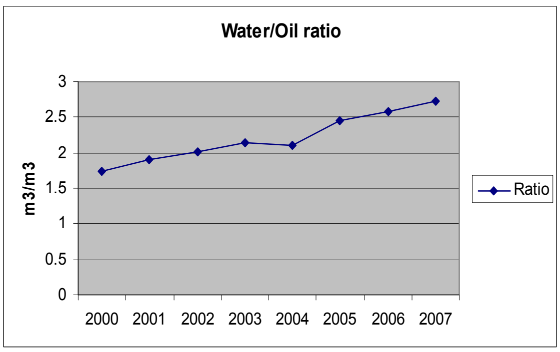

Fig. 2. Water use in oil production (Shell Oman, 2000 – 2007)

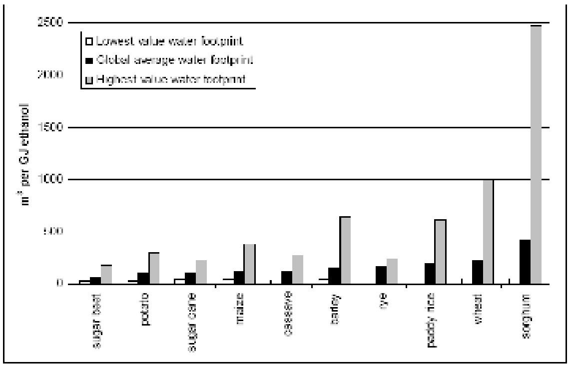

Fig. 6. Water footprint for energy for ten crops providing ethanol. *(Source: Gerbens-Leenes, et al. Aug 2008)*

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v **Braat, L., P. ten Brink, et al**, "The Cost of Policy Inaction – the case of not meeting the 2010 biodiversity target", Executive summary, May 2008.

[vi] The TEEB project, endorsed by the G8+5 Environment Ministers in 2007, aims to evaluate the costs of the loss of biodiversity and the associated decline in ecosystem services worldwide, and compare them with the costs of effective conservation and sustainable use. It is intended that it will sharpen awareness of the value of biodiversity and ecosystem services and facilitate the development of cost-effective policy responses, notably by preparing a "valuation toolkit". See http://ec.europa.eu/environment/nature/biodiversity/economics/index_en.htm

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[viii] World Resources Institute. EarthTrends: Environmental Information. International Energy Agency (IEA)

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Based on 2005 data, the average total energy consumption per capita for developed countries is about 4,720 kilograms of oil equivalent (kgoe) or about 199 Giga Joules (GJ). For the same year, in developing countries, the figure is 975.9 kgoe or about 41 GJ.

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[xv] Gerbens-Leenes, P.W., A.Y. Hoekstra, Th.H. Van der Meer, "Water Footprint of Bio-energy and other primary energy carriers", UNESCO-IHE Research Report Series No. 29, March 2008.

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[xvii] Energy Information Administration, 2006.

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[xix] Gerbens-Leenes, P.W., A. Y. Hoekstra, Th. H. Van der Meer, "Water Footprint of Bio-energy and other primary energy carriers", UNESCO-IHE Research Report Series No. 29, March 2008.

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Perspectives on water and climate change adaptation

Vulnerability of arid and semi-arid regions to climate change – Impacts and adaptive strategies

World Water Council
World Water Forum

co-operative programme on water and climate

IUCN

IWA International Water Association

المجلس العربي للمياه
Arab Water Council

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

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

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

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

Participants were invited to contribute perspectives from three categories:

1. **Hot spots** – These papers are mainly concerned with specific locations where climate change effects are felt or will be felt within the next years and where urgent action is needed within the water sector. The hotspots selected are: Mountains (number 1), Small islands (3), Arid regions (9) and 'Deltas and coastal cities' (13).

2. **Sub-sectoral perspectives** – Specific papers were prepared from a water-user perspective taking into account the impacts on the sub-sector and describing how the sub-sector can deal with the issues. The sectors selected are: Environment (2), Food (5), 'Water supply and sanitation: the urban poor' (7), Business (8), Water industry (10), Energy (12) and 'Water supply and sanitation' (14).

3. **Enabling mechanisms** – These documents provide an overview of enabling mechanisms that make adaptation possible. The mechanisms selected are: Planning (4), Governance (6), Finance (11), Engineering (15) and 'Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA)' (16).

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

9 Vulnerability of arid and semi-arid regions to climate change – Impacts and adaptive strategies

A perspective paper by The Arab Water Council

Vulnerability of arid and semi-arid regions to climate change – Impacts and adaptive strategies

Climate change is caused by accelerated increase in greenhouse gas (GHG) concentrations in the atmosphere. There is now a strong consensus that climate change presents a fundamental challenge to the well-being of all countries, with potential of being the most harsh on countries already suffering from water scarcity. Water scarcity is a well-established context for development in arid and semi-arid countries. A recent IPCC report (IPCC, 2008) predicts that climate change over the next century will affect rainfall patterns, river flows and sea levels all over the world. For many parts of the arid regions there is an expected precipitation decrease over the next century of 20% or more. Even if efforts to reduce greenhouse gas emissions are successful, it is no longer possible to avoid some degree of global warming and climate change.

The 5th World Water Forum will pay particular attention to 'Adapting to climate change' in its thematic, regional and political processes. This Perspective Document focuses on the arid and semi-arid regions of the world and is one of 15 other documents which are intended to provide input to address adaptation to the consequences of climate variability and change in the short and long term in these regions. The rationale is to provide an overview of the specific issues in the geographical settings of these regions, share areas with shared key features, provide insight into subsector or specific interest, and identify enabling mechanisms that make adaptation possible within the arid and semi-arid regions. At the invitation of the Topic Coordinator of the 5th World Water Forum, the Arab Water Council (AWC) accepted to lead the preparation process of this Perspective Document in consultation with regional stakeholders.

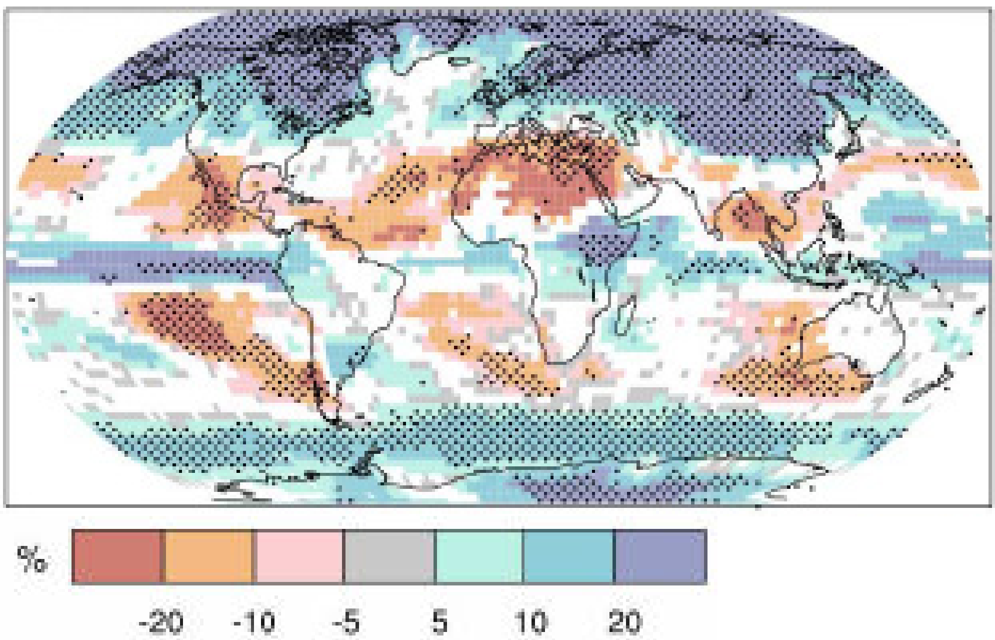

Figure 1: Arid regions will suffer the maximum precipitation decrees worldwide. Colours: Change in precipitation. Source: IDA, 2007.

1 Impact of climate change on the water sector

Climate change impacts add to already difficult water management challenges in the arid and semi-arid regions. In the Middle East and North Africa (MENA), South and Central Asian countries, and several areas in North and South America, 'traditional' approaches to managing water scarcity - based on lifestyle adaptations that minimized consumption and maximized beneficial local use - were dominant up to the 1970s and are still used today in many of these regions. Terraces were constructed to capture rainfall for crop production; spate flows in rivers were diverted to provide supplemental irrigation; shallow aquifers were exploited by open wells; and *qanats* were constructed to intercept hillside aquifers. These widely varying technical approaches to water management shared two important characteristics. First, because annual rainfall was the direct source of water, consumption did not exceed supply (except, in the short term, excess withdrawl from shallow aquifers). Second, with the exception of very large scale, flood-based irrigation in Egypt and Central Asian countries, coordinated actions were usually concentrated around small groups of farmers who owned and managed the water resources, and developed procedures for sharing available water.

More recently, technological innovations – especially deep tubewells and high-powered pumps – significantly altered water management behaviors. Deep tubewells allowed continual, unsustainable drawdown of aquifers as well as access to fossil water, wherever available. Pumps allowed faster abstraction from canals and rivers than previously possible, disrupting historical patterns of consumption. Both these innovations disturbed the equilibrium – in terms of resource allocation and organizational arrangements. In parallel to these technical developments, population has been growing and incomes steadily rising, adding to the demand on water. Thus, stable and sustainable supplies have been disrupted in recent decades and the current usage is, in many areas, no longer at sustainable levels. As a consequence, the possibility that water resources will limit the socio-economic development of many arid and semi-arid regions has gained credence.

Climate change will impact several sectors of the economy and have worldwide ramifications. The changes in other parts of the world will impact the economy of arid and semi-arid regions too. Many countries in these regions depend on river flows originating in tropical or temperate regions. The overall water stress will increase. Climate change is expected to lead to declining precipitation in most parts of the world. But projected temperature increase will imply higher evaporation and drier conditions. Rain is also expected to reduce in frequency but increase in intensity. All these will result in frequent droughts and floods. Climate models project decreasing precipitation in already dry areas, such as northern Africa. In South Asia, earlier snow melt and the loss of glacial buffering in the Hindu Kush-Himalayas will affect the seasonal water supply for significant proportion of the population of the subconenent.

The consumption of groundwater is likely to become unsustainable. Already in many parts of the world – certainly beyond the arid regions where the problem is most common – aquifer drawdown is such that future reliance cannot be placed on this resource. In much of the Arabian Peninsula, for example, the high value of water in all uses, often accentuated by subsidized power, has resulted in significantly larger withdrawals of water than the rate of natural aquifer recharge. According to the IPCC the unsustainable depletion of groundwater will likely be worsened by reduced surface water infiltration in the MNA region. In addition, the increase in the intrusion of salt water to coastal aquifers from sea level rise will further reduce the availability of usable ground water (IPCC, 2007; IDA, 2007).

Agriculture and food security are threatened. Recent research indicates that even if basic adaptive measures are taken (such as changing crop types) global agricultural production will decline 3 per cent by 2080. The demand for water generally increases with temperature – particularly crop water demand. Thus, while climate change is expected to *f* the supply of water, *demand* will be moving in the opposite direction. One study (Döll, 2002) has estimated that crop water demand will increase by 5–8% by 2070, with regional variations up to 15%. In addition, potential crop yields tend to fall at high temperatures, so the productivity of water in agriculture will fall (Kunzewicz et al, 2007; Cline, 2007). A research on Africa found that dryland farms are specifically sensitive to climate change, the elasticity of net revenue with respect to temperature being –1.6 for dryland farms as against 0.5 irrigated farms. A 2.5°C rise in temperature in Africa will result in decline of net revenues from agriculture by US$ 23 billion (Kurukulasuriya et al, 2007b)

Urban areas face multiple challenges from climate change. While coastal cities are vulnerable to sea level rise and storm damage, flooding from more intense rains and higher peak river flows presents significant threats to cities inland. Failures of sewerage and storm water systems could lead to major disease outbreaks. With growing dependence on air conditioning, frequent heat waves could result in major losses to productivity and even cause loss of life if power supplies fail. Rural-to-urban migration is likely to increase under climate change conditions, as many rural livelihoods become less viable. To cope with the threats, urban design, building codes, and energy efficiency will need to be reassessed.

The effects of climate change on water resources could significantly affect hydropower in many developing countries, placing stress on the energy infrastructure. Larger facilities for water storage will be needed in many parts of the world. More erratic river flows will affect water quality and consequently human and animal health. Extreme weather events already threaten vulnerable infrastructure, such as roads.

Ecosystems, particularly forests and wetlands are at risk. Changes in water flows through river systems and from coastal storm surges threaten to destroy many wetlands, with loss of filtering and buffering services they currently provide. Hot, dry conditions will increase the risk of wildfires in all types of forest, while warmer and longer growing seasons in mountain forests could lead to an explosion of pest population.

Coastal areas are vulnerable from the increase in sea levels, flooding, storm surges, and stronger winds. More than 150 million people in developing countries live less than five metres above sea level. During this century, flooding from the rising sea level and storm surges will threaten the viability of some islands as well as some major deltas, such as the Nile and Mekong. The IPCC (2007) projects that sea levels will rise by 20 to 50 cm during this century. There is, however, large uncertainty about the rate at which the ice sheets of Greenland and Antarctica are melting, so the sea level rise estimate could significantly exceed. The Nile Delta region in Egypt is highly vulnerable to any expected rise in sea water levels due to climate change. A sea level rise of one metre would flood a quarter of the Nile Delta, forcing about 10.5% of Egypt's population from their homes. It also would hit Egypt's food supply as nearly half of Egypt's crops, including wheat, corn, and rice, are grown in the Delta. The impact would be all the more staggering if Egypt's population, as expected, doubles to about 160 million by the middle of the century. The situation is serious and requires immediate attention.

Disease patterns are likely to change, making control more difficult. Climate change will affect human health through increase in heat stroke mortality, tropical vector-borne diseases such as malaria, and urban air pollution (ground-level ozone levels are sensitive to ambient temperatures). Africa, for example, is already vulnerable to several climate-sensitive diseases such as Rift Valley Fever, which afflicts both people and livestock; cholera, associated with both floods and droughts; and malaria. Climate change has already resulted in the spread of malaria to the highlands of Kenya, Rwanda, and Tanzania (IDA, 2007). Dengue epidemics have been more frequently observed in Delhi in the past several years.

The impacts of climate change are likely to affect women and girls more severely. They will need to spend more time collecting water and fuel/wood and more time caring for sick family members. In addition, because most agricultural work in many developing countries is undertaken by women, any increased work load is likely to fall on them (IDA, 2007). In Kenya, the frequency of drought has resulted in women walking as much as 10 to 15 km per day to collect water, facing personal risks in the long treks. Girls are unable to attend school. The physical burden of carrying water long distances is debilitating to their health. Small-scale water harvesting is becoming common.

Climate change has the potential to escalate existing regional tensions. Although it is complex to link, there is evidence that scarcity of renewable resources can intensify latent conflicts. For example, it has been observed that frequent drought cycles in Darfur resulted in differing interpretations of rights to access water and land among nomadic and sedentary groups. These differences contributed to the escalation of ethnic tensions.

Conflicts will also occur because of uncertainty in cooperation between nations sharing international watercourses. The Arab countries, for example, depend on international watercourses for 65% of their water requirements. If upstream riparians maintain constant use while river flows decline, the downstream users will be severely impacted. Similarly, investments in hydraulic infrastructure by upstream riparian can change the water availability of downstream users. The Greater Anatolia Project of Turkey, for example, affects water availability in Syria and Iraq (IDA, 2007).

Quality of water will decline. IPCC reports state that higher water temperatures, and an increase in droughts with lower stream flows, will adversely affect water quality due to pesticides, pathogens, sediments, dissolved organic carbon, and thermal pollution. In the congested rural settlements along the Nile River delta, for example, residents and farmers have become an important lobby group demanding the cleaning up of canals and rivers from municipal and agricultural pollution. Among farmers, exporters of high value farm products have been concerned that the marketability of their products is affected by water pollution. Overall, tour operators and resort owners are powerful interest groups that have joined environmentalists and farm exporters to lobby for enhanced water quality management.

2 Policy challenges

There are several key policy challenges that have to be confronted for successfully adapting to climate change in respect to water. The first challenge concerns information and data collection and sharing. The current knowledge on the impact of climate change to water resource management requires systematic and well-planned improvement. With accurate scientific data, planning for adaptation, as well as advocacy among stakeholders, will be easier to achieve. The collection of information can be a complex process, as coordination among sectors, countries as well as among knowledge sectors that do not ordinarily interact, will be essential.

The adaptation strategy is another challenge, varying from one country to another based on the projected impact of climate change. There are multiple stakeholders in a region, and the interest of each will have to be prioritized. Moreover, the community should be aware of the adaptation strategy, which implies that the development of the strategy should be preceded by community discussions and debates. Some of the strategies may require changing behavioral patterns, which could be controversial and take time.

The institutional capacity should be strong enough to undertake adaptive measures. The challenge here is to develop policies that are specially directed to climate change, incorporating climate change perspective in other policies, establishing organizations that will ensure focus on adaptations, embed adaptive processes in existing institutional structures and re-train water managers to the changing realities.

One of the greatest policy challenges would be the financing of climate change adaptive measures. With imperfect information about the magnitude of climate change impact, the allocation of financial resource to construct expensive infrastructures will be a great challenge for developing countries. Over time, as the information base improves, this decision is likely to get easier. However, there is an urgent need to allocate money for collecting information itself. The conceptual difficulty is in determining the appropriate financial allocation for collecting information today, which will help in accurately predicting, sometime in the coming decade, climate change-related calamities further into the future. If this investment is not made, on the other hand, there would be no accurate information about future calamities, and financial planning will risk being over- or under-estimated.

3 Current adaptive experiences

Many countries and regions in the world are already taking actions that will help them manage the challenges of climate change. The MNA region is one of them. Others include countries in the Andean region, Central and South Asia and Africa. The approach that each has followed is specific to the context of the region or the country. The main emphasis is on improving information, strengthening institutions and devising strategies for reducing the negative impact on vulnerable population groups. These are discussed below.

The Nile River basin extends over 10 nations, eight upstream riparian (Ethiopia, Eritrea, Uganda, Rwanda, Burundi, Congo, Tanzania and Kenya) and two downstream (Sudan and Egypt). The basin is home to 190 million people, half of whom live below the poverty line. Six of the riparian nations figure among the top 10 poorest in the world. The Nile is, therefore, one of the toughest transboundary water issues in the world. Climate change has the potential to create conflict in the region with serious ramifications for the poorest. NASA is closely associating with the AWC and existing institutions in the Nile basin to develop satellite-based water management and forecasting techniques, improving hydrological data for cooperative water management.

Currently, the Nile Basin Decision Support System (NBDSS) engages all 10 riparian nations in water management and planning. The Egyptian Ministry of Water Resources and Irrigation (MWRI) has developed a Nile Forecast System for the Aswan Dam. Although both these systems are operated by skilled technical staff, there is a deficit of data which renders the models incomplete. NASA is developing a Land Data Assimilation System (LDAS) to merge high quality satellite data with data obtained on the ground to develop a dynamic model which reflects real-time hydrological changes. This will improve NBDSS reliability in applications that include flood warning, reservoir management and irrigation planning (Zaitchik, 2008).

The anticipated benefits from the NASA supported project include understanding the impacts of various climate change scenarios, choosing future development strategies with due appreciation of social costs and benefits, early opportunity to take actions against impending floods or droughts, mapping crop and irrigation intensity for superior accounting of water use and identification of water resources hot-spots along the basin through trend analysis.

NASA is planning a similar LDAS for the Arab region as a whole to drive a suite of advanced land surface models with the goal of providing optimal estimates of hydrological states and fluxes relevant to water resource management (NASA, 2008).

The impact of climate change is expected to be severe in high altitude mountain ranges. A project is currently underway in the Andean region of South America to understand how climate change will impact countries of this region. Increase in temperature is resulting in accelerated retreat of glaciers in the mountain tops, increasing variability of water flows to downstream regions and threatening sustainable water use planning for the future. Tropical glaciers in the Andes covered an area of over 2,940 km^2 in 1970 but declined to 2,493 km^2 by 2000. The largest of these glaciers in the Cordillera Blanca have lost 15 per cent of their glacier surface area over the past 30 years. Several glaciers in the region, such as Cotacachi in Ecuador, have already disappeared and the region has experienced a decline in agriculture and tourism as well as loss of biodiversity. Waterless streams and decreased water levels have led to water conflicts which are expected to worsen with time.

Glacier retreat will affect regional water supply. For large urban centers such as Quito in Ecuador (pop. 2 million) where glacier basins (Antisana and Cotopaxi in particular) supply two thirds of Quito's drinking water, or La Paz and El Alto in Bolivia (pop. 2.3 million) where the glaciers of the Cordillera Real have until recently supplied 30–40 per cent of potable water, the changing circumstances can affect costs of supply and ultimately the ability of urban centres to maintain vibrant economies. Glacier retreat and other climate changes will also impact local agriculture. Arid and semi-arid mountainous ecosystems in the region are highly vulnerable to disruption of local hydrological patterns, placing subsistence agriculture and consequently rural livelihoods at risk. Moreover, the region relies on hydropower to cover most of its power requirements (80% in Peru and 50% in Ecuador). While glaciated basins only contribute to a small fraction of those tapped for hydropower, changes in water regulation induced by warming of these basins will reduce the potential for power generation (World Bank, 2007a).

The project in the Andean region is expected to result in a better understanding of climate change impacts through: (i) an analysis of current glacier hydrology, including an update of previous glacier inventories, glacier variations, and records of glacier melt hazards and disasters; (ii) estimation of the availability of water resources due to glacier melt at the national level up to 2050; and (iii) an evaluation of adaptation strategies in the management of hydro resources in basins with a glacier under climate change conditions. These outputs will guide the selection process of priority adaptation measures for the Andean region in the future and will strengthen their design (World Bank, 2007a).

Empirical research on the behavior of farmers in Africa to sustained changes in weather conditions has found that farmers will likely adapt to climate changes by sowing crops that are suitable to the new conditions. Thus, climate change in the Continent will result in farmers opting for heat tolerant crops. The research emphasizes the scientific discovery of seed varieties that have higher heat tolerance. The research also cautions against over-estimation of losses resulting from climate change because, as stated, farmers will reduce losses by switching to crop varieties that are heat tolerant (Kurukulasuriya, et al, 2007)

In semi-arid regions of South Asia – Rajasthan in India and Sindh in Pakistan – the World Bank has undertaken projects aimed at strengthening institutional arrangements for water management as well as for developing technical capacity in irrigation. The Rajasthan Water Sector Restructuring Project supported the creation of the State Water Resource Planning Department for the purpose of planning and regulating water allocation across economic sectors, including irrigation. The project improved data collection procedures and encouraged community-based management practices. Similarly, the Sindh On-Farm Water Management Project concentrated on strengthening local level institutions for better water management practices. Farmer's organizations were formed, which provided training for efficient water management and formally assigned responsibilities to manage the irrigation systems. In addition, technical improvements for higher agricultural productivity were also undertaken, such as drip irrigation, modern agronomic practices, etc. (World Bank[1]).

Ebro River Basin Authority in Zaragoza, Spain, has developed sophisticated information management systems which help in predicting and surmounting natural calamities such as flood and drought. The Ebro Basin Agency is the oldest organization of its type in Spain – having been founded in 1926. The agency, manned by 1000 staff, is the apex organization which (a) prepares and implements the basin hydrologic plan, (b) monitors the quality and quantities of water resources, (c) decides on the uses and allocation of water resources in the basin and (d) constructs and manages the operation of the major infrastructure of the basin (dams, canals, monitoring stations, etc.).

The advanced Hydrological Information System in the Ebro basin is supported by 662 remote stations and provides real-time data on the stock of water resources. Decision Support System (DSS) software analyses the data and helps in assessing current water levels and forecasting likely future scenarios. Both the quantity of water as well as its quality is analysed. All major decisions are taken by the management board of the Authority which is constituted of user's representatives (33.3%), communities or territories (33.3%) and ministries, trade unions and civil society (33.3%). The investment is normally financed by the central government and amortized in the tariff.

The MNA countries have undertaken institutional reforms to adapt to changing water resource availability in the region. Morocco is one example. The rivers service the farms and a growing urban and regional economy. Improved agricultural practices have been supported by excellent road communications to the export market for fruits and vegetables. Large urban centres have become magnets for migrants from rural areas, attracted by off-farm jobs, though their untreated wastes pollute the river downstream. Water is everybody's business, and its management is influenced by policy within and outside the water subsectors.

The experience of the Central Asian countries of Kazakhstan, Krygyz Republic, Tajikistan, Turkmenistan and Uzbekistan are relevant to understanding how communities will be impacted if irrigation diminishes in a predominantly agrarian and dry region. Some 20 to 40% of the GDP of these countries comes from agriculture. Until the last two decades, these countries had robust irrigation infrastructure under the erstwhile Soviet rule, but the infrastructures are in advanced stages of decay because they were not maintained after the political changeover of the early 1990s. The yields per hectare have diminished and soil salinity has increased. The farmers have adapted to this situation by switching to drought or salt resistant crop. They are limited, however, by government policies in some of the countries, which prescribe what they must grow where and when. Farmers often lack information on diversifying crop or adopting new water management and soil management techniques. The local elites are very dominant, in the absence of sound institutions, and they divert much of the canal water upstream, often resulting in conflict with downstream users. There

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1 http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/SOUTHASIAEXT/EXTSAREGTOPWATRES/0,,contentMDK:20273283ﬃpagePK:34004173ﬃpiPK:34003707ﬃtheSitePK:494236,00.html, accessed on 14 Oct 2008.

are no proper conflict resolution mechanisms. Many villagers have abandoned agriculture, taking to animal husbandry or becoming farm laborers. But very few have migrated, which is probably because of lack of opportunities elsewhere and also strong ties to family and cultural roots.

Studies have found that rehabilitating the infrastructure is economically viable in many parts of the region. Even where it is not economically viable, the repair will have positive short to medium-term socio-economic consequences and is worth undertaking. Halting the deterioration of the infrastructure will benefit the poor significantly.

Kenya, which is highly vulnerable to climate change because it is a predominantly dry country, has acted early to adapt to climate change. Currently implementing the Kenya Arid Lands and Resource Management Project (ALRMP), the government has realized the need to incorporate climate change issues too. Hence, a new project is being undertaken – Kenya Adaptation to Climate Change in Arid Lands (KACCAL). This project is embedded within the highly successful ALRMP. The objectives are to improve national coordination of information and action for management of climate risk, integrate long-term climate risk perspective in local planning and investments, support community driven initiative on livelihoods and provide technical assistance at the local level (World Bank, 2007b)

4 Global/national level planning and actions

Traditionally, water-scarce regions have developed and managed their water resources productively and sustainably. For centuries, water systems operated to benefit the population, providing essential supplies to municipal, domestic and agricultural sector, and protecting against negative impacts through drainage systems and flood control works. These successful water management systems have followed a clear and common pattern that can be summarized as the ABCDEF of water management (Perry, 2008).

The essential elements are:

- Hydrological information on the *availability* of surface and groundwater available to society (**A**ssessment)
- The political process through which society decides on the *principles for allocating* available water resources (**B**argaining)
- The legal process that translates policy into *rules and regulations* defining the water services to various use groups (**C**odification)
- The empowerment of *agencies* (government, private, cooperative, etc.) responsible for delivering water services (**D**elegation)
- The construction of *infrastructure* necessary to deliver water to users (**E**ngineering).
- The effectiveness of adaptive measures through *monitoring* and *evaluation* (**F**eedback)

These elements – which also point to the contributing disciplines of hydrology, political science, law, institutional economics and engineering – can be observed in the *aflaj* in Oman, Balinese Water Temples in Indonesia and traditional *mesqas* in Egypt. Each has different rules, allocation procedures, operational responsibilities and engineering design – but these elements are clearly defined and mutually supportive.

The water management planning to face the emerging challenges went through three distinct phases:

- Pre-IWRM (pre-1990s) was a phase in which the water management practice was driven by the urgency to invest in all forms of hydraulic infrastructure – the pure supply-driven approach – with assessment being restricted to standard cost-benefit analysis for justifying the investments.
- IWRM phase (post-Dublin and Rio) emphasized sustainable outcomes, with some codification (such as cost recovery for WSS utilities, bringing the various water sub-sectors under one water ministry, etc.). While there was progress, incentives outside the sector (notably energy subsidies, virtual water imports, political reluctance to raise tariffs, etc.) were not fully incorporated in water management practices.
- Post-IWRM phase in which there is a greater understanding of the drivers for reforming water management. This phase emphasizes the need for a new management approach.

The three phases are compared in terms of the ABCDE elements of water management in table 2 below.

Table 2: Comparing water management approaches over time.

Phases Elements of water management approaches	The ideal sequence in water management	Pre-IWRM	IWRM	Post IWRM
Understanding how much water is available – **ASSESSMENT**	1	No	Partial	Partial
Allocating the water among competing uses – **BARGAINING**	2	No	No	Partial
Setting the **rules** and understanding the **incentives – CODIFICATION**	3	Partial	Partial	Partial
Assigning responsibility for mitigating **risks – DELEGATION**	4	No	No	Partial
Developing the facilities – **ENGINEERING**	5	Yes	Yes	Yes

Assessment requires much information. The current knowledge stock on climate change, now more than ever in the past, requires constant and systematic updating. Cooperation between various institutions spread across the world and cross-sectoral knowledge is necessary for this purpose. As, for example, cooperation between NASA and the 10 nations of the Nile Basin is critical for developing information on Nile river flow trends. With real-time data on water flow, and fairly good estimation of future flows, the planning process will be much simplified for all countries in the region.

IPCC and others have recommended that adaptation planning should consider a portfolio approach. Since it is difficult to predict the magnitude of climate change, this approach will provide flexibility, developing coping strategies against an array of climate change scenarios. To simplify information complexity of organising such a huge task, adaptation strategy could begin by undertaking a bottom up vulnerability assessment of the existing system. Thus, instead of analysing complex climate change models, the local water management institution could analyse information it already possesses, and assess the type of quantity and quality changes which will present the greatest threat to its current functioning. Based on this knowledge, the institution could plan several initiatives that will lessen the impact of climate change whenever it occurs.

Bargaining, codification and delegation are institutional issues. The European Environmental Agency has advised that the top priority for adaptation in water sector should be to minimize vulnerabilities of people and communities to changes in hydro-meterological trends, increased climate variability and extreme weather events. Human survival should, therefore, be the central focus of any adaptive strategy. The second should be to protect and restore ecosystems, and the third to close the gap between supply and demand. The Agency also advocates embedding adaptation strategies within the existing national policy and institutional framework, enabling integration of climate change with other issues that drive the economic sectors.

Involvement of multiple stakeholders is important in adapting to climate change. As adaptation at one level can strengthen- or weaken- the adaptive capacity, it is essential to have national, sub-national and local level interactions. Civil society and the business sector should also be involved. Policy actions for adaptation can range from capital investments to campaigns for promoting behavior changes.

The learning and capacity-building programme for water management at the national and local levels requires re-definintion to meet the challenges of climate change. Executive education water programmes need to be developed, with the purpose of creating water managers who are able to look beyond their narrow areas of specialization, respecting the contribution that other specialists make. The inspiration comes from successes in the field of business management through executive management programmes that promoted 'lateral' thinking by visionaries like Alfred Sloan and Peter Drucker. Through these programmes business management became a more systematic process of directing and controlling people and entities with the objective of accomplishing the enterprise goals. The MNA countries, for example, have recognized this challenge and, through the leadership of the Arab Water Council, are establishing an Arab Water Academy to organize learning events that would create a new genre of 'water managers' from different disciplines, representing all sections of the society.

Water management is as– if not more- multi-disciplinary than running a modern business enterprise, and requires a different culture of thinking with stakeholders ranging from farmers, slum dwellers, civil society, media and political leaders to civil servants, planners, economists and engineers. Involving these disciplines and interest groups in the national, regional and local decisions that they face requires a framework for the discussion, such as that provided by ABCDE outlined above. The framework requires appreciating the human, financial, natural and technological aspects of water management through systematic engagement of stakeholders in learning about water management, and recognising that any change (to allocations, technology, laws, etc.) has implications for other aspects of the system.

Demand management is an important tool against climate change. The challenge for water management, therefore, is about using financial, economic and institutional instruments to sustainably and productively manage with less, but more predictable, water supply, while balancing the growing demands from many competing uses – including domestic, environmental flows, industrial, commercial and agricultural uses. Also, investment options should be flexible to enable alignment with changing priorities. The options could be of different types, such as building new dams against less costly management options and whether to encourage decentralized decision-making, create incentives for partnerships with other riparian communities and focus on wastewater reuse for maintaining status quo.

Another powerful influence is national economic policies (notably trade regimes, taxes and subsidies). International trade allows water scarce countries to import 'virtual water' through water-intensive commodities – ideally exporting 'expensive' virtual water in fruits and vegetables while importing 'cheap' virtual water in cereals. Government policies that support free trade will tend to result in such outcomes without specific 'virtual water' policies. Chart 1 below illustrates these trends by taking the example of MNA countries. Green represents renewable sources (both from surface and ground water), and includes desalinated water. Pink represents the proportion of water extracted from non-renewable sources (the proportion is larger in countries with significant energy subsidies), and brown represents virtual water embedded in agricultural commodities that are imported through trade.

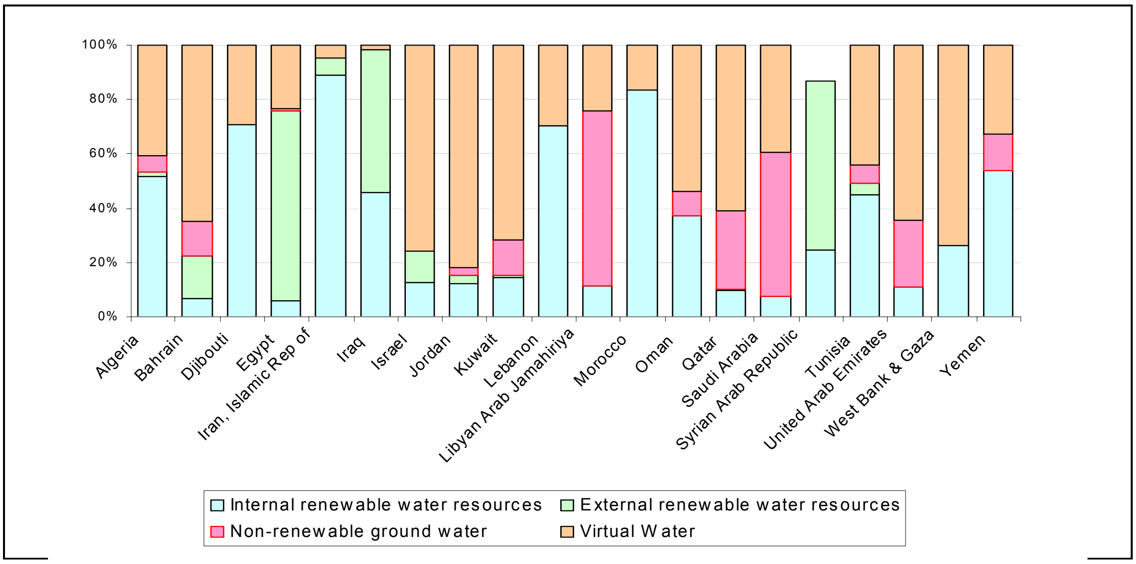

Chart 1: Role of renewable, non-renewable and virtual water in MNA countries.

Increased rice, wheat, dairy and beef imports, for example, result in significant virtual water being available to local consumers, while exports of fruits, vegetables, olives and dates have relatively low water embedded in their production. Countries with more liberal trade policies are able to augment the quantity and value of scarce local water resources by importing virtual water. However, the global changes in food prices and cost of energy call for flexible policies which allow each country make the right choice for optimum usage and management of their water resources.

5 Conclusion

Water resources management in countries that are already severely water stressed faces new challenges and new opportunities. In addressing this uncertain future it is critical to draw as much strength as possible from the lessons of the past, particularly to ensure that the approach chosen – which may vary from country to country – is coherent and clearly articulated to reflect the varied responsibilities and disciplines involved in successful water resources management. The optimal water allocation for a growing number of competing water management requirements (e.g. agriculture, public consumption, industry, hydro-energy, ecosystems, etc.) under a changing climate system places a heavy burden on water managers.

Climate change is a serious threat confronting the world and it is necessary to plan for this challenge. As its impact is likely to be faced most severely by the least-developed countries, there is an urgent need to plan adaptive strategies at the global level and work towards strengthening national capacities. The current water resource management approaches will have to modified, taking into account the climate change scenarios. Prior to all this, however, the systematic collection of data, sharing of cross-sectoral knowledge and developing global and national institutions focused on climate change are critical issues to immediately address. The following few actions are recommended from an arid region perspective:

1 Arid and semi-arid regions are most vulnerable to climate change. Adaptive strategies to manage the climate change risk are necessary to be formulated for countries falling in this category. The measures will vary from one country to another.
2 Political focus on climate change offers opportunities to invest in reduced uncertainty and improved results in water management. If policymakers can anticipate changes and use opportunities to promote reforms, climate change may help improve water management.
3 Systematic collection of information on water resources and their dissemination is essential for comprehending climate change impacts. This could require multi-disciplinary approach and involve trans-global cooperation. An institutional framework for sharing information at the global and regional levels, and their dissemination to the local level, is necessary.
4 There is economic value to the information collected on climate change in relation to water. Hence, governments should be encouraged to commit to investments in this objective. An advocacy plan to promote this objective needs to be formulated.
5 Robust irrigation infrastructure, even if economically not viable, may be necessary to cope with climate change risks in the short to medium-term, until farmers are trained in alternative livelihoods. Maintenance of existing infrastructure in vulnerable countries deserves early attention.
6 The institutions for water management should be improved to manage the risk of climate change. The capacity of water managers in developing countries should be expanded through training and exposure to adaptive measures in developed countries.

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Annex 1

Financial modeling for climate change

Investment in events that are inherently uncertain in their likelihood of occurrence or magnitude is a serious challenge for policy-makers. The impact of climate change in a country, as already discussed, can be of several types. The exact series of events that will occur and for which investments should be made is hard to predict. The magnitude of these events is harder to quantify. Investments are needed for collecting information over time and the new information, it is expected, will decrease uncertainty about likely future scenarios. The question is how much should one invest currently for acquiring information that might prove useful in the future.

When analysing complicated risk problems, it is useful to model them as games against nature which assume that nature will randomly, and non-strategically, select a particular state of nature. In its normal form, games against nature have the following elements: (i) states of nature and their probabilities of occurrence; (ii) actions available to decision-makers facing the nature and; (iii) payoffs available to decision-makers against each combination of state of nature and action.

As an example, the following three scenarios are possible in the case of climate change in next 50 years: severe, moderate, none. The three possible actions are high investments, moderate investments and low investments. The corresponding probabilities and payoffs are given in table 3 below.

Table 3: Games against nature: Expected value of climate adaptation alternatives.

State of nature	Severe impact of climate change	Moderate impact of climate change	Low or no impact of climate change	
Probabilities	0.001	0.004	0.995	
Actions (alternatives)		Payoffs (net cost in billions of dollars)		Expected value (billions of dollars
High investments	5,060	1,060	60	69
Moderate investments	10,020	2,020	20	38
Low investments	30,000	6,000	0	54

Adapted from Boardman et al, (2001).

Table 4: Reformulated games against nature: Value of information on climate change.

	Game 1 **P = 0.001**		**Game 2** **P = 0.999**		
State of nature	**Severe impact of climate change**		**Moderate impact of climate change**	**Low or no impact of climate change**	
Probabilities of states of nature (over next century)	1		0.004004	0.995996	
Actions (alternatives)	**Payoffs** (net costs in billions of dollars)	**Expected value**	**Payoffs** (net costs in billions of dollars)		**Expected value**
High investments	5,060	5,060	1,060	60	64
Moderate investments	10,020	10,020	2,020	20	28
Low investments	30,000	30,000	6,000	0	24

The lowest expected value is US$ 38 billion, which is the most preferred action given the probabilities.

A greater fundamental problem is that state of nature is likely to be known only if investments are made in collecting information. How much should the world (or a country) invest in collecting information? Assuming that collection of information will result in certainty of knowledge whether or not severe climate change impact will occur in the case of a country. In such a case, the game against nature can be characterized as in table 4.

In the case of Game 1, the ideal course of action is investing US$ 5,060 billion and in Game 2, US$ 24 billion. Prior to collecting the information, we do not know which of the two Games is likely to be played. Hence, the expected value of the two games is $0.001 \times 5060 + 0.999 \times 24$ = US$ 29 billion.

The optimal choice of action without information was US$ 38 billion from the previous computation. Hence, the value of information is US$ 38– 29 = US$ 9 billion. Consequently, as long as it costs less than US$ 9 billion to gain information about the future, it is efficient to have it. This cost modeling is a simple example and will have to be developed further for actual applications. Some of the challenges are determining the probabilities of events and, of course, computing payoffs.

Acronyms

ABCDE	Assessment-Bargaining-Codification-Delegation-Engineering
ALRMP	Arid Lands and Resource Management Project
AWC	Arab Water Council
BCM	Billion Cubic Meters
CO_2	Carbon Dioxide
DSS	Decision Support System
GHG	Green House Gas
IPCC	Intergovernmental Panel for Climate Change
IWRM	Integrated Water Resource Management
KACCAL	Kenya Adaptation to Climate Change in Arid Lands
LDAS	Land Data Assimilation System
MNA	Middle East and North Africa
MWRI	Ministry of Water Resources and Irrigation
NASA	National Aeronautics and Space Administration
NBDDS	Nile Basin Decision Support System
NPV	Net Present Value

World Water Council
World Water Forum

co-operative programme on water and climate

IUCN

IWA International Water Association

Perspectives on water and climate change adaptation

Climate change and the water industry – Practical responses and actions

IWA International Water Association

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

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

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

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

Participants were invited to contribute perspectives from three categories:

1 **Hot spots** – These papers are mainly concerned with specific locations where climate change effects are felt or will be felt within the next years and where urgent action is needed within the water sector. The hotspots selected are: Mountains (number 1), Small islands (3), Arid regions (9) and 'Deltas and coastal cities' (13).

2 **Sub-sectoral perspectives** – Specific papers were prepared from a water-user perspective taking into account the impacts on the sub-sector and describing how the sub-sector can deal with the issues. The sectors selected are: Environment (2), Food (5), 'Water supply and sanitation: the urban poor' (7), Business (8), Water industry (10), Energy (12) and 'Water supply and sanitation' (14).

3 **Enabling mechanisms** – These documents provide an overview of enabling mechanisms that make adaptation possible. The mechanisms selected are: Planning (4), Governance (6), Finance (11), Engineering (15) and 'Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA)' (16).

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

10 Climate change and the water industry – practical responses and actions

This paper has been prepared by the IWA Specialist Group on Climate Change (CCSG), on behalf of the IWA. The primary purpose of this paper is to communicate the IWA perspective and to trigger discussion at various events, including the 5th World Water Forum. It is not intended to provide a complete overview of the impacts of climate change on the water industry; rather it is a thought-provoking document.

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Climate change and the water industry – practical responses and actions

This paper outlines the key vulnerabilities of the water industry to climate change and the most important adaptation strategies, responses and actions. It has been prepared by the IWA Specialist Group on Climate Change (CCSG), on behalf of the IWA. The vulnerability of the water industry in terms of water security and water quality to the impacts of climate change is firmly established. Water professionals and utilities acknowledge that climate change is unequivocal, and shares an increasing concern of the need to take action now to mitigate and adapt.

1 Introduction

The impacts will exacerbate the increasing human pressures on water systems, and decision-makers and managers need to address the challenges in an integrated fashion. Impacts will be felt differently in different geographical regions. Here, climate change impacts are described according to different climatic conditions: a) Low lying countries and river deltas which are more prone to flooding and under threat of sea level rise; b) Mountainous regions, which will be affected by retreating glaciers and snowmelt; and c) Arid and semi-arid areas that will be impacted by less rain and increased evaporation.

This paper summarizes the potential impacts of climate change on the water industry, provides some examples of practical responses and actions (through the use of policies, tools and changed practices) and outlines some main recommended actions.

A primary challenge for the industry will be to enhance the capacity to cope with impacts on for example groundwater, surface water quality, flow seasonability, urban flooding, potable water supply, waste water treatment, ecosystems, social and economic activity etc. Adaptive management, flexible approaches, diverse portfolios of water sources and management strategies and an ability to move quickly to make and implement decisions will be imperative. Continuous monitoring and evaluation will be essential to underpin the knowledge of decision-makers. Adaptation strategies for drinking water supply should address both the demand and supply side. With increasing frequency of extreme events recommended interventions include early warning systems, improved physical defense for existing facilities and careful site selection for new facilities. The paper lists specific strategies for the different climatic regions. In regions affected by melting snowpack measures need to address a broad spectrum of interventions to address uncertainty and make staged investments that enhance system capacity. In low lying countries it is also important to reduce the vulnerability to flooding, where careful urban planning is required and future developments must take into account the safe provision of vital water services under future climate scenarios. In drying climates a proactive approach is needed to avoid sourcing reactive emergency supplies. Furthermore, it is of vital importance to diversify resources and building capacity especially in low- and middle-income countries. This paper also includes aspects of mitigation since it is linked to adaptation. Pursued climate change mitigation options should demonstrate co-benefits that facilitate climate change adaptation, such as constructed wetlands as well as reducing non-renewable water. Finally, the paper includes a section on recommendations for actions for governments, the water industry at large and individual utilities.

A longer version of this paper is available on www.iwahq.org (under Programmes and Climate Change).

2 Impacts of climate change on the water industry

The vulnerability of the water industry to the impacts of climate change is firmly established, impacting on both water security and water quality. The scale of the issue was identified by Howe et al. (2005) who identified over 100 potential impacts on the services provided by Melbourne Water in Australia.

2.1 Background – the need for adaptation in different geographical settings

The predicted changing climatic conditions will exacerbate the growing human pressures on water systems which include population growth, increasing urbanization, increased water demands, changing land use, intensive engineering works and so on. Over the past century, such changes have led to a general increase in the vulnerability of society to extreme hydro-meteorological events.

While the projected changes in precipitation are regionally specific and highly uncertain, there are some general patterns that are evident from the review of GCM output. These impacts will not be elaborated in this document, however, given the variability of impacts across regions, it is critical that the water sector is well informed of the nature and magnitude of projected impacts in the region where they operate.

IWA has adopted the approach of analyzing impacts and responses divided in different climatic and geographical regions. The main categories that are used in this paper are:

- Low lying countries and river deltas
- Mountainous regions (retreating snowpack)
- Arid and semi-arid areas.

Low lying countries and river deltas

Low lying countries and deltaic regions are particularly vulnerable to the impacts of climate change as they are prone to flooding by both the sea and rivers.

Most of the research on climate change and water in low lying areas to date deals with flood risk assessment, especially in heavily populated coastal areas. Risks of droughts are also recognized, especially with regard to the effects on navigation, agriculture and energy production (specifically the availability of cooling water).

Mountainous regions (retreating snowpack)

Climate change is projected to have significant impacts on the hydrology of basins characterized by glaciers and the annual accumulation and melt of snowpack. Utilities that rely on mountain-based snowpack systems share some common vulnerability with respect to climate change. Increases in temperature will reduce the amount of snowpack that accumulates in the mountains above system reservoirs. Warmer temperatures may also affect the quality of the source water. The significance of these impacts may vary, however, both by region and by water supply system. Systems that have reservoirs versus those that rely on 'run of the river' diversions may experience different degrees of impacts. Regions where reduced snowpack is supplanted by increases in precipitation will likely face different impacts from those areas where reduced snowpack is accompanied by decreases in overall precipitation.

Arid and semi-arid areas

Climate effects in the arid and semi-arid countries of the world are expecting increasing temperatures, more extreme weather events, increased evaporation and sea level rise with accelerating rate in future. There is however a lack of consensus among the global climate change models as to what the likely changes in rainfall will be for certain areas. Figure 1 illustrates the projected patterns of precipitation change; the white area are where consensus is weak and the dot-patterned areas are where consensus is strong.

The most serious *effects* and resultant *impacts* for drying climates are:

- less rain which leads to reduced yields from surface water catchments;
- changed distribution of runoff which leads to much slower, less reliable and predictable groundwater recharge;
- more extreme events so that surface catchments are eroded with decrease in water quality and rivers provide less reliable supply;

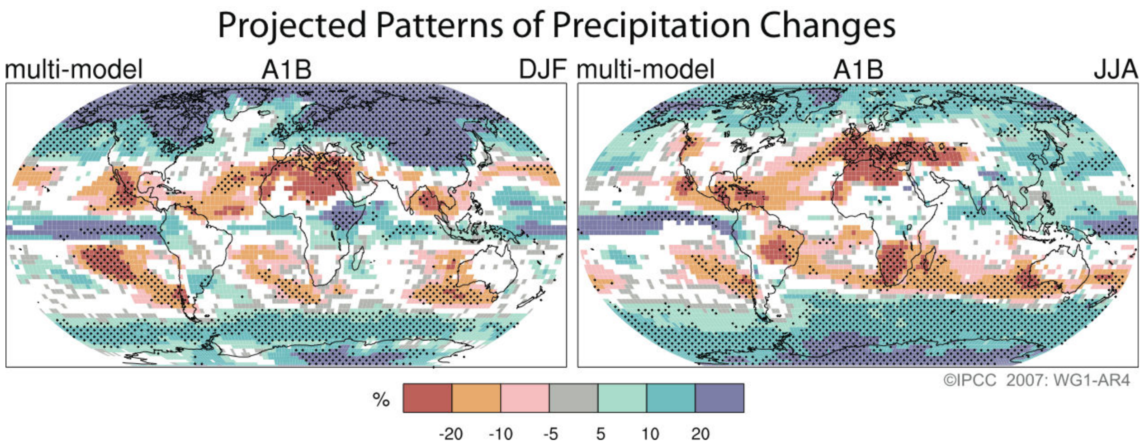

Figure 1: Projected patterns of precipitation changes (IPCC Working Group 1-AR4).

- increased evaporation through prolonged increase in temperature exacerbating water storage depletion;
- locally-specific changes in humidity levels with potential ecosystem impacts;
- water quality is impacted from all of these effects, including degradation of fisheries and potential wetland habitat loss;
- the combined effect of these impacts is very significant leading to whole communities becoming threatened and a broader impact of social defabrication in the most vulnerable drying climates.

3 Key vulnerabilities and main problems for the water industry

The water utility sector has a unique set of challenges ahead. A primary challenge for the water sector will be to enhance its capacity to cope with the impacts of climate change and these other human pressures on water systems while fostering greater resiliency to extreme hydrologic events.

The impact of climate change on drinking water resources and services is of increasing concern to a growing number of utilities worldwide. Driven by shareholder expectations, regulatory constraints, customers with their own set of growing expectations, and governments with responsibilities to deliver on both water quantity and quality objectives, these concerns present a future of increased risk across the climate, social and economic areas.

3.1 Impact on water resources

In addition to pressures from increasing demands and highly variable supplies, climate change also has the potential to influence water quality and the ability of the utility or catchment authority to meet (mandatory) ecological objectives. The response of water systems to changing meteorological conditions is highly dependent on a number of factors including: soil characteristics, topography, land use (urbanization, agricultural development), the presence of inundation areas and runoff management. Examples of some of the impacts of climate change on water resource management are given below:

Too little and/or saline groundwater

Groundwater dynamics are expected to change significantly due to climate change. During extended droughts, lowering of the groundwater table may have serious effects on terrestrial ecosystems, which are further exacerbated by the abstraction of groundwater for other purposes. In drought-sensitive areas, it will become increasingly difficult to combine ecological objectives (such as maintenance of biodiversity) and groundwater extraction, which endangers the license to produce drinking water. The anticipated effects are even more pronounced if increased agricultural and drinking water demands during heat waves and droughts are taken into account.

In areas where rainfall is reduced recharge is slower, but dryer conditions also lead to greater extractions and a lowering of water tables. Another aspect of groundwater mining or over-exploitation will be greater agricultural water usage under a future climate of higher temperature and evapotranspiration. Aquifers will need better management and strenuous efforts will be required to improve recharge.

In many coastal regions, groundwater resources are increasingly vulnerable to salinisation due to sea level rise. Overconsumption or unregulated extraction of groundwater exacerbates the problem. Coastal rivers are likely to be threatened by the creep of saltwater wedges upstream. A combination of sea level rise and reduced river flows will lead to increased seawater intrusion into river mouths, limiting the use of the water for irrigation and drinking water production.

Reduced surface water

In drying climates reduced yield from surface catchments (watersheds) is complex, exaggerated by normal hydrologic processes, which mean that dryer soils take up more water before any net runoff occurs, so the percentage reduction in runoff typically substantially exceeds the percentage precipitation reduction. Increased evaporation from storages reduces the yield from a catchment further. Evapotranspiration also increases with temperature, exacerbating reduced runoff. Each situation has to be modeled for its local circumstances, but a minor rainfall reduction can translate to a catastrophic drop in yield.

Rivers which receive less runoff tend to dry out more frequently, and in arid climates they are often ephemeral. Water extractions from rivers, for irrigation and urban water supply purposes, increase during dry periods placing even greater stress on ecological health. Even where net extractions do not increase, the proportion of natural flow extracted is higher under low-flow conditions. Under normal conditions, many rivers gain water from aquifers in certain reaches, and lose water to aquifers in others. During climate induced aridity, the tendency is for there to be greater losses and less inflow, exacerbating other river problems.

Shift in flow seasonality and water availability

Snowpack and glaciers have a large impact on water storage and flow seasonality, and with global warming, vanishing glaciers and diminishing snowpacks potentially pose a major threat to the water availability in the regions identified in figure 1. In a warmer world, a smaller proportion of winter precipitation falls as snow and the melting of winter snow occurs earlier in spring (Eckhardt and Ulbrich, 2003; Vanham et al., 2008a).

Even without any changes in precipitation intensity, both of these effects lead to a shift in peak river runoff in winter, out of summer and autumn when demand is highest (Barnett et al., 2005). Where storage capacities are not sufficient, much of the winter runoff will be lost to the oceans.

Climate change will alter the behaviour of river runoff including the probability of flooding. In regions where most of the winter precipitation currently falls as snow, the seasonality of river flows will become less pronounced. Spring discharges will decrease due to reduced or earlier snowmelt, and winter flows will increase. This has been observed in the European Alps, Scandinavia and around the Baltic, Russia, the Himalayas, and most of North America. The increased winter flow in some areas will enhance the threats of greater winter floods caused by ice jams. In regions with little or no snowfall, changes in runoff are much more dependent on changes in rainfall than on changes of temperature. Most studies in such regions (e.g. the monsoon region) project an increase in the seasonality of flows, often with higher flows in the peak flow season and either lower flows during the low-flow season or extended dry periods.

As a result of climate change, the water retention characteristics of river basins are likely to change due to the change in ecosystems in mountainous regions resulting in faster collection time and a lower time-gap for organizing flood defense measures.
Figure 2 shows the contribution of specific mountain systems to lowland water resources (Viviroli et al., 2007). It can be seen that mountainous snowpacks and glaciers have high contributing potential to several dry regions in the world (the blue regions in the figure) including the North American coastal region west of the Rocky Mountains (e.g. Los Angeles) the mountainous sources of the Tigris and

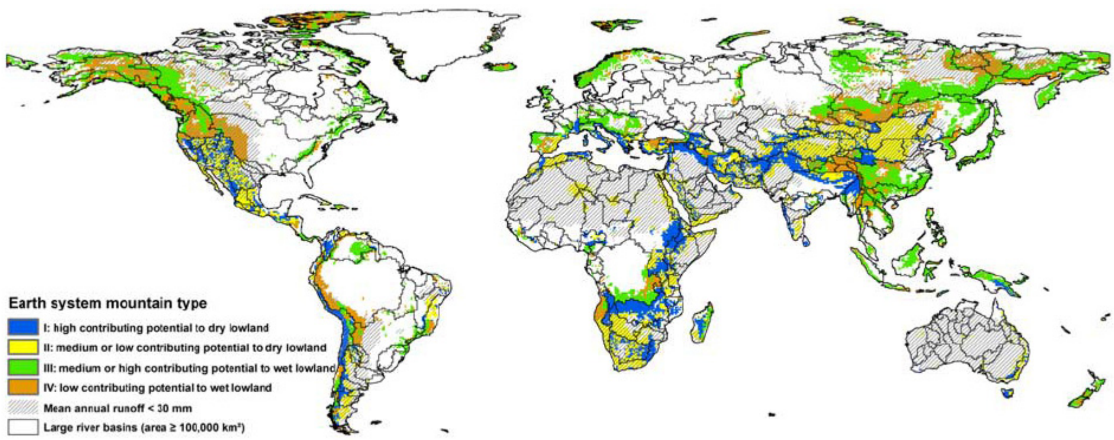

Figure 2: Earth system mountain types – contributing water to lowland (Viviroli et al. 2007).

Euphrates Rivers, the Hindu-Kush-Himalaya mountain range for the river basins of the Indus and Ganges-Brahmaputra and the Andes glaciers for cities like Quito. The green regions show areas with medium to high contributing potential to wet lowlands (including the Alps in Europe which feed into river basins like the Rhine, Danube, Po or Rhone, and the snowpacks in Japan on which cities like Tokyo depend for their water supply.

Surface water quality

The projected trend towards more frequent and extended droughts will also affect the water quality of surface waters (Murdoch et al., 2000; Van Vliet & Zwolsman, 2008), threatening the functions assigned to water systems (agriculture, recreation, drinking water). Low river discharges are generally associated with a decreased dilution capacity for point source pollutants, resulting in higher concentrations of contaminants in the water. Increased precipitation variability may lead to longer periods of low flow followed by high flow events which result in high concentrations of pollutions from diffuse pollutant sources (Thorne, 2008).

Increasing temperatures and an increase in the frequency and/or intensity of drought also have the potential to increase the occurrence of algal blooms in lakes and reservoirs. The occurrence of potentially toxic blue green algae (cyanobacteria) which take advantage of high water temperatures are of particular concern, both to ecosystem functioning and to water services. Changes to meteorological conditions have also been linked to changes in the concentrations and characteristics of natural organic matter in drinking water sources.

These changes to water quality have the potential to adversely impact on the treatment of water for potable use and may result in taste and odour problems, ineffective treatment processes (such as coagulation and chlorination) and unacceptably high levels of disinfection by-products in distribution systems.

Depending on the extent of the changes and the site-specific water treatment processes, poor raw water quality may ultimately result in elongated intake stops.

In addition to concentrating pollutant loads from wastewater treatment plants during prolonged dry periods, climate change can also lead to increases in raw water turbidity and natural organic matter, including disinfection by-product precursor concentrations. In recent years some regions have reported an increase in high flow events (e.g. the Schoharie Creek watershed which is part of the New York City Catskill watershed). These elevated flows have eroded stream banks and have led to an increase in raw water turbidity levels. Increases in raw water turbidity are a concern to water suppliers for several reasons: interference in the disinfection process, increased coagulant doses and costs, overloading process functionality, increased solids handling costs and increased public health threat – especially for supplies that do not filter.

Climate change can also lead to longer-term changes in the quantity and character of natural organic matter. Many utilities in the northeastern US and northern Europe have noted increases in raw water color and disinfection by-product levels (especially haloacetic acids). This change is thought to be associated with warmer temperatures and decreased snowpack leading to increased microbiological activity.

3.2 Sea level rise and flood protection

The main structural defense against sea level rise in developed countries will continue to be dykes and other hard engineering measures. Improved public and scientific awareness will also play an important role in the development of shoreline management plans which may include plans for retreat and relocation in addition to physical defenses. Such strategies have already been developed in parts of Europe.

Sudden shifts in population (away from flood prone regions) will also provide challenges. Special attention must be paid to waste water treatment plants located in zones of potential inundation as flooding of such facilities can have serious public and environmental health consequences.

3.3 Disaster prevention and resilience to extreme events

Extreme weather events – risk of death and health, and damage to infrastructure

Another aspect of climate change relevant to water utilities is the projected increase in extreme weather conditions, such as tropical cyclones, storm surges and rainstorms. This may cause mass destruction of the infrastructure and changes in flood risk, including flash flooding and urban flooding. However, there may be some reductions in the risk of spring snowmelt floods and ice jam floods in certain areas. Floods have a considerable impact on health in terms of number of deaths, disease burden, and also in terms of damage to infrastructure. While the risk of infectious disease following flooding is generally low in high-income countries, populations with poor infrastructure and high burdens of infectious disease often experience increased rates of diarrhoeal diseases after flood events. There is increasing evidence of the impact that climate-related disasters have on mental health, with people who have suffered the effects of floods experiencing long-term anxiety and depression.

Urban flooding

The design of urban drainage systems is often based on critical 'design storms' that are determined through analysis of historical precipitation statistics and described by Intensity-Duration-Frequency (IDF) curves. Other design approaches include the use of hydrodynamic models which utilize long time series to represent precipitation variability. However, both methods lack the ability to represent future climatic conditions. Alternative design methods are required to ensure that the system can continue to function as designed even under future climate scenarios.

Urban drainage and waste waster treatment

Surcharge of drainage systems – The topography of deltaic countries is flat which leads to minimal slopes in gravity drainage systems. Sewers carrying rainwater tend to behave like a sponge which gradually fills. The transport capacity is maintained by pumping stations. Further compounding the problems is the character of the soil in these areas which is typically constituted of fine materials such as clay and silt, thus ruling out the use of infiltration to increase drainage capacity of the system.

With increased rainfall intensities, surface runoff peaks increase as well. This creates the danger that runoff volumes may exceed either the capacity of sewer entries (gullies) or the design discharge of sewer reaches[1].

Combined sewer overflows – Heavy rainstorms may challenge the capacity of the sewer system to deal with large amounts of water in a short period of time. If the capacity of the sewer system is exceeded, polluted water may be discharged into surface water (sewer overflows), causing water quality deterioration, both chemical and biological (pathogens), and incidental fish kills. Moreover, water from the sewer system may flush back to street level during rainstorms, posing a threat to human health and well-being. The increase in rain events also leads to ele-

1 Preliminary assessment of small catchment shows, that a change from 3-year design storm to intensities of current 5-year design storms lead to a 10% to 15% increase in the discharge peak (Staufer et al., 2008). The impacts of rare events are probably more severe.

vated raw water turbidity levels which are especially problematic for unfiltered supplies such as New York City.

As for the shift of the water balance from the drier part of the year (northern hemisphere summer) to the wetter part, heavy rainfall coincides with long dry weather periods, which increase the loads spilled by combined sewer overflows (cso)[2].

Waste water treatment – Waste water treatment plants are endangered by flooding from both rivers and the sea. The emission of the bacteria and pollutants stored within the biological treatment risk public health, water supply and aquatic life (Pinnekamp et al., 2008).

3.4 The provision of potable water supply

Climate change will impact on the ability of water utilities to meet potable water demand in many regions around the world. Increasing source variability and declining raw water quality, combined with increased demands and increased competition between different water users (municipal, agriculture, industry, ecology) will create challenges for providers of potable water.

- Sea level rise will result in saline intrusion into coastal aquifers, affecting the suitability of the water for potable use. This is particularly an issue in areas where ground water is the sole source of drinking water (e.g. a case in the dunes area of the Province of West Flanders in Belgium).
- In drying climates potable water sources can be impacted by more concentrated pollution, higher temperatures, increased carbon dioxide levels and higher turbidities. This affects waterway health, especially for lakes and reservoirs. Algal blooms can be expected to increase, with attendant problems. Treating blended or compromised water sources to service a given community imposes greater challenges.
- Infrastructure for water utilities will become more difficult and costly to manage in drying climates. Water mains and sewers are structurally challenged by drying and hence shrinking soils, so they can crack, leading to increased infiltration and exfiltration, which in turn exacerbate treatment and groundwater or stormwater contamination problems. Similar problems can arise with stormwater drains. Corrosion increases in sewers – thanks to the combined effects of higher temperatures, increased strengths, longer retention times, and stranding of solids – shorten asset life and increase maintenance demands.

3.5 Effect of climate change on ecosystems

Climate change may have adverse effects on the ecology of mountains, which in turn can have an indirect impact on water supply systems. Forested watersheds could be more susceptible to pest infestations and diseases, which could lead to deforestation and impacts on water quality. Higher temperatures, coupled with weakened forest health, could increase the likelihood and severity of forest fires, which can also impact quality and quantity.

Wetlands come under pressure as water becomes more scarce, so habitats are lost and trees which rely on periodic watering begin to die. In coastal regions, wetlands (and estuaries) can become more saline, impacting on mangroves, invertebrates and other species which rely on particular ranges of salinity. Owing to saltwater intrusion, coastal areas could be challenged by the need to relocate water intakes further upstream, resulting in more disruption of wetlands.

Fisheries are threatened by lower flows, changing salinity, change of stream flow seasonality, loss of habitat and increasing fishing effort as economic pressures narrow choice for economic activity.

3.6 The human dimension

Large-scale climate change forces people to move from low lying coastal regions to resettle in areas with available water resources and safety from sea

[2] The effect of the shift from summer to winter precipitation was investigated with a hydrological model for a catchment with a single storage tank. The results emphasize an increase of mean annular pollutant loads of 10% although total annular precipitation remained constant (Staufer et al., 2008). Butler et al. (2007) gained results from a case study that in London the number of storm events filling the storage tank rise by 35% and conclude that 57% additional storage volume would be necessary.

level rising. Many of these target areas for relocation are floodplains. Resettlement also results in losses in local knowledge, which is an important factor when people move to high-risk locations. Such improperly prepared resettlements may rise the possible costs, and even the death tolls of flood events. Thus, growing population density in high risk locations, such as riverine neighbourhoods, is very likely to increase the vulnerability of societies to climate change. This mass relocation has already occurred in a number of small island developing nations such as Tuvulu, which is currently assessing options for relocating the country's entire population.

This migration also creates pressures for water utilities which must be able to provide services to these regions of rapidly growing population.

Social and economic impacts will be perhaps the most challenging for drying climates as:

- Communities in regional areas, especially those dependent on agriculture, could be threatened by reduced water availability. For the water industry, this poses risks in terms of the long-term viability of systems and the size of treatment units. A conventional water treatment plant, designed for stable or growing population levels, might end up as a stranded asset.
- Managing water in times of scarcity is more complex and exacting, which imposes greater demands on human and other resources, and the skills of staff involved. Water theft has been tolerated in many communities, but a drying climate makes issues like theft much harder to ignore. More accurate water accounts will have to be kept and, to support it, better metering will be demanded.
- Water demands will increase. A good indicator for dry climates is the increasing proportion of water used for irrigated agriculture. Tensions over water allocation become more severe as the supplies become more scarce.
- Reduced crop production and food security are very significant downstream. Vulnerable communities face under an uncertain and worsening water resource regime, and food security has already demonstrated that it will impact developing nations severely in the very short timeframes.

4 Practical responses of water utilities to climate change adaptation

4.1 General responses

Adaptive management holds the key to survival for arid areas under the influence of climate change. Flexible approaches, diverse portfolios of water sources and management strategies and an ability to move quickly to make and implement decisions will be imperative. Continuous monitoring and evaluation will be essential to underpin the knowledge of decision-makers.

At the level of utilities, the awareness, impacts and response to climate change is diverse and locally specific. Yet, it is imperative that the water sector take measures and actions to respond to a changing climate in combination with other relevant pressures (e.g. population growth, urbanization).

The EC (DG Env) Communication on Water Scarcity and Drought and associated action plan is under preparation. Climate change impacts and adaptation are key considerations. Its 'water hierarchy' approach sets out the need to **prioritize water savings/water efficiency** before looking at other alternatives.

Potable water supplies

Adaptive strategies for drinking water supply should address both the demand and supply side.

Demand strategies may both apply to water allocation issues between sectors (agriculture, industry, drinking water, ecology) and to a reduction in water consumption. In warm climates, agriculture is by far the largest user of fresh water (e.g. 80% in Spain), so reduction of water losses by agriculture should be top priority. Technological innovation (e.g. improved irrigation techniques) may make this possible. With respect to public water supply, increasing public awareness of water scarcity and water saving is needed as a first step, although mandatory measures may be necessary in times of water crisis. Possible measures include public information campaigns, introduction of progressive water tariffs, and setting of specific regulations regarding the use of drinking water during periods of water scarcity (e.g. a ban on private car washing or watering the garden). In recent years, mandatory water restrictions have been used to successfully reduce domestic water demand in Australia during drought periods.

Supply strategies aim to increase water resources availability. Relevant aspect of such strategies are costs, customer perception and environmental sustainability. Worldwide, studies have focused on the exploitation of sea water, precipitation, brackish ground water and domestic wastewater, using innovative treatments, such as membrane technology, as alternatives to commonly applied water resources. Some concepts are already widely applied in specific regions. For example, desalination is a commonly applied technique in (semi) arid areas, like the Mediterranean countries. Drawbacks of this technique are the high investment costs and energy consumption (opposing CO_2 mitigation targets).

Flexible water resources management is a promising concept to guarantee the continuity of drinking water production and supply at acceptable costs. Application of the 'Flexwater concept' is based on large treatment systems, designed for constant production, combined with local sources to deal with peak demands. The use of locally available water resources is an essential element of this concept. The Flexwater concept is expected to be cost efficient in remote areas and newly developed urban areas. For instance, the 'closed city concept' is based on the use of local rainfall for drinking water production in urban areas. During dry periods recycled waste water treatment plant effluent and regional surface water may be used as supplementary sources to create a more flexible system (provided appropriate treatment techniques are available). This can reduce the vulnerability of urban areas to water scarcity. Another example of the Flexwater concept is the use of excess rain water or pretreated surface water as additional sources for drinking water or for non-potable uses (e.g. flushing toilets) in combination with temporary storage in aquifers, and the excess water is then recovered during dry periods. At several locations in the world (e.g. USA, Canada, UK, Israel, Australia), this concept is already applied. It should be mentioned that this technique may have serious implications for the quality of the injected water (e.g. mobilization of arsenic).

Extreme events

Water utilities should work closely with the developers of shoreline management plans as in low lying and deltaic regions it is likely that their infrastructure will be vulnerable to flooding, compromising their ability to provide necessary services. Possible measures to protect against such disasters could include early warning systems, improved physical defence for existing facilities and careful site selection for new facilities.

Extreme hydrological events pose a big challenge to water utilities' daily operations. Demand patterns and flows in water mains and sewers will become more dynamic as a result of rainstorms and droughts. Treatment works will be challenged with more variable sewage flows, either diluted (rainstorms) or concentrated (droughts), sewers may not be able to cope with rainstorms, leading to sewer overflows and backflushing of sewage to street level, etc. This may lead to serious public health issues. Knowledge and models are needed to understand and assess the consequences of extreme weather (rainstorms, heat waves, droughts) on the entire urban water cycle and on the interaction between the urban water cycle and the hydrological cycle, aiming to develop best management practices at local level. We need smart and robust monitoring systems with sensors and communication tools for early warning of **rainstorms** and associated pollution events and for remote control of supply and sewer systems. These systems should contain 'control handles' to enable more flexible operations and adaptation to extreme weather conditions. We need more knowledge and technologies (such as toxicity assays and sensors) to assess public health effects of urban flooding and controlled sewer overflow events. **Droughts** will increasingly cause imbalance between water demand and supply. On the one hand this asks for smart technologies and communication strategies to save or reuse water in households, industries and agriculture, and on the other hand it calls for innovative technologies to exploit alternative and non-conventional resources such as brackish groundwater, sea water, greywater and treated wastewater. And we should further develop technologies and approaches to store and recover water in local aquifers (ASR), taking account of possible adverse impacts on water quality (e.g. mobilization of arsenic). We have to assess and monitor the microbiological risks of high temperatures in water mains and plumbing systems (e.g. *Legionella*). The hydraulic functioning of the sewer system and the purification performance of waste water treatment facilities during rainstorms and droughts is another issue at stake.

There is also a major challenge related to mitigation. To ensure that adaptation strategies do not contribute to further global warming, the water sector must aim to lower its energy demand and GHG emissions and introduce energy recovery and renewable energy systems. Research and technology development is needed to support the water sector in this ambition. Further discussion is provided in Chapter 5 of this document.

Capacity-building

A general concern is the need for capacity-building for adaptation through a knowledge exchange between countries and to showcase adaptation examples worldwide. Toolkits need to be developed in different areas and sharing of knowledge and best practice needs to be facilitated.

4.2 Adaptation responses and strategies in deltaic countries

Adaptation to climate change in low lying and deltaic countries will rely on a combination of physical defence and careful development of response strategies and disaster action plans. To reduce the vulnerability of communities to flooding, careful urban planning is required, and future developments must take into account the safe provision of vital services (including water) under future climate scenarios.

Adaptation to reduced sea level rise/storm surge

This section mentions some of the measures not previously under extreme events.

The building and strengthening of dikes will protect land from being inundated by the sea. Reforestation and coastal vegetation (mangroves) can act as natural barriers to erosion and destructive storms. However, with sea level rise saline waters will be entering the ground and surface waters with implications for agriculture and water production. At the same time adaptations have to target increase of pollutant concentrations in rivers during low flows (micro pollutants EDS's/ PPCPS's, organic material, etc.) and the subsequent impact on drinking water treatment, ecology, swimming water, etc. Alternative sources of water have to be considered such as desalination or use of rainwater harvesting, filtered pond water, etc.

Adaptation to flooding

Other than building embankments, there are other approaches in learning how to live with floods and develop flood resilient systems, landscapes and infrastructure. This includes flood proof storage of chemicals/ fuel. River flooding will increasingly affect agricultural areas and adaptation may be carried out through 'floating crop beds' and hydroponics.

In general there will be a need for expenditure on maintenance and repair, for example, improved infrastructure engineering and design to protect underground assets due to changing soil conditions.

Adaptation of urban drainage and waste water treatment in deltaic countries

The increasing impact of rainstorms on sewer systems can be dealt with by creating more open water, underground storage, and a separate collection of rainwater and sewage, but these are costly measures and there may not always be enough space to implement them, especially in urban areas.

Adaptation of drainage systems has to aim at different levels which are separated by the return period of a rain event. With respect to sustainable development of urban areas, adaptation has to be based on an integrated approach that minimizes the number of end-of-pipe measures, thus focusing on source control.

Long droughts and the increasing number of formerly very rare events will cause the operation of drainage systems to act more decentralized.

If flood protection is established or enhanced, waste water treatment plants should not be forgotten. If necessary, additional pumping stations for high water times are needed that ensure the operation during this time.

4.3 Adaptation responses and strategies in mountainous regions

Current water management practices may not be robust enough to cope with the impacts of climate change on water and will need strengthening. Moreover, current water management practices are not flexible enough to cope with the seasonal contrast of floods and drought at the same geographical location, especially in lowland plains. Climate change challenges the traditional assumption that past hydrological experience provides a good guide to future conditions, and new approaches have to be made. The consequences of climate change may alter the reliability of current flood defence systems and infrastructure.

A portfolio approach to climate change adaptation

Given the uncertainty associated with the possible impacts of climate change, it is critical that utilities pursue adaptation strategies that enable them to make staged investments that enhance their system capacity in a financially sound manner. An initial area of focus is system operations: utilities should analyze how to enhance the operations of their existing utility system as it may lead to greater knowledge of their system at low to no cost. In assessing the possible impacts of climate change on its water supply system using three climate scenarios, Seattle Public Utilities was able to offset all the projected reductions of supply in 2050 in two of the three scenarios through low cost, operational adjustments. While changes in system operations will be a critical component of water managers' responses to climate change, it is also critical for water managers to think more expansively and consider portfolios of adaptation strategies that operate in multiple realms to enhance the coping capacity of their system and the communities they serve. A partial list and description of these realms is given below.

Operational

Water managers should develop flexible operational strategies that are dynamic and responsive to real time conditions. Water managers should test their systems to identify latent system flexibility that could be deployed as needed to accommodate variability that may be amplified by climate change. Utilizing observational networks to enhance access to real time information that informs operational decisions should be evaluated. Aggressive leak reduction strategies should be deployed in order to reduce system withdrawals and reduce vulnerability to drought events.

Structural

The projected hydrologic impacts of climate change, as well as the GHG emissions associated with different options, should be factored into decisions about system expansion or additions. Reservoirs are often operated, or are expected to be operated, for multiple purposes that often have competing objectives, e.g. water supply and flood retention. System operations and expansion should recognize these sometimes competing objectives of water system management and attempt to enhance system flexibility through strategic investments that are staged appropriately and pursued in tandem with other strategies.

Sociological

Demand management strategies, such as conservation programmes and tiered pricing, can be instrumental in helping to maintain or increase the gap between supply and demand. Behavior modification and social marketing strategies can be pursued to assist in redefining people's relationship to water. Meaningful outreach and involvement strategies with citizens can enhance a community's water intelligence and enable water utilities to access tacit knowledge in the community about water.

Technological

As 'water smart' technologies continue to advance and decentralized approaches to water provision become more acceptable and safe, it would be advantageous to water managers to develop integrated water management approaches that support hybrid strategies of decentralized and centralized strategies, e.g. rainwater harvesting that complements traditional centralized water supply systems. Such approaches can add resiliency and diversity to water supply portfolios. If lacking such pro-active approaches, technological advancements could lead to outcomes that are disruptive to current utility business models.

Political

Water managers may want to engage in discussions about water allocations between sectors of society and be active in issues, such as decisions about which types of new energy generation facilities are developed that have implications for the withdrawal and use of limited water resources. Identifying and implementing water use efficiencies in the agricultural sector should be top priority, since this sector consumes most of the fresh water resources globally. Collaborating with other utilities to share best practices, jointly advocate for resources that would enhance adaptive capacity, such as the establishment or expansion of observation networks, and fund research that enhances knowledge and addresses issues of common concern, should be considered.

Technical

Water managers should be engaged in helping to shape and frame the climate change research agendas of governments and research institutes so that the research is addressing the needs of user communities and generating research products that can be used by water utilities to enhance their understanding of the impacts of climate change and develop appropriate adaptation strategies.

Institutional

Building institutional capacity within utilities to operate and think strategically across these realms is critical if utilities are to pursue a broad-based approach to developing adaptation options and capitalize on opportunities beyond the traditional domain. Evolving conditions and uncertain futures merit the evaluation of institutional capacity to respond to them.

4.4 Adaptation responses and strategies in drying climates

Because of the effects of prolonged droughts in many semi-arid and arid nations there has been a realization that water resource management including planning and investment in infrastructure must be underpinned by sustainability principles, which incorporates social and economic aspects together with the engineering.

Introduction to water utility issues (drying climates)

For utilities in drying climates climate information is critical to ensure there is adequate lead time to source alternative supplies, assess the suitability for potable use and put in place management or treatment options. For developing country utilities, it is critical to have this information to break the cycle of sourcing reactive, emergency supplies. Furthermore, the water utility structure in both developed and developing nations face existing and growing pressure of industry capacity and capability.

Asset management

Emergency management, resilience planning, flood warning systems and predictive modeling all form important pillars for both developed and developing nations. These systems will be a small yet important step in assisting developing nations in escaping a reactive cycle when water resources become scarce in a short period of time or when a village is relocated due to floods for instance.

Water resources management including developing a diverse water resource portfolio:

- **Water efficiency and demand management** are important when water is scarce and, in many cases, they have no impact on the quality of life of consumers, but enable communities to use much less water. These are also generally the most cost effective measures to cope with reduced supplies, particularly for developed countries.
- **Pricing signals** should reflect more accurately the cost of securing and delivering safe potable water.

- **Mapping and predicting groundwater resources** needs to be further developed, particularly as the resource itself becomes more unreliable from a quality and quantity point of view. Any tools that can be implemented to assist communities manage surface and groundwater resources will help to address the potential for social dislocation in remote and rural areas.
- **Desalination** of sea water and brackish water is truly climate independent and it profoundly affects the risk management dimension for water utilities. The use of desalination also acts to disconnect cities from water systems in a positive way. The externalities associated with water extractions from natural systems can be avoided when desalination is employed. There are now innovations available for desalting saline groundwater that are more appropriate for developing nations without the resources or expertise available to operate heavy engineering type processes.
- **Reuse of water** (recycling) at scales ranging from on-site to metropolitan and for purposes ranging from agriculture to drinking water, enables arid areas to drive every litre of water further. An entirely closed loop is impractical, but many communities in arid areas already recycle anywhere from 50% to 100% of their used water.
- **Aquifer storage and recovery (ASR)** techniques have a lot to offer under the right conditions, and are likely to be more widely used than they have up to now. If suitable aquifers are accessible, ASR has many benefits when compared to other storage options. ASR can be applied to both recycled water and to stormwater.
- **Stormwater harvesting** will become more attractive, for the dual purposes of supplementing other sources and managing the impacts of storm runoff, which is likely to increase in some areas. The methods will include water sensitive urban design (WSUD), best management practices (BMPs) and a general move towards lower impacts. The cost of storages is a major hurdle for stormwater capture projects, but it is still an approach to try.
- **Reservoir management** needs to be more sophisticated to maximize yield from a given catchment and storage combination; the desire to minimize evaporative losses, and the demand for optimum water quality outcomes. Techniques such as destratification, selective draw-off, and manipulation of multiple, linked storages, need to be applied where feasible.

Capacity-building for water management

Most arid countries (both developing and developed, but especially developing) will need to build human capacity to cope with the challenges, ranging from water treatment plant operators in the field, climate change modelers and politicians and bureaucrats who will need to make complex decisions.

There is also a need to build capability in the agricultural sector for water resource planning and, while in the direct remit of a typical water utility as pressures for a diminishing resource increase, more indirect planning documents such as land use planning may need to be considered.

5 Climate Change Mitigation in Water Utilities

Adaptation strategies are required to ensure that water utilities can continue to provide services in the face of changing climates. However, mitigation is equally as important to ensure that solutions do not further exacerbate the problem. This chapter addresses several issues related to climate change mitigation in water utilities (i.e. green house gas emission reduction efforts).

5.1 Research on climate change mitigation in water utilities

Worldwide many water utilities are engaging in visionary efforts to reduce carbon and energy footprint in their operations. Water supply and wastewater treatment are energy intensive industries.

Within the research community, the research effort towards a better understanding of the relationship between the water industry and climate change is staggering. As more research results become available, we observe with increasing frequency that commonly accepted engineering practices may be associated with severe impacts on the surrounding environment.

Enhanced wastewater treatment levels are now been reassessed *vis-à-vis* CO_2 emissions related to higher water quality standards. A balance between these two aspects is most needed.

Mathematical modeling of wastewater treatment plants is currently being upgraded to provide for a better estimation of N_2O and CH_4 emissions.

5.2 The link between mitigation and adaptation

Mitigation measures can reduce the magnitude of impacts of global warming on flood disasters, in turn reducing adaptation needs. However, mitigation can have considerable negative side effects if projects are not sustainably allocated, designed and managed.

Pursued climate change mitigation options should demonstrate co-benefits that facilitate climate change adaptation. In many cases climate change will increase current risks for utilities such as extreme flooding events. Utilities need to investigate existing response plans or risk management plans that identify vulnerabilities in the utility system. Climate change mitigation measures that increase the efficiency of a utility can be applied to vulnerable infrastructure and demonstrate co-benefits by providing hazard mitigation against extreme events.

An example of a programme that links climate change mitigation and adaptation is the regional wetland assimilation system planned for New Orleans. The planned implementation of the largest wetland assimilation system in the world will utilize natural wetlands to assimilate over 4.4 m^3/s (100 MGD) of secondarily treated, disinfected municipal effluent to restore approximately 12,000 ha of critical cypress wetlands. Currently nutrient rich effluent from both parishes is discharged to the Mississippi River where it contributes to the hypoxia of 13,000 km^2 in the Northern Gulf of Mexico. Rerouting the effluent will allow the nutrients to be used to replenish the wetlands, rather than increasing damage to the coastal environment. Furthermore, it was proven during Hurricane Katrina that wetlands are effective for climate change adaptation, since they dissipate surge and wave energies, thereby protecting levees from breeching and failure. An additional climate change benefit of wetland assimilation is that almost 1 million tons of CO_2-e a year are reduced through biosequestration and burial. Wetland restoration is an important climate change adaptation-mitigation measure for combating CO_2 emissions, increased tropical storms, and relative sea level rise (Nolasco, 2003 and 2004).

5.3 Mitigation and wetlands

Treatment wetlands have emerged as a viable option for wastewater treatment, especially for tertiary or polishing applications. One of the key collateral benefits of treatment wetlands is the low energy requirement, which includes the elimination of chemical additions to accomplish treatment. Land area and energy input from the sun are substituted for the normal energy inputs required to operate a wastewater treatment system. The total carbon footprint of all potential treatment processes needs to be understood, including that of treatment wetland systems. The key GHG issue for treatment wetlands is the balance between net carbon sequestration in wetland sediments and the emission of CO_2, CH_4, and N_2O. These fluxes are comparatively well understood for natural wetland systems. However, much less is known about GHGs and treatment wetlands, where loading rates tend to be considerably higher. Initial comparisons of advanced wastewater treatment with treatment wetland systems suggest that the carbon footprint of a typical treatment wetland system designed to accomplish a similar level of treatment will be considerably less than conventional tertiary treatment. Especially when considering alternatives such as treatment wetlands, carbon footprint is an inadequate criterion, in that a full life cycle analysis that includes aspects such as net environmental benefits (e.g. habitat restoration) will provide a more robust assessment.

6 Recommendations for actions

Governments (political messages):

- Take adequate steps to model climate change;
- Monitor and evaluate unfolding climate and its impacts;
- Develop nimble, adaptive management strategies;
- Ensure that all personnel employed in the field of water are adequately educated and trained;
- Establish and provide access to data monitoring and observational networks and support needs-

driven climate research that is developed with the involvement of the water sector;
- Pursue climate change mitigation options that demonstrate co-benefits with climate change adaptation;
- Adaptation in the water sector should be part of the discussion in multi-lateral talks for the successor to the Kyoto Protocol and a focal point for the Adaptation Fund that is being created.

The water industry:

- Close the gaps in impact data;
- Promote the development of adaptation plans for the water industry and put in place measures to provide assistance as required;
- Provide information sharing mechanism (IWA);
- Development of successful case studies on adaptation, mitigation, and mitigation-adaptation projects through websites/web portals, workshops and reports;
- Practitioners in water need to take personal responsibility for being up to date and proactive in their work. One way to achieve this is to be actively engaged with IWA and local water associations;
- Adopt of energy recovery and energy efficient technologies for the water sector;
- Support evidence-based research on the pollution potential of and mitigation options for N_2O;
- Develop collaborative partnerships between the research community and the water utility community for the development and application of applicable climate research.

Individual utilities:

- Engage with the research community to better understand the projected hydrologic impacts of climate change in the region where they operate;
- Conduct vulnerability assessments to better understand the specific attributes of the system they are responsible for managing and what the implications are given the projected hydrologic impacts in the region where they operate;
- Foster discussions and knowledge transfer between developed and developing countries;
- Broaden the discussion on the multi-shift usage of the aquatic environment with respect to water quality, heat loads and (decreasing) biodiversity;
- Participate as stakeholders, e.g. in EU or (inter)national projects on climate change (impacts, adaptation, mitigation) and water availability;
- Bridging the technology gap between the North-South divide by raising climate change adaptation and mitigation awareness and building partnerships with all stakeholders through mutual sharing of information among the utilities (e.g. Water Operator Partnership (WOP) networks).
- Develop water loss reduction programmes (unaccounted-for water reaches 30% and up to 70% in developing countries, i.e. a huge waste of resources and an unnecessarily large C footprint).

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Perspectives on water and climate change adaptation

Climate change adaptation in the water sector – Financial issues

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

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

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

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

Participants were invited to contribute perspectives from three categories:

1 **Hot spots** – These papers are mainly concerned with specific locations where climate change effects are felt or will be felt within the next years and where urgent action is needed within the water sector. The hotspots selected are: Mountains (number 1), Small islands (3), Arid regions (9) and 'Deltas and coastal cities' (13).

2 **Sub-sectoral perspectives** – Specific papers were prepared from a water-user perspective taking into account the impacts on the sub-sector and describing how the sub-sector can deal with the issues. The sectors selected are: Environment (2), Food (5), 'Water supply and sanitation: the urban poor' (7), Business (8), Water industry (10), Energy (12) and 'Water supply and sanitation' (14).

3 **Enabling mechanisms** – These documents provide an overview of enabling mechanisms that make adaptation possible. The mechanisms selected are: Planning (4), Governance (6), Finance (11), Engineering (15) and 'Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA)' (16).

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

11 Climate change adaptation in the water sector – Financial issues

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Climate change adaptation in the water sector – Financial issues

The present document discusses the economic and financial issues of adaptation to climate change. The (inter)national adaptation funding instruments presently available were inventoried and analysed. The analysis clearly showed that projected needs cannot be met with these instruments alone, while an overarching harmonized strategic financial framework, without which the benefits for the global environmental environment will remain suboptimal, is still lacking. The document therefore describes what other options for financing could be developed.

Introduction

Studies by the World Bank, the Stern Review, the Human Development Report research team, the UNFCCC and Oxfam estimate global adaptation costs to be in the order of tens of billions of dollars per year (see Table 1), while the adaptation costs in the water sector specifically are estimated to be around US$ 531 billion from now to 2030 (Kirshen, 2007). The actual global costs could exceed US$ 100 billion per year and will be sensitive to many factors, including how much and when mitigation will take place. The limited quantitative information on the costs and benefits of economy-wide adaptation makes estimating global costs, to say the least, challenging[1]. Though exact figures are not yet available, it is clear that a large amount of new and additional investment and financial flows will be needed to address climate change adaptation.

1 Global funds for adaptation

This section will give an overview of the current global adaptation funding instruments:

1 UNFCCC Funds
   a GEF Trust Fund
   b Least Developed Countries Fund
   c Special Climate Change Fund
2 Adaptation Fund
3 Other UN Conventions
   a Convention on Biological Diversity
   b Convention on Wetlands
   c Convention to Combat Desertification
4 World Bank Adaptation Funds
   a Clean Technology Fund
   b Strategic Climate Fund (SCF) with a Pilot Program for Climate Resilience (PPCR)
5 New Bilateral Funds

1.1 UNFCCC Funds

The Global Environment Facility (GEF)[2] is currently the entity entrusted with the operation of the financial mechanism of the United Nations Framework Convention on Climate Change (UNFCCC)[3], and as such provides the instruments for the transfer of financial resources from developed to developing countries. The instruments for adaptation funding via the GEF are:

1 The GEF Trust Fund;

[1] Adaption actions will be myriad, widespread and heterogeneous, while adaptation needs depend on the magnitude and nature of climate change. In addition, the range of estimates is the result of the uncertainty of expected impacts, the different understandings of what adaptation entails and the use of different models. Furthermore, there are few estimates of adaptation costs. More analysis of the costs of adaptation at the different levels is required to support the development of an effective and appropriate international response.

[2] See http://www.gefweb.org. The GEF is funded by donor countries, some of which are also recipients, who commit resources every four years through a replenishment process.

[3] The United Nations Framework Convention on Climate Change (UNFCCC) commits developed countries to assist developing countries in meeting costs of adaptation to the adverse effects of climate change.

Table 1: Estimates of global annual adaptation costs.

	Covered area	Annual costs
World Bank	Adaptation investments in developing nations	USD 3-37 billion
Stern Review	Adaptation investments in OECD countries	USD 15-150 billion; 0.05-0.5% of GDP
Oxfam International	Adaptation investments in developing nations	USD 50 billion
Human Development Report 2007	New and additional financing for pro-poor adaptation	USD 86 billion
Kirshen 2007	Adaptation in the water sector	USD 23 billion
UNFCCC	Additional adaptation investments needed by 2030	USD 8-130 billion; [*USD 11 billion for new water infrastructure; 85% of which is needed in non-Annex I countries*]

2 The Least Developed Countries Fund (LDCF);
3 The Strategic Priority on Adaptation (SPA), and
4 The Special Climate Change Fund (SCCF).

Together, these funds amount to over US$ 275 million. The SPA operates as part of the GEF Trust Fund, which in practice translates into very complex procedures for project proposals (Le Goulven, 2008). The LDCF and SCCF are independent from the GEF Trust Fund and therefore do not have to produce global environmental benefits. Since 2005, GEF has provided US$ 110 million for projects targeted mainly at studies, as well as demonstration and pilot projects on adaptation planning and assessment.

During the GEF Replenishment of 2006, 32 donor countries pledged US$ 1 billion to support activities in the area of climate change between 2007 and 2010. Currently, the GEF is in the process of reviewing, revising and focusing its climate change strategy.

The World Bank noted that the total amount of funding for adaptation projected to be available by 2012 falls well short of the estimated amounts needed. In addition, developing countries have expressed the additional concern that the complexity of current arrangements constrains their access to funds for adaptation project activities.

1.2 Adaptation Fund of the United Nations Framework Convention on Climate Change

The UNFCCC conference in Bali (December 2007) culminated in the adoption of the so-called 'Bali Road Map', which designates the timeframe and material content of negotiations for the next two years. The Bali Road Map also includes the approval and launch of the basic principles of the functioning of the Adaptation Fund[4].

The Adaptation Fund should serve for the financing of adaptation measures (in the form of projects and programmes) in developing countries. The main task of the Adaptation Fund will be to ameliorate the impacts on, in particularly, water management, agriculture and forestry in those parts of the world that are most vulnerable to the impacts of climate change.

It was decided that the Adaptation Fund should be incorporated under the management of the GEF, and the payment unit will be the World Bank. It was furthermore determined that the Adaptation Fund is to be supervised and managed by an Adaptation Fund Board represented by developed and developing countries. Although the secretariat for the fund will be held by the World Bank-based trust fund, the GEF, this is meant to be a temporary status. The secretariat would have to report to the Adaptation Fund Board and the GEF's status as secretariat will be reviewed after three years. The managing principles of the

4 http://www.adaptation-fund.org

Adaptation Fund have been provided, but priorities, eligibility criteria and disbursement criteria have not been decided upon yet.

The Adaptation Fund will receive a 2% share of proceeds from the Clean Development Mechanism (CDM) and is to finance concrete adaptation projects and programmes in developing countries that are Parties to the Protocol. Hence, the level of funding for the Adaptation Fund under the Kyoto Protocol depends on the quantity of certified emission reductions issued and their price. Consequently, a lot of uncertainty remains about the level of actual resources that will be mobilized under the agreement. Carbon trading was expected to become a US$ 70 billion a year industry by the time the Adaptation Fund went into effect in 2008. There are substantial uncertainties about how much funding the market will generate, because it will depend on both the size of the market and on prices. The variation is partly due to uncertainties in the future of carbon markets and size of future emissions caps, which are currently being negotiated in the Bali Road Map process up to December 2009. Estimates vary widely, from a few hundred million dollars to nearly a billion dollars by 2012, which would make expected funding for the Adaptation Fund comparable to the funding anticipated by the World Bank's Pilot Program on Climate Resilience or PPCR (see 1.4).

Note that none of the UN funds (or the Adaptation Fund) are structured in a programmatic way. This might result in donor countries channelling funds through the Strategic Climate Fund of the World Bank, which would allow for programmatic options.

Hence, a successor to the Kyoto protocol will be crucial to prevent further dangerous climate change. Bali got the process started with the Adaptation Fund, and during COP-14 in Poznan (1–12 December, 2008), a last minute decision and promising step forward was made to allow developing countries direct access to an adaptation fund to help cope with the effects of global warming. In addition, Parties agreed that the Fund would be a legal entity that will be operative as from January 2009 and will be able to receive projects in the course of next year. The initial allocation of US$ 80 million[5] committed by the rich countries invoked disappointed sounds from the developing nations and environmental organizations[6]. The issue is now delayed until COP-15 (Copenhagen, 2009), where it will be vital to reach a comprehensive agreement that will result in a more substantial, predictable, obligatory and reliable financial flow.

1.3 Other UN Conventions

Other UN Conventions: Convention on Biological Diversity

The UN Convention on Biological Diversity[7] (UNCBD) was adopted in 1992. The main objectives of this Convention are the conservation of biological diversity, the sustainable use of its components and the equitable sharing of the benefits from the use of biodiversity resources.

Adaptation activities can threaten biodiversity either directly – through the destruction of habitats, e.g. building sea walls, thus affecting coastal ecosystems, or indirectly – through the introduction of new species or changing management practices. Ranging from the construction of protective infrastructure to the development of corridors or the planting of resistant tree or crop varieties, adaptation activities can either have a positive, negative or neutral impact on biodiversity. Hence, numerous activities under the UNCBD agenda can potentially constitute adaptation measures or can assist adaptation.

In 2005, a practical guidance on the risk assessment and management approach to evaluating links between adaptation and biodiversity was developed under the framework of the UNCBD[8].

5 The fund could be worth USD 300 million a year by 2012. This current amount however could also be seen as a failure that caused some 'bitterness' among developing countries, considering many Parties called for an increase. Parties were unable though to reach consensus on scaling up the fund by a levy on the other two Kyoto mechanisms, the JI and the countries' Assigned Amount Units (AAU's). The reason why no consensus was reached was that countries that host JI projects thought a levy might make them more expensive.

6 Many world leaders admitted that they are waiting for Barack Obama, and all agree that no deal is worth having without the US signing up.

7 http://www.cbd.int.

8 http://www.cbd.int/doc/bioday/2007/ibd-2007-booklet-01-en.pdf

Various mechanisms can be deployed to finance biodiversity. Money can be raised directly from biodiversity, such as through the sustainable use or trade of biological resources themselves including goods such as timber and non-timber forest products and the pharmaceutical, agricultural and industrial applications of biological resources, as well as services such as water provision, climatic regulation, tourism and scientific research. Finance can also be raised by making sure that charges are levied on economic activities which contribute to biodiversity degradation and loss such as pollution taxes, land reclamation bonds and waste disposal charges. Other financing mechanisms include the transfer or redistribution of funds between individuals, groups or countries as through measures such as investment promotion, trust funds, loans, swaps and offsets.

Convention on Wetlands

The Convention on Wetlands, or the Ramsar Convention[9], was adopted in 1971 and entered into force in 1975. As of July 2008, it has 158 Parties. The Convention provides a framework for international cooperation for the conservation and wise use of wetlands. The Convention is concerned not just with isolated sites, but the management of the entire catchment of river basins.

Wetland responses to climate change are still poorly understood and are often not included in global models of the effects of climate change (Clair et al., 1997). However, wetlands are critically important ecosystems that provide globally significant social, economic and environmental benefits. Furthermore, efforts to respond to climate change may have equally negative, and compounding, effects on freshwater and coastal zone ecosystems. Hence, the vulnerability of specific types of wetlands plays a decisive role in the degree to which the development of adaptation strategies is needed. Preventing additional stress on wetlands from pollution, for example, is an important adaptation strategy for climate change.

To assist Parties in implementing the Ramsar Convention, three targeted funding mechanisms have been established[10]: (1) a Small Grants Fund for Wetland Conservation and Wise Use (a global programme); (2) Wetlands for the Future (a programme for Latin America and the Caribbean); and (3) the Swiss Grant Fund for Africa. In addition, private sources, bilateral donors and NGOs frequently provide financial resources to protect and manage wetlands.

Convention on Desertification

The Convention to Combat Desertification[11] (UNCCD) was adopted in 1994 and currently has 191 Parties. The aim of the Convention is to combat desertification and mitigate the effects of drought in countries experiencing serious drought and/or desertification, particularly in Africa.

Climate variability together with human activities, such as over-exploitation and inappropriate land use are recognized as main causes of land degradation and desertification. The UNCCD calls for cooperation with other conventions, "... particularly the United Nations Framework Convention on Climate Change and the Convention on Biological Diversity, in order to derive maximum benefit from activities under each agreement while avoiding duplication of effort". Similar to the UNCBD, the UNCCD has tight links with the adaptation component of the UNFCCC. For instance, many actions in drought-prone countries to address problems of land degradation could also be included in the list of adaptation actions.

The Convention established a Global Mechanism (GM) to promote actions leading to the mobilization and channelling of substantial financial resources to affected developing country Parties. The GM acts as a hub for a dynamic network of partners, committed to focusing their energies, resources and knowledge on combating desertification. The GM not only mobilizes financial resources, but also channels their flow, thereby guaranteeing increased financial effectiveness and efficiency and ensuring a holistic and equitable approach to resource distribution. The International Fund for Agricultural Development

9 http://www.ramsar.org.

10 For more information, see http://www.unep.org/dec/onlinemanual/Compliance/NationalImplementation/CapacityBuilding/Resource/tabid/685/Default.aspx.

11 http://www.unccd.int.

(IFAD) was selected to house the GM. In 2003, the GEF was selected as a financial mechanism of the UNCCD.

1.4 World Bank Adaptation Funds

The World Bank has approved the creation of two specific Climate Investment Funds (CIFs)[12], targeted to reach US$ 5 billion:

1. The Clean Technology Fund (CTF);
2. The Strategic Climate Fund (SCF), under which a Pilot Program for Climate Resilience (PPCR) has been set up.

The objective of the CTF is to accelerate the transformation to low carbon economies by financing a more rapid deployment of low carbon technologies and sector strategies. It has been developed to demonstrate new approaches and provide lessons to contribute to the negotiations under the Bali Action Plan. The amount of funding is still highly uncertain.

The SCF is aimed at increasing climate resilience in developing countries, and is "to be disbursed as grants, highly concessional loans, and/or risk mitigation instruments". The objective of the SCF is relatively broad and will address a host of issues, including climate resilience or adaptive capacity[13].

The Pilot Program for Climate Resilience (PPCR) under the SCF is designed to assure a strong link with the Adaptation Fund and to deliver programmatic funding in 5 to 10 countries to help transform national development planning to make it more climate resilient, by exploring ways to integrate adaptation into development planning and budgeting, building on the National Adaptation Programmes of Action (NAPAs). The Pilot Program is meant to be a pilot only, and not continue beyond 2012. It will build upon National Adaptation Programmes of Action (NAPAs) and is targeted to consist of US$ 0.5 to 1 billion in grants and concessional loans.

Both donor countries and developing countries have been critical of the PPCR with regard to its relationship to and overlap with the Adaptation Fund. The World Bank has denied any intention of competing with the Adaptation Fund and has promised to work with the UNFCCC Secretariat to ensure that they are not competitive in any way. It has been announced that the chairman of the Adaptation Fund will be on the oversight committee that governs the PPCR. The World Bank and the GEF have furthermore agreed to a set of operational principles by which each party recognizes that the other has important but different roles to play in funding adaptation.

NGOs have expressed concerns over the Climate Investment Funds (CIFs) of the World Bank, including criticism that the initiative could undermine existing multilateral negotiations on climate change and create conflicting parallel mechanisms for delivering climate-related financing. Representatives of NGOs are also concerned that the current rush to finalize the proposals for the funds could lead to the establishment of "top-down funds, without adequate participation of developing countries, without much needed accountability mechanisms, and without promoting the wider environmental and development benefits and sustainable transformations". Furthermore, parts of the climate investment funds will be counted as official development assistance (ODA, see Box 1) by donor countries which means that there will be no additionality in overall development financing to developing countries[14].

12 http://www.worldbank.org/cif.

13 Within the framework of the SCF, a forest investment fund/programme should be established by the end of 2008 to mobilize significantly increased funds to reduce deforestation and forest degradation and to promote improved sustainable forest management, leading to emission reductions and the protection of carbon reservoirs. The design process is to take into account country-led priority strategies for the containment of deforestation and degradation and build upon complementarities between existing forest initiatives. Work would also advance on a programme to support investments in low-income countries for energy efficiency, renewable energy and access to modern sustainable energy.

14 This goes against existing multilateral commitments under the UNFCCC which state that developed countries should provide new and additional financial resources to meet the agreed full costs incurred by developing countries in meeting their climate change commitments.

Box 1 – **Official development assistance and adaptation to climate change**

In view of the fact that the current global funds for adaptation are not only technically but also financially inadequate, the question arises as to whether or not alternative arrangements for adaptation funding, such as bilateral and multilateral Official Development Assistance (ODA), could address the concerns of developing countries and better meet their needs. However, should adaptation be funded out of the ODA Funds, money that is meant to address other developmental challenges could divert money and thereby threaten the pursuance of the MDGs and targets laid down for water sanitation and IWRM plans. It has been argued that additional finance for adaptation is not aid, but a form of compensatory finance – the motivation for providing adaptation assistance is not compassion, it is an acknowledgement of a responsibility to pay and must therefore not come out of long-standing donor commitments to provide 0.7 per cent of gross domestic product as aid in order to eradicate poverty.

A concerted research effort is therefore needed to answer questions concerning the efficiency and effectiveness of mainstreaming, barriers to and opportunities for mainstreaming, the accountability of industrialized countries with respect to their commitments under the United Nations Framework Convention on Climate Change (Klein, 2006) and, ultimately, how to climate-proof ODA by integrating risk reduction and adaptation to climate change into the development and poverty reduction plans of poor countries. Financially and technically adequate global funds for adaptation are crucial if international climate policy after 2012 is to be a truly global endeavour, whereby global funds serve as a catalyst for providing additional resources from bilateral and multilateral sources.

Wider issues in this context are:

- The difficulties of disaggregating the costs for adaptation activities from normal development activities may make the aid diversion issue prominent in the adaptation funding area.
- The greater ease of classifying finance for specific adaptation projects as additional, compared with finance for climate-proofing development interventions, may contribute to further divisions between these two approaches and result in a tendency toward more project-based approaches.
- The shift in fund management from ministries of development to ministries of environment (e.g. as in Norway and Germany) may make distinctions easier, but this depends on how the funds are classified. For example, in Norway funds are still classified as ODA even though they are under the Ministry of Environment.
- The innovative financial mechanisms relating to climate investments (such as air travel adaptation levies and carbon trading auctions and levies) that are being considered by some donors may help to raise additional funds that are more clearly separated from ODA.

Sources: World Bank, 2006; Bouwer and Aerts, 2006; Oxfam International, 2007; Le Goulven, 2008.

1.5 New bilateral funds

The bilateral funds[15] discussed in this section all aim to address the international funding gap for climate change, but are not yet functional, so their final structure and operational practices cannot be stated with complete certainty (Porter et al., 2008).

Four European countries, together with the European Union, Australia and Japan have made recent commitments to provide new financing to assist international measures to tackle climate change. Most funds are aimed at supporting developing countries and hence have a close relationship with development assistance. The following initiatives

[15] Not included here, because it is a multilateral initiative: the Bangladesh Multi-Donor Trust Fund (Howard, 2008). This MDTF is in the very early stages of design - but the general idea is to finance the projects to be developed along the priority areas outlined in the Climate Change Strategy and Action Plan of the Government of Bangladesh. The UK Department for International Development (DFID) will contribute £60 million into this fund and Denmark and Australia have expressed interest to contribute as well.

have been proposed (Porter et al. 2008; Howard, 2008):

1 The Global Climate Change Alliance (GCCA) - European Commission;
2 The International Window of the Environmental Transformation Fund (ETF-IW) - United Kingdom;
3 The Millennium Development Goals (MDG) Fund – Spain;
4 The Cool Earth Partnership – Japan;
5 The International Climate Protection Initiative – Germany;
6 The Agency for Development Cooperation (NORAD) Rainforest Initiative – Norway.

All of the initiatives aim to address climate change adaptation and mitigation by providing direct or indirect financial support for such activities, but only a few have wider ambitions to facilitate the coordination and negotiation between donors and potential recipient countries in the lead up to a new post-2012 climate agreement. All the funds have a limited time horizon, with no commitments made beyond the 2012 date for negotiations on a post-Kyoto agreement. This short timescale is indicative more of a piloting phase rather than any new long-term architecture of global environmental funding. The experience gained through disbursing these funds, however, will provide much valuable experience on how to channel global funds to tackle climate change in developing countries over the long term.

The total nominal amount of dedicated finance is somewhat less than US$ 3 billion per year, which represent a small percentage of the expected needs of developing countries.

A brief description of each of the proposed initiatives is given below. More information can be found in Porter et al (2008).

GCCA – European Commission

The European Commission's Global Climate Change Alliance (GCCA) will address mitigation, adaptation and poverty reduction via a proposed partnership with developing countries that will include the provision of both technical and financial assistance. Technical and financial support will be provided for adaptation. In addition, it aims to provide an informal forum that will facilitate negotiations for a post-2012 climate agreement. The GCCA also plans to add value by acting as a clearinghouse mechanism to coordinate the international adaptation initiatives of EU member states. The fund is envisioned to generate US$ 50 million (Le Goulven, 2008).

ETF-IW – UK

The UK's International Window of the Environmental Transformation Fund (ETF-IW) has two kinds of objectives. The first process objectives relate to transforming how finances are delivered. These include facilitating moves toward additional finance provided in a programmatic way; avoiding aid proliferation and ensuring coherence, and piloting models that will feed into the UNFCCC negotiation process and the Kyoto Adaptation Fund. The second set are thematic objectives that include supporting poverty reduction, providing environmental protection and tackling climate change in developing countries by addressing unsustainable deforestation, access to clean energy and activities that support adaptation. Most of the finance available under this initiative will be channelled through the World Bank's CIF Facility, although early support to the Congo Basin Conservation Fund has been provided to address uncontrolled deforestation in that region.

MDG Fund – Spain

The Spanish Millennium Development Goals Fund, which include a thematic window on Environment and Climate Change, will support efforts to reduce vulnerability to climate change and poverty reduction. The fund will support: (i) interventions that improve environmental management and service delivery at the local and national level; (ii) activities that will increase access to new financing mechanisms; and (iii) efforts to enhance adaptive capacities.

Cool Earth Partnership – Japan

The Japanese Cool Earth Partnership will assist the adaptation and mitigation to climate change and has three priorities: (i) establishing a post-Kyoto framework that will ensure the participation of all emitters and aim at fair and equitable emission targets; (ii) strengthening international environmental cooperation, under which Japan will provide assistance to help developing countries achieve emissions reductions and to support adaptation in countries suffering from severe climate change impacts; and (iii) supporting innovation that will focus on the development of innovative technology and a shift to a low carbon society. The Partnership will provide US$ 2 billion as grant aid and technical assistance to support adaptation activities, whereas the bulk of the fund (US$ 8 billion) will be made available as concessional loans to support mitigation activities.

International Climate Protection Initiative – Germany

The German International Protection Climate Initiative[16] has three objectives: (i) supporting sustainable energy systems, adaptation and biodiversity projects related to climate change; (ii) ensuring that investments will trigger private investments at a greater magnitude; and (iii) ensuring that financed projects will strategically support the post-2012 climate change negotiations. For this purpose, it will also support multilateral activities and funds focusing on adaptation and forest management. The estimate for this fund is US$ 60 million for 2008 (Le Goulven, 2008).

NORAD Rainforest Initiative – Norway

The Norwegian NORAD Rainforest Initiative is not a fund as such, but a pledge of earmarked funding to be allocated through the national budget. It will support the conservation of rainforests by promoting large-scale forest protection and the development of forest-based carbon management. More general measures will include support for adaptation and promoting clean energy in Africa.

[16] See also http://www.bmu.de/files/pdfs/allgemein/application/pdf/klimaschutzinitiative_flyer_en.pdf.

2 Other funding sources: public and private investments and insurance

As the previous chapter showed, current global adaptation funds are limited and will not be able to meet the project needs. Therefore, financing climate change adaptation should, in all probability, have to largely tap into other funds. However, drawing from other investment sources may have additional benefits, as they may be better tuned to local needs, and draw upon existing structures and expertise, and are already targeted at essential sectors. This chapter identifies these other funding sources available for financing adaptation to climate change: public investments, private investments and insurance arrangements.

2.1 Public investments

Public investments in water infrastructures can take into account the need for adaptation to climate change. There are two types of modifications:

- Existing infrastructure may be upgraded:
  - Protective infrastructure: strengthening dams, coastal defences;
  - Non-protective infrastructure: reinforce roads built on melting permafrost, improving water management to cope with flood risks and water shortages;
- Climate change can be taken into account when designing new infrastructures (roads, railways, bridges):
  - Protective infrastructures: e.g. the Maeslant Barrier (the Netherlands) and reforestation projects;
  - Non-protective infrastructures: such as heat resistant and permeable roads (rainwater can percolate easier, smaller risk of inundation), the Confederation Bridge (Canada), energy infrastructure, water supply and demand infrastructure;

Disaster risk reduction and capacity building

Governments have made commitments to make the world safer from natural hazards through investing in Disaster Risk Reduction (DRR) approaches. Thus, climate change adaptation can be linked to disaster risk reduction activities and improving poor people's livelihoods by integrating climate change adaptation concerns to national disaster risk reduction and poverty reduction strategies.

Future vulnerability reduction of communities at risk should include improving their capacities. Empowering affected populations so that they have a strong voice in recovery and rehabilitation after disasters, and the reduction of risk would increase their coping capacity. Therefore, public investments in building local capacity ought to be tunnelled toward the education and general awareness-raising on risk and climate change issues.

Box 2 – **Financing climate adaptation in the Netherlands**

The Dutch have a long tradition in water management which started early 1200. With regards to the institutional context, three levels can be distinguished:

On the national level, the Ministry of Transport, Public Works and Water management has the responsibility for water management. Within this Ministry, the Directorate-General for Public Works and Water Management sets out the general water policy, laws and regulations and is responsible for the primary flood defences. We work in close cooperation with other ministries in the fields of spatial planning, environment, agriculture, nature.

The provinces are the second level; they are responsible for regional spatial planning and supervise the regional governmental bodies.

The regional governmental bodies are the water boards and the municipalities. The water boards are the oldest democratic organizations of our country and they take care of the regional water management. Municipalities have their own water tasks in urban areas and deal with local spatial planning

When it comes to financing adaptation in the water sector, the flood protection and drainage investments are initially made by the Central Government. The operational and maintenance costs on the other hand are financed by the so-called 'water board taxes'. This assures that there is no competition for national budgets, while long-term planning is guaranteed.

Source: Vlaanderen (2008).

Box 3 – **Financing Climate Adaptation in Ukraine**

In some parts of Ukraine, the impacts of climate change are increasingly visible: there is an increased number of natural disasters, an increase of floods in the Carpathians, the steppes in the southern regions are turning into deserts, coastal areas get inundated (rise of the Black sea level is 1.5 mm/year) and there is an acute shortage of drinking water in the central and eastern regions.

A precondition for financing adaptation is the development of national and sub-national plans for different areas, and basins. The possible sources of funding to adapt to climate change in the Ukraine are:
State budget – Possible when the implementation of activities under the state programs contributes to climate change mitigation.
Loans – For the construction of large objects, like protective dams, treatment plants, irrigation systems, and the like, loans can be applied for.
State economic incentives – For example, credit concessions and allocation of funds from emission quotas sale for adaptation measures.
Private capital – Private capital can be attracted by means of the River Basin Councils and by the development of extra-budgetary targeted funds aimed at the implementation of adaptation tools that take into account all stakeholders.
Donor assistance – To draft a National adaptation strategy and adaptation programmes, donor support can be requested.

Source: Zakorchevna (2008).

Water pricing

Perhaps the best way to utilize water to the best and most-valued uses is to put a price on water, and construct appropriate tariff structures to meet different social, political and economic goals in different situations.

It has been argued that price policy can help maintain the sustainability of the resource itself: when the price of water reflects its true cost, the resource will be put to its most valuable uses (Rogers et al., 2002). Thereby, and assuming the poor can pay for such services, water pricing could contribute to adaptation and, for instance, if resources become scarce and water use is stabilized or reduced.

Furthermore, if water resources are managed in an integrated fashion where the economic, legal and environmental aspects complement each other, increased prices can improve equity, efficiency and sustainability of the resource. Thus in the future, water pricing mechanisms can be used to send a scarcity signal and help balance supply and demand.

There is a wide range of policy options available to implement price policy in the water sector. These range from direct pricing to green taxes, effluent fees, direct subsidies, utilities or to the users. The choice of policy depends upon the local political and social conditions, as well as the national economics. In addition, there are still many issues that need to be addressed, including an improved understanding of the environmental justice and equity consequences of water pricing.

2.2 Private investments

Private sector investments constitute a significant share of investment and financial flows and are thus another important means to enhance investment and financial flows to address climate change adaptation in the future. In terms of private funds, governments set the rules for the markets in which investors seek profits. Private capital flows, such as Foreign Direct Investment (FDI), could be influenced to support climate robust investment in infrastructure, business, or energy. Governments could look for ways to influence the major private investments in climate sensitive sectors, for example by providing incentives for risk reduction, and through regulation and standard setting that improves resilience.

If current market rules are failing to attract or drive private investors into more climate-proof alternatives, governments can introduce policies or incentives to help address these market failures. These include:

- Regulations and standards to overcome policy-based barriers to entry.
  An example of such a policy can be found in Korea, where the Seoul Metropolitan Government and several other cities enacted regulations to enforce the installation of a new rainwater system on the basis of the successful example[17] (Han et al., 2008).
- Taxes and charges (polluter pays principle-PPP[18]).
  In many countries, the PPP is based on the use of an environmental tax, which is determined proportionally to the amount of emissions of the polluting substances.
- Subsidies and incentives to pay the innovator.
  Governments could ensure that policies facilitate innovation and dissemination of technology. For instance, intellectual property rights (IPR[19]), particularly patents, provide the primary means for assuring necessary private sector investment in the invention, development and deployment of the technologies needed to adapt (ICC, 2008).

Governments can also shift the focus of their own investments. Governments are responsible for 10–

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17 The Star City Rainwater Harvesting (RWH) system which is built at a newly-developed housing complex with 3,000 m^3 of rainwater tank demonstrates that the safety and sustainability of current centralized water system can be increased by the addition of a Decentralized Rainwater Management (DRM) by mitigating the risk of flooding and reducing energy consumption. Seoul Metropolitan Government and several other cities enacted regulations to enforce the installation of a RWH system on the basis of the successful example of Star City project.

18 Note that the aging demographic structures of countries suggest that in the longer term increasing revenues from income taxes is likely to be more difficult than in the past. See also box 4.

19 Intellectual Property Rights serve a number of important roles, including: a) providing incentives for business to invest in risky (research) projects aimed at meeting market needs. Businesses will invest if they have reasonable certainty that they will benefit from their success. This certainty is provided by the ability to protect revenue through IPR; b) giving legal clarity and certainty for technology transfer transactions to take place. IPRs are necessary to identify what technology to transfer. IPRs provide the framework around which legal agreements for technology transfer can be structured; and c) enhancing, in the case of early patents, research and development as well as encouraging technology diffusion patents require the publication of technology, a valuable tool for research and development.

25% of the investment in new physical assets (UNFCCC, 2007). Currently, most of those investments are driven by local development priorities. In developing countries in particular, shifting funding to climate change related investments could increasingly take social and development priorities into account.

Note though that most developing countries might not have a policy base when it comes to private investments, nor do they have any standards or regulations. Without these being established correctly, taxes and charges can actually drive businesses away, especially since there will always be countries that do not require such taxes and charges.

Box 4 – **Population Growth and Climate Change**

In debates on how to adapt to the effects of climate change, is the burgeoning human population an elephant in the room? A projected 9 billion people will have to share a warming planet by 2050, yet the climatic effects of their rising numbers and shifting demographics has received surprisingly little study.

Numbers are exploding in the world's poorest societies, but they have low emissions per head. And in many countries in Europe – where reducing emissions levels is more pressing – populations are declining, so a demography-based climate strategy would be ineffective. In a generation's time, however, when developing countries begin industrializing apace, a large population could be bad news. Add the increase in urbanization as a consequence of an increase in population, and the picture worsens. Slowing the population growth and preventing climate-induced crises are therefore strongly linked; more people on the planet means more people susceptible to natural disasters such as floods, droughts, starvation – some of which are climate change induced. Adaptation to those changing conditions (including migration, if needed) is obviously much more manageable with eight rather than 11 billion people.

Source: Barnett, 2008

The private sector can only participate in large-scale adaptation initiatives on a commercial basis. Image and corporate responsibility are not sufficient. In partnership with the public sector, the barriers to entry can be overcome, and the public sector and those at risk can benefit from the private sector's need to innovate and be efficient. Thus while it has to be recognized that public sector financing alone will not suffice to reduce vulnerability to climate risks, it is important to explore how the private sector can engage in adaptation mechanisms. Governments could start by developing policies to promote private sector investment in adaptive projects and influence development practices through improved awareness, incentives and regulation.

2.3 Insurance

Insurance can be regarded as an adaptation measure, as it transfers risk from localities to regional and global insurance and capital markets. People voluntarily purchase insurance as protection for excessive losses from extreme weather events when the risks are private, and often governments require compulsory forms of insurance or pooling when potential losses are unequally distributed across a population. Setting a price on risk through insurance premiums can also help to identify vulnerable areas, and promote the reduction of risk, by providing incentives such as reduced premiums or reduced deductibles.

The engagement of the private sector that calculates risk, such as the insurance sector, could provide opportunities to gain insight into risks, and ways to either transfer or reduce risks. Moreover, innovative insurance products, such as catastrophe bonds and weather index insurance systems (e.g. providing payments during drought), can play a viable role if tied to efforts aimed at vulnerability reduction.

2.4 Transboundary aspects: International coordination of policies

The impacts of climate change (on water resources) are likely to cross political and geographical boundaries. However, governments are typically short of funds and fund diversion from politically more urgent concerns at home to transnational activities is often politically sensitive. One mechanism to achieve greater funding may be specific earmarked taxes. These could either be levied by governments and earmarked for specific transboundary activities, or levied by the institutions themselves. Direct private sector investment is another option and, for obtaining more secure, longer term financing, Endowment or Trust Funds, which can draw in government, private sector and donor funds. Other financing mechanisms identified by the DIDC (2001) are:

1 **Direct funding from taxes and charges** – Taxes and charges to fund environmental services have become widespread in the past 15 years, both in developed and developing countries. However, levying taxes or charges to support transboundary water management services is far more complicated and, moreover, there are only a handful of transboundary river commissions, for which this would apply.
2 **Private sector investments** – The role of the private sector – domestic or international – has been limited to revenue-generating projects and does not normally deal with public goods investments, such as transboundary water resources management. However, it can be argued that there is a role for the private sector in supporting international and regional public goods. The private sector investment most relevant to transboundary water management has been in hydropower where transboundary concerns frequently exist. Outside of hydropower development, however, there do not appear to be any instances of private sector involvement in transboundary water resources management.
3 **Endowments or trust funds** – Trust funds offer a plausible option for sustaining transboundary river institutions and longer term planning and programming. Because a trust fund must have a board of directors, it is in a strong position to encourage stakeholders to participate in the management of the resource – and the base for stakeholders can be quite wide, embracing NGOs, commercial enterprises and donors. Funds can provide a means for encouraging commercial and private sector participation either in kind, through providing management skills, or as direct financial contributions.
4 **Inter-riparian financing** – A fourth innovative financing mechanism concerns investments, made by some riparians in activities that are implemented in the territory of other countries[20]. A form of permit, or allowance-based contribution for riparians could help such inter-riparian investments. Within a basin, wealthier countries might support investments in poorer countries, although there are few precedents for such an approach. Such a mechanism could be developed within a river basin whereby – if certain investments are needed in both a rich and a poor country – the richer one could make the water-related investment in the poorer one if it was a lower cost option, and realize a higher level of investment than would otherwise be possible. However, even where such international structures are effectively in place there are relatively few examples of inter-riparian financing.

The challenge for (transboundary) water managers is to find out how these mechanisms can be used towards the implementation of adaptation measures to climate change in their international river basin.

In general, costs of implementation of adaptation measures should be borne by each country and governments should make efforts to include budgets and economic incentives in relevant bilateral and multilateral programmes. The poorest countries, that are often also most vulnerable to climate change, should be supported by rich countries in their development towards climate proofing of water management (UNECE/WHO, 2008).

3 Discussion, conclusions and recommendations

According to estimates, at least US$ 50 billion a year is needed to help poor people face the impacts of a changing climate, and far more if emissions are not cut fast and far enough. Investment needs for adap-

20 The closest parallel is perhaps the Clean Development Mechanism (CDM), proposed as a means to encourage reduction in greenhouse gas emissions. However, unlike emissions of greenhouse gases, the impact of water-related activities varies significantly by location. For the emission of GHG the geographical location is immaterial, which makes the procedure conceptually more straightforward. Even so, the implementation of CDM is proving very difficult, given that the means for calculating GHG emission reductions and the implications for sustainable development (a core element of CDM) is yet to be adequately resolved. The position of such a 'trade' in a river basin is considerably more complex and would require some means of measuring equivalence between investments and their impacts on different stretches of a river basin system.

tation will almost certainly increase substantially in the latter decades of the 21st century. These projected needs cannot be met with the instruments inventoried in this analysis alone. In addition, the current global funds are inadequate with respect to their efficiency and fairness and insufficient when it comes to responding to developing countries' needs. The current financing architecture is primarily aimed at filling the gap until adaptation is mainstreamed in the overall development plans. These special mechanisms are for temporary practical purposes (or at least should be). And while promising steps have been made during COP14, an overarching harmonized strategic financial framework is still lacking.

It is therefore crucial to consider tapping into other international and multilateral (environmental) financing sources, as well as other domestic public and private sources. Private funding sources may cover a portion of the costs, and public resources are expected to play a dominant role in all sectors.

The future funding mechanism for adaptation needs to be sufficient, predictable, reliable and obligatory, not allocated through annual budgets, and it needs to be new funding, additional to aid.

In light of the above, several issues warrant attention and will be discussed in the next sections.

3.1 Duplication of activities among new funds

In the area of funding for climate adaptation, there appears to be an obvious overlap - at least in regard to objective - among the proposed new World Bank PPCR under the SCF framework, the Kyoto Protocol's Adaptation Fund and the existing funds to support adaptation by developing countries managed by and under the GEF.

In addition, activities carried out under the GCCA, the Cool Earth Partnership and the Spanish MDG Fund include mainstreaming of climate into development as a means of adaptation[21].This points to a situation of funding overlap and complexity with, as yet, little sign of effective coordination.

The level of harmonization between the different initiatives cannot be determined at this stage. It is clear that initiatives have been donor-driven and talks between various initiatives have followed.

As indicated earlier, there are substantial uncertainties about how much funding the CDM market will generate for the Adaptation Fund, because it will depend on both the size of the market and on prices. The uncertainties associated with the market leaves open the possibility that the Adaptation Fund would seek funds from donors for adaptation as well. If this happens, there will be competition between the Adaptation Fund, the existing GEF-managed adaptation funds and the PPCR or a successor organization that plans to continue the same kind of work for some of the same bilateral donors' support.

The anticipated problem posed by the interaction of the PPCR with existing adaptation funds is not that they are doing the same thing, but that they might compete for funding from the same donors under the same rubric. The question, therefore, is whether donors are prepared to increase their funding for adaptation to support two different approaches or to support the new approach at the expense of the old one.

3.2 Other issues regarding new funds

The confusion about the relationship between adaptation and development is a definitional problem that has hindered not only project design, but also the allocation of funding for adaptation efforts. Among other key concerns raised since the appearance of the new funds is the question of whether the resources provided to the new funds by bilateral donors will be additional to existing ODA commitments[22]. At pre-

21 The GCCA will focus on integrating adaptation plans into poverty reduction and development strategies. It plans to help develop the institutional capacity in LDCs and SIDS for mainstreaming and will focus on climate-proofing EU-funded programmes and projects. The Spanish MDG Fund also plans to support mainstreaming environmental issues in national and sub-national policy, planning and investment frameworks. The Cool Earth Partnership will support the mainstreaming of adaptation measures in the formulation of development plans and support measures that facilitate coordination between sectors.

22 Adaptation and development policies are intertwined: climate change may affect development projects, the community / ecosystem benefiting from development projects may be vulnerable to climate change and the development projects may have effects on the vulner-

sent, it is still unclear how donor agencies will ensure that aid diversion does not occur as a result of these new funds. Climate-related finances will need to be classified and reported separately from developmental aid transfers. Failure to clarify the relationship has meant - and will continue to mean - that funding mechanisms create redundancies or leave gaps in the landscape of critical adaptation and development activities (McGray et al. 2007). See also Box 1.

3.3 Private investment sources

According to the UNFCCC, up to 86% of the global finance flows needed to respond to climate change will come from private investment sources (UNFCCC, 2007). However, in general, private sector engagement still appears weak. This, in turn, may be attributed to the slow development of climate policy frameworks and associated government policies, incentives and regulations. Financial institutions as well as insurers and institutional investors hold pivotal positions in this context. One of the most obvious opportunities[23] lies with investments in adaptation strategies and technologies.

Improvement in, and an optimal combination of mechanisms discussed in this document and new and additional resources, will be needed to mobilize the necessary investment and financial flows to address adaptation to climate change. Financial issues under a future climate change regime with increased effectiveness will require (UNFCCC, 2007):

- Shifts in investment and financial flows to more climate-friendly and climate-proof investments;
- Scaling up international and public capital dedicated to climate-friendly and climate-proof investments;
- Optimizing the allocation of the funds available by spreading the risks across private and public investors, for example by providing incentives for private investment in the early deployment of new technologies.

ability of the community / ecosystem to climate change (Klein et al., 2007).

23 Others lie in the arena of renewable energy, cleaner energy, energy efficiency projects, carbon trading and carbon funds, and risk mitigation instruments.

3.4 Future requirements - financial architecture

With regards to the construction of an overarching financial architecture for climate adaptation funds, the following issues ought to be addressed (Porter et al., 2008):

- The need to scale up efforts and to act with greater urgency;
- The need for policy coherence;
- The need for independent coordination; and
- The need for North-South accord in carrying out measures for global environmental benefit.

Thus far, donors have shown no real interest in any alternative to the revision of the system implicit in the proliferation of new funds. But the needs of the system for coherence and effectiveness demand a serious consideration of a reform of the existing system in preparing for the post-2012 phase of international cooperation on climate change. Note that a serious barrier in implementation could be the absorption (disbursement) capacity of the recipient governments; hence an issue that deserves further research.

A process of harmonization among the new bilateral funds is urgently needed (Porter et al., 2008). As the publicly announced funds are translated from statements of commitment into operational terms that include geographic priorities, funding processes and qualifying criteria, the overlaps, redundancies, competing views and lack of synergies will become increasingly apparent. A harmonization process, initiated sooner rather than later, will deliver benefits to donors and recipients alike and significantly increase their combined benefits for the global environment and human enterprise.

The emergence of new funds and bilateral financing schemes over the past months indicates a realization among donors of the urgency and importance of adaptation measures. However, none of the funds are ear-marked specifically for a sector, let alone the water sector; all of the adaptation funds are linked to environmental agendas and fall under the responsibility of environmental ministries alone, while climate is broader than the environmental agenda and adaptation in the water sector flows across sectors. Similarly, adaptation investments at the national level should be optimized and move from stand-alone projects to sector-wide and programmatic interventions. An example is given in one of the other Perspective Documents on the inclusion of climate change adaptation in the Strategic Environmental Assessments (Slootweg, 2009) where the scope is broadened and now includes the multi-sectoral level. Lastly, because the financing framework for adaptation is at an embryonic stage, the access to these funds as well as criteria (e.g. processes of disbursement, documentation needed and format of projects required) are under development and, as of yet, largely unknown. Finally, the myriad of funds adds to the level of complexity and uncertainty. Nonetheless, all things considered, now is a momentum to ensure that the initiatives complement and build on each other rather than undermine and duplicate each other.

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Perspectives on water and climate change adaptation

Climate adaptation – Aligning water and energy development perspectives

World Water Council
World Water Forum
co-operative programme on water and climate
IUCN
IWA International Water Association
International Hydropower Association IHA

12 Climate adaptation – Aligning water and energy development perspectives

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Climate adaptation – Aligning water and energy development perspectives

Energy and water systems are dynamically linked. The production, provision and transportation of one resource cannot be achieved without making use of the other and there is growing scientific consensus that climate change is affecting the supply and quality of both. Thus, if past efforts have concentrated on mitigating climate change, policy-makers are now becoming increasingly aware that climate adaptation must also be an integral part of thinking and action to provide sustainable water and energy futures. Some observers suggest the future water-energy interface is even more fundamental: 'crack energy and you crack water' (for example: break down seawater to basic hydrogen and oxygen components (1) to provide hydrogen to create a low-carbon energy economy (power, transport and heat), and (2) drive advanced forms of desalination – a limitless source of freshwater).

This paper highlights the interlinkages between the water and energy sectors and points out the effects that climate change has on the provision of energy and water resources as well as providing guidance and inspiration for policy makers. Far from giving a pessimistic outlook on the energy future in the climate change context, it will be shown that there are, in fact, numerous ways to adapt to the challenges.

The first part provides an analysis of the effects of climate change on the water and energy sectors and shows that there remains considerable scope for fuel-switching and financing of adaptation strategies. The second part highlights five key issues which investors and policy-makers should take into consideration in designing their future water and energy strategies. The third part deals with the threat of ideological or maladaptive policy prescriptions, which indicate the imperative to drive action in a more practical, collaborative and informed direction.

1 Context

Since ratification of the UNFCCC (1992), which called for all countries to implement measures to mitigate *and* adapt to climate change, worldwide efforts have largely focused on the mitigation side of the equation (i.e. GHG emission reduction). This was reinforced by the commitments made under the Kyoto Protocol (1995). However, as provided for under Article 4 of the 1992 Convention, attention is increasingly moving to adaptation.[i]

Though the science and thinking that it embodies is constantly evolving, consensus is emerging that strategies for sustainable water and energy development must encompass explicit measures to adapt to climate vulnerability, recognising that:

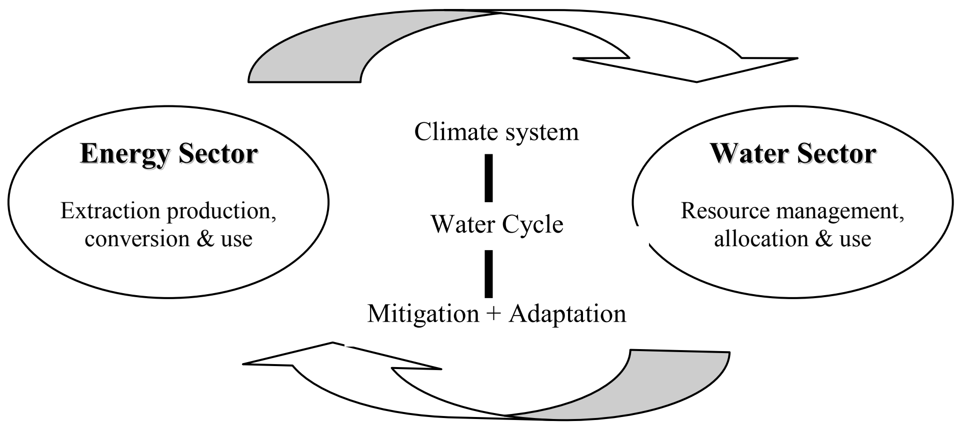
- Pathways to sustainable water and energy futures are intrinsically (1) interdependent, and (2) contextually linked through the water cycle.
- Climate change comes on top of current pressures on resource systems and efforts to protect water resources and expand access to water and energy services.

To coalesce thinking on future adaptation strategies that align water and energy resource development, it is helpful to revisit a few basic principles of the interdependence.

The physical or technical interface

Figure 1 is a highly simplified representation of dynamic physical links between the energy and water sectors, the climate system and the water cycle. The **first aspect** of the physical interface, one which this graphic highlights, is simply that:

- All human-devised energy systems have a water footprint, to one degree or another (e.g. non-consumptive transformation of river flows in the



case of hydropower, consumptive use of water to grow bio-fuel crops).[1]

- The water footprint of energy systems impacts, in varying degrees, the quantity-quality of water available to support other human needs and healthy ecosystems. Scale of course is important (i.e. whether water footprints are localized, manifest at the scale of the river basin, or on international rivers).
- In the other direction, a region's water resource endowment, defined by the features of the regional water cycle, influences the energy options a society can choose and shapes energy needs, in conjunction with other factors.[2]
- The impact of the climate system on the water cycle is complex, dynamic and non-linear - leaving ample scope for informed (and un-informed) debate seeking innovative solutions appropriate to a given setting.

Scientific consensus is that global warming has already, or will in the immediate future, trigger phenomenon like greater hydrological variability (e.g. greater seasonal and year-to-year variation in precipitation, more frequent and prolonged drought spells), and more frequent and intense extreme weather events (e.g. heavy rainfall events and torrential storms) and increased transpiration and evaporation through elevated temperatures.[3]

The effects of global warming of course are expected to vary across of the world. Table 1 is an illustration of the projected first order impacts of climate change on hydrological systems in the Mediterranean region, as an illustration. Table 2 is a simplified typology of how these changes may affect water-energy linkages viewed from an energy system perspective.

At first glance it is apparent that:

- Biomass, still the dominant energy source in global energy statistics (e.g. fuelwood, charcoal, agriculture waste, dung, etc. in the household sector) is vulnerable to adverse effects of water cycle changes on river catchments (combined with elevated temperature) affecting the poorest segments of global society.
- The electric power sector has strong links to the water sector, defined largely in terms of non-consumptive water use and the convergence of issues around the water, energy, and environment security nexus.
- Bio-fuel crops, as a fast-growing consumptive use of water, are potentially in competition with other water uses.

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1 An energy system harnesses and converts primary or secondary energy sources into useful energy (heat, motive power, electricity).

2 For instance, hydropower is part of the electricity supply mix in over 150 countries because of water resource availability. Desalination is a major consumer of oil and gas in the hot, water-stressed climates of the Arabian Peninsula and is planned or developed in water-stressed basins from the Western Cape in South Africa to the Jucar basin (Valencia) in Spain.

3 Many climate scientists agree that the planet is probably in the early stages of more accelerated climate change, whether they agree fully on how to separate the human and natural drivers of climate change. Thus, instead of being a secondary, longer-term consideration, "planned" adaptation requires more immediate attention.

Table 1: Projected First Order Impacts Of CC on Mediterranean Hydrological Systems [ii].

Aspect	Representative Impacts
More variability and extreme weather events:	
	Higher surface runoff with less chance for infiltration
More frequent and intense storms	Increased variability in river flows through the year
Increased number of days of heavy rainfall events and torrential downpours	More frequent and higher floods, especially over northern parts of the Mediterranean basin
More frequent and longer lasting droughts spells	Increased soil erosion from intense storms and sediment
Greater seasonal and year-to-year variation in precipitation, especially in semi-arid areas	in runoff (in conjunction with effects of drought making soils erosion-prone)
	Lower groundwater recharge rates with drought
Wetter winters and dryer summers	
	Shift in season of peak flows in rivers spring to winter,
More precipitation in winter, less in summer, with variability in basins	Runoff in a particular basin may increase or decrease on average, but the seasonal distribution will change
Earlier snowmelt (e.g. shifting to Jan- Mar)	Lower groundwater recharge rates in dry summers
More winter precipitation falling as rain (in mountainous and colder climate regions)	Less efficient rainwater infiltration feeding inland and coastal areas and fragmentation of fresh water aquifers
Hotter summers and heat waves	
	Increased soil evaporation, plant evapo-transpiration
Warming trend greater in summer than in winter	Dryer and more erosion-prone soils
Hotter and longer summers	Acceleration of desertification effects
Heat waves becoming the norm	Multiple impacts such as increasing water needs in human, agriculture and natural systems

- Broadly, the water footprint of energy systems is relevant when the technologies involve significant water use, compete with water for humans or nature, or have significant water quality implications.

In addition, there are numerous, complex second order linkages between water and energy resource systems. These could become significant in the future either in a local context or in terms of becoming more widespread -- like the development of hydropower storage (including pumped-storage) for hybrid wind-hydro systems.

How important are these links to adaptation thinking, and is the public aware of these relationships? Clearly, public perceptions are important to generate political support for investments in adaptation and to take action at different levels – local to global.[4]

Perhaps what marks a broader shift in public perception of adaptation in the last few years are (1) the accelerated pace of 'perception shaping events' that help people understand what it means to live in a changing climate system – hence the need to prepare, and (2) the failure to recognize linkages, like unintended consequences of current climate mitigation measures and adaptation policy.

- Witness media coverage of the effect that diversion of irrigated and rain-fed corn production to bio-fuels (25% of the USA corn crop in 2008) had on staple food prices in the Americas (north, central and south), and how it ignited and lent a human face to the 'water for energy' versus 'water for food' debate.

A **second aspect** of the energy-water technical interface is the unique importance of the energy sector both in climate mitigation and climate adaptation.

[4] Individual consumers must also take action. Public support is needed for the investments that adaptation will entail, including higher costs for water and energy services in many cases.

The essential point is that the synergies between mitigation and adaptation must be fully exploited.

Global production and burning of fossil fuels today account for nearly two-thirds of total anthropogenic GHG emissions. Thermal power generation based on coal, oil and gas alone accounts for up to one third.[iii] Much has been written about the required transition to a low-carbon energy economy, also what it means for global energy security, and how *efficiency* and fuel *substitution* need to be advanced.

There is, for instance, clear evidence of progress in decoupling economic growth from energy intensity in some rich OECD countries. Despite what some voices claim is an impossible task, or that no progress has been made, western society now uses about half the energy per unit of GDP as in the 1970s. Most international energy agencies predict that energy intensity per unit GDP (and per capita) in post-industrial societies will continue to fall, while rising rapidly in the developing world – in line with trends over the last few decades.

Table 2: Simplified typology of energy, water and water cycle linkages – first order.

Energy System	Energy System Component	Water Sector Linkage	Climate Change influence On Water Cycle
Electric Power Sector (Focusing on the grid system)	Hydropower	Factors into IWRM as a non-consumptive water use; evaporative loss from large reservoirs may be an issue; Water storage (multi-purpose) and river flow transformations Watershed conditions (e.g. erosion & sedimentation) Impacts on efforts to maintain healthy ecosystems	Increased variability in river flows through the year: +ve when connected to water storage for multiple needs (water + energy security) -ve when connected to prolonged drought leading to power generation restrictions
	Thermal power (e.g. power stations dependent on fresh water cooling)	Non-consumptive water use Allocation of river flow Potential for acid rain & water quality impacts on lakes	Reduction in river flows / water availability May be a concern in heavily modified river basins; thermal plume
	Nuclear Power (plant depending on fresh water cooling)	Non-consumptive water use Allocation of river flow	Reduction in river flows / water availability May be a concern in heavily modified river basins; thermal plume
	Coal Mining	Potential for localized water pollution	Surface & groundwater systems under more stress
Household Energy Sector	Fuelwood (household cooking, animal husbandry, etc.) Agriculture waste	Rain-fed forests Forests under competition for other land uses (pressure to over harvest)	Sub-catchments under multiple stresses, reduced fuelwood yields Hydraulic functions of forest ecosystems reduced
Transport Sector	Biofuel crops	Rain-fed (water table) and irrigated crops Competition for consumptive	Changes resulting in water scarcity and multiple pressures on water for bio-fuel crops

The fuel-switching or carbon substitution opportunities in energy systems relate to the three main forms of useful energy, namely: heating, motive power and electricity.[iv] Table 3 illustrates the carbon and non-carbon alternatives for each form of energy that the public is now increasingly familiar with. Again, while progress has been made, global fossil fuel use is still projected to double between 2004 and 2030.[5]

5 Source: http://www.eia.doe.gov/oiaf/ieo/index.html

Table 3: Fuel Switching.

		Dominant Carbon Energy Sources	Non-Carbon Substitution
Heating	(i.e. space heating for shelters, homes and buildings, cooking and a wide variety of traditional sector agriculture needs, industrial process heating, etc.)	Gas, oil Fuelwood, charcoal [v]	District heating from non-carbon sources Passive and active solar Electricity generated from non-fossil sources[vi] Heat pumps, etc.
Motive power	(i.e. engines and turbines powering all modes of transport, and motorized activities such as farming, fishing and construction)	Petroleum products (diesel, petrol, kerosene)	Electric / hybrid mobile systems or all electric (battery systems) charged by non-fossil electric generation Bio-fuels Hydrogen
Electricity generation	(i.e. generation from households, to isolated systems to utility scales)	coal gas oil	Nuclear Hydro Other renewable (wind, tidal, solar PV or towers, wave, ocean, etc.)

Clearly, there is enormous pressure today to increase the share of electricity generation from non-fossil sources, a departure from the 'dash to gas' in the 1990s. The evidence is provided in the trends underway in the electric power sector in OECD and other countries since 2000. These include revival of attention to: (1) supply and demand side efficiency and conservation programs, (2) nuclear power[6], (3) hydropower, and (4) a variety of large and small-scale alternatives including wind, solar, wave, tidal and geothermal to meet new national and regional policies. Minimum portfolio standards like the EU for renewable generation target of 20% in Member States by 2020 are a prime example.

While curbing GHG emissions is an important factor, other motivations to move off-oil brought into focus by the recent turmoil in international oil markets include regional energy security concerns, and the impacts of rising costs of imported fuel for debt sustainability in developing countries as well as prices for consumers in western societies.[7]

A **third aspect** of the energy-water physical interface is the uneven distribution of water and energy resources and rates of consumption across the world and within countries, and how this affects strategies in the global fight against poverty.

For many developing countries, biomass accounts for 85%–90% of total energy supply, mostly traditional forms for household cooking, heating and rural livelihoods. It is not difficult to see how adverse changes in the water cycle can exacerbate the price and availability of this source. Over 2.4 billion people today rely on various forms of traditional biomass. Over 1.5 billion people lack access to electricity. Generally, poor access to traditional and

6 Issues that could slow the expansion of nuclear power in the future include plant safety, radioactive waste disposal, and the proliferation of nuclear weapons, which continue to raise public concerns in many countries and may hinder the development of new nuclear power reactors (IEA, 2008).

7 The motivations are many, including: expanding access to energy services to support the growth and equity targets in the United Nation's Millennium Development Goals; addressing regional energy security concerns and rising costs of imported fuel, which has serious implications for debt sustainability in many developing countries; and to mitigate dangerous anthropogenic interference with the global climate system

modern energy services negatively affects prospects for realizing equitable and sustainable development in line with the Millennium Development Goals.[vii]

The United Nation's coordinating body for the energy sector, UN-Energy, states that 'the world faces twin energy-related threats: that of not having adequate and secure supplies of energy at affordable prices, and that of environmental harm caused by consuming too much of it.'[8]

The governance and resource management interface

Ongoing governance reforms around resources and restructuring of the energy and water sectors since the early 1990s provide a dynamic backdrop for evolving climate adaptation strategies linking these sectors. As the reforms move from policy to practice (like IWRM in the water sector, and increasing private investment in the power sector) new opportunities and challenges are created for climate adaptation.[viii]

Box 1 illustrates how such reforms strengthen connections between the power and water sectors. It is important to consider that adaptation strategies cannot be developed in isolation of the wider sector reforms.

In many countries there are divergent views on the infrastructure strategies that should emerge from global water and energy reform processes, including how to balance environmental and social values, share benefits and public versus private sector roles.[ix] Many of these issues are prominent in the water divide. While polarized positions often reflect divergent philosophical approaches to development, one area of common ground is to view adaptation planning in the context of the IWRM framework for water resource planning (e.g. land-water-environment interactions).[9] And within that framework, to consider the water footprint of energy systems and technologies, as well as looking for synergy with water security, environment and energy security strategies.

The finance interface

Money - especially the lack of it - remains a key factor in adaptation. The International Energy Agency (IEA) World Energy Outlook Report (2006) produced a Reference Cost Scenario for the period 2005-2030, in which current laws and policies of countries remain unchanged throughout this period. Thus, the IEA projected a cumulative investment of 20.2 trillion US$ in the energy sector during this time, of which the largest amount, $11.3 trillion US$ (about 56%) would be spent for electricity sector investments (see Figure 2). World net electricity generation nearly doubles in this timeframe.[10]

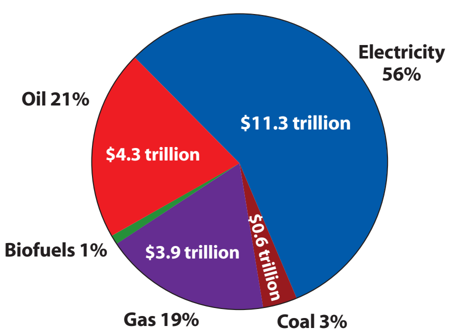

Figure 2: Cumulative Energy Sector Investment 2005-2030 IEA Reference Scenario. Source: IEA World Energy Outlook 2006

Box 2: Projected water investment by region. (2005-2030) $US trillion

Asia/Oceania	9.0
South/Latin America	5.0
Europe	4.5
US/Canada	3.6
Africa	0.2
Middle East	0.2

8 Energy in the United Nations: An Overview of UN-Energy Activities, 2006

9 Responses to climate change would also be integrated with national economic, social and regional development planning, and harmonized with other resource and environmental management activities at both policy and practical levels.

10 It suggests that global hydropower capacity could reach 1.431 GW in 2030, compared with 851 GW in 2005, equivalent to an average annual increment of about 23 GW capacity. As a point of reference, the International Hydropower Association (IHA) estimates 18.5 GW of hydropower was added globally in 2000.

The IEA's Alternative Policy Scenario for the same period considers how policies driven by concerns for energy security, energy efficiency and the environment, that are under discussion but not yet adopted, could curb the large projected growth in carbon-based energy demand. The scenario features accelerated investments in efficiency, non-carbon power generation and petroleum product substitution in other sectors. While predicting that the infrastructure transition will cost considerably more than the Reference Scenario, the carbon footprint and annual fuel costs would be less, and thus the global economy would become more resilient to international oil price shocks.[11]

Projected water sector investments are equally staggering. Up to 22.5 $US trillion will be spent to create and maintain water supply and sanitation infrastructure (see Box 2 for regional estimates).[x] Other observers suggest even more investment is needed to meet the needs of the 1.2 billion people worldwide who lack access to potable freshwater, and of the 2.6 billion who do not have adequate sanitation facilities. Furthermore population growth will have to be considered.

The relevant points for the energy-water finance interface are:

- Global society needs to rethink how developing countries access the international financing system to invest in water reforms, and adaptation as part of that effort.
- Governments must play a stronger role in facilitating investment, when societies choose more capital-intensive options implicit in moving to a low-carbon energy economy and reducing vulnerability to climate change.
- Clearly there will be competition for available investment resources, thus the many synergies between investment in sustainable water and energy systems need to be exploited to the maximum potential.

2: Key issues

With regards to the interconnection between the water and energy sectors, future actions will have to combine climate change mitigation with climate change adaptation. The following five key issues are offered to inspire thinking on the mechanics of both. Some of these concepts are already found in the climate debate, but deserve emphasis when revisiting the theme of Global Change & Risk Management.

Issue 1: The imperative to reconcile demand and supply to provide climate 'headroom'.

Patterns of water and energy demand must be reconciled with resource availability to take stress off water and energy resource systems already under multiple pressures. This creates room to manoeuvre and enhances physical capacity to adapt. As a risk management strategy, it gives societies more time to cope with rapid or unforeseen climate change that will otherwise cause more severe social, economic and environmental dislocation.

Box 1: Power sector and water sector reforms are linked in many countries	
Power sector reform: much has been written about the major transitions in power sector restructuring, where governments are moving to play more of an enabling and regulating role. The shift toward competitive generation markets in China, much of Asia and Central and Eastern Europe illustrate the scope of change. In the 1990s this led to a shift to fossil generation, gas where available. More recently the priority is to maximize indigenous energy resources, including hydropower. Regional power pools and energy grids also change the economy of scale in power generation and have increased attention to regional water resource developments with hydro.	**Water sector reform:** Similarly, the global transitions in water governance and resource management seek to place decisions about the development and management of water infrastructure and energy projects with large water footprints into a river basin context, applying integrated water resource management principles. One illustration is the European Union (EU) Water Framework Directive (2000) to be operational in all EU countries by 2015. Through the European Water Initiative (EUWI) the EU also aims to align its technical and financial support to developing countries in water infrastructure to WFD principles.

Box 3: Demand-Supply Reconciliation in South Africa

In its post-1994 democratic transition, South Africa introduced progressive water legislation that received international acclaim. A key aspect of the new water resource strategy is reconciling demand and supply as the basis for all planning. In a first test of the laws, approval of the Berg Water Project (a dam diversion scheme) giving an 18% supply increment was contingent on parallel implementation of water demand management programs to reduce projected water demand by 20%.

Opportunity: This imperative applies equally to the management and wise use of water and energy resources. Fundamentally, climate stresses come on top of resource systems already under multiple-stresses when demand exceeds available supply.

While there are local, regional and international dimensions to this issue, the river basin is key as the hydraulic unit to reconcile water demand-supply under IWRM approaches. Similarly, demand-side management and supply-side efficiency are proven to be achievable in the power sector, without compromising growth and human advancement – given the appropriate regulatory framework and market-based incentives. Box 3 refers to demand-supply reconciliation imperative built into South Africa's water legislation.

Strategy elements: In the context of the energy-water interface, adaptation strategies broadly need to encompass:

- mandating demand-supply reconciliation studies when formulating catchment management strategies within the IWRM framework, especially in water-stressed basins;
- introducing statutory requirements for water and energy supply utilities to prepare and implement demand-side management programs with specific targets and timeframes, otherwise another entity supervised by a regulatory body with an explicit demand-supply mandate;
- evaluating the sensitivity of demand-supply balances against scenarios for water cycle change in partnership with the science community; and
- ensuring existing demand-side management programme are funded and benchmarked against successful models that as yet are too few and far between.

Constraints: The chequered global history and total failure of many past attempts at demand-side management in the water sector and electricity sectors will give policy-makers some concern. But it is essential to get past that hurdle. Reasons for past failures need to be clearly understood and tackled; among these (1) lack of pricing signals and communication strategies to influence consumption behaviour; (2) failure to invest in the infrastructure and markets and the supply chain to make energy and water saving devices available; (3) well-known contradictions in promoting demand-side management through supply-side utilities that have incentive structures to optimise sales; and fundamentally (4) regulatory failure.

Issue 2: The electrification imperative in low-carbon energy systems.

Expansion of electricity services is implicit in a low-carbon energy future and therefore in mitigating climate change. Electricity is unique in offering flexibility in terms of: (1) energy source (generation by carbon or low-carbon energy resources), (2) scale of generation, (3) application (e.g. useful energy for electrical services and motive power), and (4) scope for end-use efficiency improvement.

Opportunity: While traditional biomass energy sources (seen as carbon neutral) still dominate the global energy picture, electricity is the fastest growing modern energy form in percentage terms. There are many reasons. Electricity is unique in terms of its flexibility and absence of pollution at the point-of-use in homes, factories, offices and farms in all regions of the world.[12] Few informed observers question whether the proportional share of electricity in the energy economy will continue to increase. As noted in Figure 2 previously, the electric power sector

[12] Access to electricity permits societies to urbanize, modernise, improve productivity through savings in time and labour, and provides a host of social benefits such as modern health care and education.

is expected to represent 56% of total global energy investment.

Moreover, if a 60% reduction in global GHG emissions is contemplated by 2050, significant penetration of electricity in the transport sector, in particular, is essential (along with bio-fuel and eventually hydrogen technology still in early stages of commercial development – and recognizing processes to produce hydrogen are electricity intensive).[xi]

In the near term, advancing the availability of electric hybrid vehicle-drives coming onto the market and pure electric vehicles (as electric battery storage advances) and certainly for public transport and rail will play a large role. Such developments would see a quantum increase in global electricity generation.[xii] Displacing fossil fuel use in road transport with electric sources (rail and road transport) is part of the EU strategy to combat emissions in the transport sector as noted in Box 4.

Box 4: Transport and electricity

Transportation now accounts for 60% of global petroleum product use. Transport accounts for some 71% of all oil consumption in the EU. Road transport uses 60% of all oil.

EU Transport policy is closely intertwined with energy policy, on the basis of common objectives: lowering CO2 emissions and reducing EU import dependency on fossil fuels by improving fuel efficiency on the vehicle side and gradually replacing oil by other fuels be it bio-fuels, natural gas, hydrogen, electricity or others on the energy side.

Source: European Commission Sustainable Mobility on our Continent (2004-2007)

Similarly, advanced desalination technology (e.g. membrane-reverse osmosis) is expected to expand freshwater supply to coastal and near coastal areas - where much of the world's population resides. Indeed if one looks at a map of projected water-scarcity it is clear what the future holds for desalination. The desalination processes are also electricity-intensive, as are the associated water pumping needs.

On the horizon is the much heralded revolution in distributed power for both stand-alone and grid feeding roles.[xiii] A range of non-conventional and renewable technologies would play an ever-bigger role in extending energy services locally via electricity.

Strategy elements: Consensus must first be reached on the role of electricity in driving toward a low-carbon energy economy, i.e. specifically policies to accelerate electrification in major sectors of the economy as a substitute for fossil fuel use – and as the next step, work on the water footprint nexus.

Generic issues in advancing these strategies include:

- providing a clear regulatory framework for non-carbon generation in the electric power sector: e.g. renewable energy portfolios; priority grid access for renewable energy sources; long-term payment for renewable sources to make them profitable to install and operate; carbon tax, other tax and fiscal incentives, etc.;
- providing industry, markets and the research community with the clear regulatory signals and incentives to: (1) accelerate non-carbon generation in grid and isolated systems, (2) clarify policies to encourage future expansion of grid and distributed power systems, and (3) set out policies and targets to maximize electrical penetration in other sectors, especially the transport sector;
- properly accounting for the water footprint of the energy systems (see Issue 4) and climate proofing (previous Issue 1); and
- aligning research and development budgets, tax and incentives to achieve these objectives.

Constraints: Many voices still ridicule the idea of continued or even accelerated electrification of the global energy economy. Concerns are expressed that it means a larger role for nuclear power, will lead to token levels of investment in other renewable generation options, or will required new technologies like carbon capture from coal power stations. These views are all part of the current debate around energy policy in the United Kingdom, for example. The UK government itself has couched its announcement of a major nuclear re-build around climate and energy security concerns – something virtually unthinkable a decade ago.[13]

Equally, developing countries seeking to diversify and modernize their economies continue to expand electricity generation (still relying heavily on conventional thermal generation) limited mainly by financial constraints, as shown in Energy Outlook Reports produced by international energy agencies.[xiv] Perhaps the core challenge going forward on this aspect is to create consensus on what a low-carbon energy economy means nationally and regionally in terms of the role of electricity and refocus efforts to enhance sustainability of the generation options selected and the adaptation linkages.

Issue 3: 'Climate proof' water, energy and ecosystem services.

Adaptation strategies need to explicitly identify ways to 'climate proof' water, energy and ecosystem services on which human societies and a healthy environment depend.

Opportunity: Climate change will cause changes in the water and energy supply structures of many countries and regions. While some countries will face water scarcity, others will have to manage the negative effects of a water surplus. Planners need to ensure systems and infrastructure for water and energy service provision are robust over a plausible range of climate-induced changes in the water cycle. This notion must extend to aquatic and terrestrial ecosystem services sensitive to changes in water quantity and quality. It includes the hydraulic functions and services that healthy forest and wetland ecosystems otherwise provide, like improved infiltration in catchments to replenish ground water storage, water purification, flood buffering services, and minimization of soil erosion and river sedimentation.[14]

Box 5: Climate proofing wetland systems

Wetlands systems downstream of dams and water abstractions can be climate proofed by introducing sustainable flow assessment and provision measures that recognize different flows required in normal hydrology years and in drought periods to maintain critical functionality of ecosystems.

Protection of water quality is an obvious concern, as is protecting ecosystems (e.g. how much fragmentation or degradation can ecosystems tolerate before they lose critical functionality, as noted in Box 5).

In the electric power sector, the quality and reliability of bulk power supply hinges on having a complimentary mix of energy generators with performance characteristics to ensure grid systems remain stable and responsive to demand. Most segments of the economy are highly vulnerable to power outages and interruption.

Unfortunately it is not as simple as 'plug and play'. This entails considering performance aspects of different generation options from a system perspective and ancillary services (e.g. ability to follow load, quick start, peaking, VARs, outage rates, intermittency, etc.) and taking into account the high variability of most forms of renewable energy generation.[15] Equally, it is important to ensure traditional biomass supply sources and systems (fuelwood, agriculture waste, etc.) are climate proofed in the sense that the adaptation strategies for forest, agriculture and land management are fully integrated.[xv]

Strategy elements: Again there are many ways to climate proof water, energy and ecosystem services. The strategy and emphasis will be unique to a particular river basin context. Generic adaptation strategies may include:

- adopting climate proofing as a specific objective in energy and water sector policy and strategic

13 Along-side a large increment funding for building energy efficiency, a mandatory bio-fuel addition to petrol (gasoline) sold in Germany, and expansion of renewable electric generation.

14 Also providing food, fodder, biodiversity habitat, recreation and a variety of services.

15 E.g. because of dominant performance characteristics an electric power system based entirely on wind (intermittent) or nuclear (steady, base load) would either be hugely and unnecessarily expensive or unreliable.

planning processes (like SEAs) and in key project-level assessment tools -- planning will have to work with impact assessments taking into account environmental, social and economic aspects;
- incorporating strategies to reduce risks associated with hydrological variability -- this will involve catchment management strategies, infrastructure strategies (both design and operation aspects), drought as well as flood management;
- ensuring that criteria for the reliability of energy systems and ancillary services are factored into electricity sector regulations to advance non-fossil generation and grid connection, and to evolve similar reliability standards appropriate for water service provision – contextually, involving end users in defining levels of service;
- ensuring that environmental flow assessment and provision (taking into account surface as well as groundwater components and environmental as well as social aspects) are adopted in planning energy systems that have a significant water footprint, coupled with ensuring outcomes are appropriately linked to river basin planning and water allocation procedures; and
- ensuring that ecosystem functionality is factored into drought management strategies for surface and ground water systems and water allocation policies.[16]

Constraints: A major constraint is weakness, or the outright lack of integrated planning and management around which to base climate-proofing measures – despite the fact that legislation may (and frequently does) prescribe integrated approaches. Fundamentally climate proofing of services needs multi-stakeholder processes to advocate adaptation thinking within existing planning and water allocation systems.

[16] For informed decisions on climate proofing ecosystem services, for example, there needs to be better understanding of the resilience of ecosystems and their ability to recover after drought episodes, and the functionality of ecosystems in ephemeral rivers. For the electric power sector, much better public communication on technical attributes of the various non-carbon generation options and the unique role they play in the stable operation of modern power grids is essential to inform regulatory policy (e.g. base, peak, or intermittent/variable supply; fuel or capacity displacement, ancillary services, etc.).

Issue 4: Understand the water footprint of low carbon energy systems and reconcile water storage holistically, in terms of water, environment and energy security.

Energy systems with low carbon and low water footprints need to be advanced. A distinction must be made between a water footprint characterized by consumptive and non-consumptive water use to avoid unhelpful confusion of issues. Centrally, decisions about surface water storage (i.e. dams) must be holistically reconciled, balancing water, environment and energy security concerns in the river basin context.

Opportunity: There is broad consensus on the need to move towards a low-carbon energy economy.[17] Lately, much consideration has also been given to the water footprint of human activities. Presently no form of energy can be demonized and outlawed. It is important to distinguish between water-consumptive and non-consumptive energy systems. Furthermore, these have to be considered in their context by policy makers.

For example, bio-fuel crops have been criticized for their high water footprint. This is critical if they are grown on fertile, irrigated land. However, no significant adverse impacts on the water table or competition with human or environment needs can be stated for rain-fed bio-fuel crops grown on lands too marginal for other forms of agriculture.

Similarly, the essentially non-water-consumptive nature of hydropower has been diminished by the argument that in some cases reservoirs lose considerable amounts of water due to evaporation.[xvi] All reservoirs (whether for hydropower, or irrigation and water supply) have evaporative losses. Evaporation rates, however, vary considerably according to the surrounding climatic conditions. Logically, higher ambient temperature results in higher evaporation, therefore reservoirs in cooler climates state only neg-

[17] From the analytical perspective, a life-cycle or “cradle to grave” analysis, all technologies presently involve some use of fossil fuels. From the policy perspective, non-carbon supply substitutes exist and need to be encouraged, not only in OECD economies but also in non-OECD transitional and developing countries.

ligible losses. In tropical regions, on the other hand, frequent rainfall often counters evaporation losses. The real loss is only determined by the net difference between water losses in the river basin before and after impoundment. It is inappropriate to account as a 'loss' evaporation from a body of water that has been stored (and therefore would not have been available otherwise) for critical water and energy services during water scarce periods.

Two related issues underline the growing importance of the water storage issue in climate change mitigation and adaptation thinking. The first is the ongoing debate around the net change a reservoir may have on the natural GHG emissions in a river basin, particularly in warmer tropical settings. The emissions are due to aerobic decomposition of biomass in river water (producing CO_2) and anaerobic decomposition of biomass, which is more potent (producing CH_4).[18]

Box 6: The water storage nexus

"The reservoirs of the world are losing their capacity to hold water as erosion brings silt down to settle in behind dams, the chief of the United Nations Environment Programme (UNEP) warned today. Speaking to the Bonn International Conference on Freshwater, UNEP Executive Director Klaus Toepfer said that siltation is reducing the capacity of the world's reservoirs to hold water, a result that is hastened by the clearcutting of forests.

The issue of dams can arouse strong passions on both sides," Toepfer told the delegates. "Some people are very much in favor of building dams and others are vehemently against. However, what we are talking about here is the state and fate of the existing stock of dams and reservoirs on whose waters billions of people depend for not only irrigation and drinking water, but also for industry and the production of hydroelectricity."

The second aspect concerns the threat of accelerated loss of the world's existing capacity for water storage – and consequently the loss of climate 'headroom', as noted earlier. This loss of existing surface water storage (variously considered to be 1% to 3% per annum) is due to a host of factors accelerating soil erosion in the world's catchments, which make adaptation even more urgent and difficult.[19]

Despite attempts by UNEP to publicly raise the profile and human development implications of this issue from 2001 (see Box 6),[xvii] it appears to have dropped off policy-makers radar screens. Global warming will, in all likelihood, exacerbate the rate of storage loss from existing reservoirs – in watershed specific ways.[20]

This ongoing and real phenomenon cuts both ways in the debate about adaptation, as it depends on the basin context as to whether replacing lost storage is prudent or not. Certainly, if lost storage cannot be restored or replaced, it can have profound implications for many water-stressed basins around the world.[xviii]

Strategy elements: Among generic steps to connect these considerations to thinking about adaptation are:

- Reflect both the analysis of water and carbon footprints of energy systems in strategic studies linking water, environment and energy security – but in doing so, clearly distinguish between consumptive and non-consumptive uses of water.
- Establish processes to gather the best available information at the international level to help reconcile analytical differences that impede clarity and consensus reaching around key questions about:
  i –calculating net carbon emissions from water reservoirs, particularly those in tropical settings;
  ii – viewing evaporation from reservoirs (for all purposes) in the perspective that water cannot be seen to be 'lost' through evaporation if the body of water would not have existed prior to impoundment; and
  iii – sharing knowledge on the dynamics of reservoir sedimentation and sediment management and control measures.
- Approach decisions about water storage in an integrated way from combined water, environment and energy security perspectives in multi-

18 This issue is currently under investigation through an international project hosted by the International Hydrological Programme of UNESCO and the International Hydropower Association.

19 Loss of live storage capacity in small to large dams globally

20 E.g. a combination of dryer and more erosion-prone soils due to elevated temperatures, effects of fire removing vegetation cover and intense rainfall events resulting in higher rates erosion and sediment in runoff.

stakeholder processes, within an IWRM framework.

- Plan regional promotion of bio-fuel crops taking into account consumptive impacts on water and agriculture and opportunities for cultivation on marginal land.

Constraints: Perhaps the most challenging issue is establishing 'sufficient consensus' on the meaning of the water footprint of energy systems, and moving objective, evidence-based analysis into debate on policy implications. At the international level it is important to offer ways to bridge the divide on these issues, at minimum, to offer an objective framework for analysis. At the country-level, genuine multi-stakeholder dialogue processes will help cut through confusion and remove barriers to action.

Box 7: The possible effect of carbon-capture on acid rain

The focus on climate change mitigation and on greenhouse gas reduction should not be made without consideration of relating effects. While efforts have been made to reduce the CO2 emissions of fossil-fuel plants by capturing the carbon, this approach may not result in fewer overall emissions. A recent study of the International Journal of Greenhouse Gas Control suggests that emissions of SO2, NH3 and NHx may not decline and even increase during the process. These gases are known to be the causes for acid rain and, from the water sector perspective, are very problematic for the environment and agricultural production. The processes to capture SO2, however, are very different from those of capturing CO2 and are not widely integrated in power plants with CCS. Furthermore, NH3, which can have quite important impacts on acidification, is currently considered negligible and no efforts or restrictions indicate the emissions of NH3 will be reduced in the future.

Issue 5: Build appropriate capacity: knowledge, technology, industry and finance.

Appropriate capacity at national, basin and local levels is needed to make adaptation thinking an integral part of water and energy sector reform processes and to implement agreed upon adaptation strategies and measures.

Opportunity: A guiding principle is that adaptation measures must be practical and involve government, civil society and private sector actors as well as community-based organizations that can take local action. For example, in the water sector, rather than creating new institutional structures for adaptation, it is important to use and strengthen existing institutional structures to the maximum extent. Practical measures that strengthen entities created for IWRM water resource management in the basin can be pursued; and likewise for demand-side reductions can be pursued by reforming water service organizations closely supervised by regulatory authorities.

In the power sector, institutional capacity to implement energy options would rely on strengthening existing power-system institutional capacities and regulatory capacities. The actual public, private or community-based entities that deliver (plan, build and operate) new and renewable energy systems of course would depend on the technologies and the scales. Industry and the private sector would have to gear up in various ways with know-how (knowledge and technology). Much has been written on what this means in terms of job creation globally and 'green' jobs for sustainable development.

On knowledge sharing, it is important to bring together existing water and energy networks and newly-forming, climate change adaptation networks for information and technology exchange. Regional networks and north-south networks are important. Knowledge sharing networks involving arid and semi-arid countries are an example of networks that can be reinforced to deal with climate adaptation issues as a matter of priority. They are high-risk in the sense of being water-stressed and share many challenges.

Finance capacity of course underpins capacity to adapt and is a major factor in what measures are realistic in a given setting. Some of the issues include:

- Many of the required major structural adaptation investments are well beyond the current financial capacity for developing countries to pursue on their own.
- Financing measures unique to adaptation should be incorporated within existing sector investments, otherwise they may be left out.
- Public and private financing will have to play a role due to the sheer scale of investment needed.
- A critical issue is making better strategic use of international public finance in the mitigation and adaptation areas.
- Both top down and bottom-up thinking on finance is needed to harness the private sector and

- the creativity and ingenuity in the entrepreneurs in all settings.

It is not just about government investment. It is also about mobilizing community and private investment and providing the appropriate incentives for collaboration.

One logical place to start is the Clean Development Mechanism (CDM) which focuses on mitigation: (1) rethink the approach to project eligibility to reinforce sustainable performance – social, environmental and economic performance; (2) whether an equivalent mechanism on adaptation is needed is a moot point, but otherwise adaptation needs to be an explicit, increasing element in north-south financial cooperation in the water and energy sectors.

Strategy elements: Among those measures generic relevance may include:

- start with 'least regret' adaptation measures.[21] Low cost actions today that can have a large impact in the future – but would be costly to introduce later;
- earmark capacity building funds, but give the mandate to existing institutional structures with clear accountabilities;
- establish knowledge development and dissemination networks (appropriately) i.e. build adaptation themes into existing network co-operation;
- use concise, objective analysis and avoid rhetorical confusion to help improve access to financing for adaptation interventions.

Constraints: Various constraints exist, for example: time, money, lack of appreciation of the need, lack of any sense of urgency, paralysis because of the perception of complexity and lack of champions.

3 Observations – on the way forward

A theme this paper advances is that adaptation planning is a discrete activity which adds tremendous value by mobilizing consensus on adaptation. But to be truly sustainable, adaptation must not be seen in isolation, rather as an integral element of evolving water and energy resource planning and management practice.

It is also important not to underestimate the challenges climate-induced changes in the water cycle pose. A case in point is the Murray-Darling river basin, widely acknowledged to be one of the best-managed watersheds in the world in a drought prone area. Despite many highly sophisticated water allocation measures, trading procedures, statutory allocations for nature, and advanced multi-level regional planning agreements the effects of the recent prolonged drought still led to the basin drying out. This resulted in devastated ecosystems, adverse impacts on the local economy and reduced energy production.

Clearly, adaptation requires long-term significant change in how societies manage and use water and energy. Beyond these concerns, it is increasingly clear that:

- It is best to avoid narrow, ideological policy prescriptions (especially those that limit scope for action and developing countries access to international finance).
- The energy sector is uniquely central in framing local to global strategies for mitigation *and* adaptation. Synergies need to be captured if a 60% reduction in global GHG emission by 2050 have any chance and at the same time make genuine progress in adaptation.
- All countries need to rethink and 're-tool' as needed, to adjust their water resource and energy systems, overcome maladaptive land use practices in catchments and seek to optimise hydrological services of natural ecosystems.
- National Adaptation Programmes of Action (NAPAs) long required under the UNFCCC need to be advanced.[xix] Reasons for the lack of progress in developing NAPAs (or similar instruments for the water and energy sectors) must be addressed, whether it is due to a lack of cooperation, no sense of urgency, or unavailability of funds.

Central to this is investment is rethinking and redefining of international financing mechanisms to

[21] Adaptation measures that would improve the performance of water resource or energy systems in today's climate conditions, whose further delay could increase vulnerability, or lead to increased costs at a later stage, sometimes referred to as "win-win", or "least-regret" measures. They would be effective and sensible as resource management measures and have high social and economic returns, even in the absence of significant climate change effects (e.g. climate-sensitive land zoning, specific policies not locating strategic energy infrastructure in vulnerable flood plains).

promote investments in energy systems and energy technologies connected to climate change mitigation and adaptation. Instruments like the CDM need eligibility criteria that are not narrow, but more widely cast and designed, for example, to:

- promote knowledge creation, where there is scientific uncertainty or lack of developing country experience in mitigation or adaptation measures;[xx]
- finance enhancements to sustainability dimensions of projects (social, environment and economic performance); and
- reduce transaction costs, minimize uncertainty in eligibility, and be more open and transparent and subject to formal appeal processes.

What is needed is the appetite and means for the 'bolder policy solutions' and thinking outside ideological positions. Facing the water divide as a call for collaboration and not allowing it to remain an excuse for in-action.

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[i] The UNFCCC/IPCC stress that cost-effective strategies and measures for adaptation must be identified and implemented nationally and locally, engaging policy-makers and resource managers at all levels of government, and involving water users, the private sector, civil society and non-government organizations. This would be best achieved in overlapping "top down" and "bottom up" processes. The strategies and measures need to take into account important social and economic implications, and would be implemented on a stage-by-stage basis, in a prioritized way.

[ii] Source: L.Haas, WATER, WETLANDS AND CLIMATE CHANGE Building Linkages for their Integrated Management "Mediterranean Water Resources". Based on various primary sources: IPPC, Scientific Blue Plan Report, Planning and Climate Change Adaptation, for IUCN, 2002.

[iii] IPCC Assessments. Thermal is the fastest growing electricity generation source (in quantity terms) globally. Grid-scale wind generation is growing the fastest in percentage terms, but from a very low base.

[iv] Primary energy includes non-renewable energy and renewable energy. Secondary energy is an energy form, like electricity, which has been transformed from one primary energy form to another.

[v] Biomass is considered to be carbon neutral (IPCCC) though it has a strong water footprint. Biomass fuels can substitute more-or-less directly for fossil fuels in the existing energy supply infrastructures without contributing to the build-up of greenhouse gases in the atmosphere.

[vi] Space heating with electricity however, is not encouraged in most jurisdictions because it is: (1) expensive, and (2) violates the laws of thermodynamic efficiency when generated by fossil sources.

[vii] http://www.unesco.org/water/wwap/facts_figures/basic_needs.shtml

[viii] Lowering the walls between public and private investment has embodied a shift in the rights, risks and responsibilities of all actors in government, civil society and the private sector – but not without problems or controversy.

[ix] The World Commission On Dams (2000) in its Electricity Options Thematic Paper noted that there are divergent viewpoints on:

- national policies, strategic choices and national resource endowments;
- the ability to find common ground on a series of controversial social equity and ecological issues surrounding dam site selection, planning, construction and operation;
- the outlook for competing demand side management and electricity supply options including the emergent renewable sources;
- the evolving context of power sector market reform and regulation, and sources and the availability, structure and cost of project financing;
- the extent of stakeholder participation in planning and decision making; and emerging goals for sustainable development and its implementation, especially with relation to widening access to modern energy services in poorer countries and reducing the risks of environmental degradation at local, regional and global levels.

In particular, there are divergent viewpoints on:

- the impacts of market reform in the electricity sector including effects on investment choices and the potential loss of public benefits, including investments in energy efficiency, renewable energy technologies and widened access to electricity services for the poor;
- whether hydropower in all circumstances should be classed as a renewable energy resource and should enjoy government promotion on that basis. There are also divergent viewpoints on the theoretical, technical and economically feasible hydropower potential and on what may be considered economically feasible related to the extent of internationalisation of all costs and benefits;
- the role of community-based energy planning initiatives, particularly in rural areas of developing countries, and the extent to which they are supported or ignored in governments-based planning;
- the implications of regionalization of planning for electricity generation and the impact on internal political discourse within the country on which options to develop to support regional loads;
- how centralised and decentralised (distributed) power systems will co-exist and their compatability;
- whether leap-frog development in developing countries is likely and the enabling conditions;
- whether access to capital for developing countries is skewed by considerations of ideology, political influence and other vested interests rather than on substantial questions of need;
- the potential for green-power sales in market economies and whether “clean energy” will generally be more expensive than other forms of electrical supply; and
- the need for and likely success of public policy initiatives to increase the market share of efficiency and renewable sources.

[x] Scientific American, Running out of Water: A 6-point global plan to avert a global water crisis. August, 2008.

[xi] Over the next 25 years, world demand for liquid fuels and other petroleum is expected to increase more rapidly in the transportation sector than in any other end-use sector.
http://www.eia.doe.gov/oiaf/ieo/highlights.html

[xii] Transportation now accounts for 60% of global petroleum product use.

[xiii] Distributed energy generally refers to electricity generation from many small energy sources either in combination with large-scale generation feeding grids or in isolated grids. It also encompasses decentralized en-

ergy and shifts to a hydrogen fuel economy. The following description is extracted from the WCD Thematic Review Options Issues Series IV.1, Electricity Supply and Demand Side Management. Options Final Version: November 2000 Prepared for the World Commission on Dams (WCD) Annex 8. Submissions by Organisations: Stakeholder Perspectives. "Some observers suggest the twenty-first century may be as profoundly shaped by the move away from fossil fuels as the twentieth century was marked by the move toward them. Although the details of the new energy economy are far from certain, the broad outlines are becoming clear. They suggest that the new energy economy may be highly efficient and decentralised, using a range of sophisticated electronics. The new energy system may bear the same relationship to that of the 20th century as the personal computer age does to the era of mainframes. Natural gas is likely to be the increasingly dominant fuel of a more decentralised energy system. But over time, new primary energy resources are likely to emerge: the sun, the wind, and other "renewable" sources of energy. And over time, hydrogen – the lightest and most abundant element in the universe – may become the main fuel for the 21st century, derived at first from natural gas and agricultural residues, but later produced from water using solar and other renewable energy sources. Employed in fuel cells, hydrogen could power everything – from automobiles and jet aircraft to electric power plants that are small enough to be deployed in home basements."

xiv Total electricity generation in the non-OECD countries increases by an average of 4.0 percent per year from 2005 to 2030, as compared with a projected average increase of 1.3 percent per year for OECD electricity generation. See reference above.

xv Such strategies must also take into account the gradual process of fuel substitution (historically to kerosene and then LPG, gas or electric – or a mix) as rural populations adopt modern forms of energy; and equally, also not preclude future small-scale and decentralized options with hydraulic aspects, or those with locally significant water footprints.

xvi The water storage issue is often at the frontline of debate about balancing water for people and water for nature, especially in water-stressed basins. There are often complex considerations of scale, e.g. mass small-scale schemes for water harvesting versus reservoirs, or alternative investments in ground water recharge where geology and soil condition permit. Water for energy enters that debate not only with hydropower, but also for other low-carbon systems like pumped storage, or reservoirs to irrigate bio-fuel crops.

xvii http://www.ens-newswire.com/ens/dec2001/2001-12-04-03.asp

xviii E.g. Mohammad IV in Morocco.

xix In COP-7 (2001 decision 28/CP.7) a set of guidelines for National Adaptation Programmes of Action (NAPAs), aimed at non-Annex developing countries were approved. These are cited in Annex B. They were for all sectors, not just water resources. The rationale for developing the guidelines rests on the comparatively higher vulnerability, but low adaptive capacity of many developing counties, which renders them in need of immediate and urgent support to start adapting to current and projected adverse effects of climate change. Activities proposed through NAPAs would focus on those whose further delay could increase vulnerability, or lead to increased costs at a later stage. The decision at COP-8 was that the current versions of the guidelines would be maintained for the time being, and updated at COP-9 based on progress in applying them and working group recommendations.

xx The 50 MW hydropower project in Sierra Leone is a case in point. The Governments of Sierra Leone and the Netherlands reached agreement and signed the Emission Reduction Purchase Agreement in 2005, subject to the CDB Board certification (CERs). The ERPA was valued at about $US 10 million for carbon emission reductions between 2007 and 2012. The money was to finance sustainability enhancements in the project over a longer term that the government would have difficulty financing on its own. This included supporting a benefit sharing program with a multi-stakeholder board based on community driven development approaches, financing and environment offset for the project, financing and watershed management entity, and initial payment for claims for resettlement that dated back to the war where agreements were recorded but the war precluded any payments being made. The proposal was submitted three times to the CDM Methodology , each time responding to requests for further analysis and elaboration raised in the previous review. The CDM Methodology Panel summary recommendation to the Executive Board, June 2007, on the last submission, recommended rejection of the proposal. The basis given for rejection was not concerns over the Bumbuna project itself, but the presence of divergent views over procedures to obtain samples of the emissions from reservoirs, as noted below.

http://cdm.unfccc.int/methodologies/PAmethodologies/publicview.html?OpenRound=11&single=1&OpenNM=NM0121

"*The Meth Panel considered reports from experts on the scientific agreement on methods for the measurement of greenhouse gas emissions from reservoirs, prepared following the request of the Panel at its twenty-sixth meeting for the case NM0121-rev. The Meth Panel noted that the experts were of the view that the extrapolation of point measurements to estimate reservoir-wide emissions may not be very reliable. The experts also noted that further work is underway to improve measurement procedures and these efforts are not likely to conclude in the immediate future. The Meth Panel agreed to recommend that submissions for project activities involving hydro power plants with a power density less than 4 W/m2 should only be considered after the expert community working on methods for the measurement of greenhouse gas emissions from reservoirs have concluded their work, except for reservoirs where it can be demonstrated that the emissions are negligible.*" The CDM experts took this position despite the proposed use of best practice procedures for emission monitoring so as to help resolve an ongoing, unresolved debate about the level of uncertainty which fuels controversy on this issue. The parties involved in preparing the submission feel that apart from the clear and demonstrated carbon offset benefits, there can be no timelier project than Bumbuna, to obtain a profile of emission changes in the first 5 years of impoundment. This is especially important to the whole CDM community.

Perspectives on water and climate change adaptation

Adaptation to climate change – Another challenge in the sustainable development of deltas

World Water Council
World Water Forum

co-operative programme on water and climate

IUCN

IWA International Water Association

Deltares
Enabling Delta Life

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

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

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

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

Participants were invited to contribute perspectives from three categories:

1. **Hot spots** – These papers are mainly concerned with specific locations where climate change effects are felt or will be felt within the next years and where urgent action is needed within the water sector. The hotspots selected are: Mountains (number 1), Small islands (3), Arid regions (9) and 'Deltas and coastal cities' (13).

2. **Sub-sectoral perspectives** – Specific papers were prepared from a water-user perspective taking into account the impacts on the sub-sector and describing how the sub-sector can deal with the issues. The sectors selected are: Environment (2), Food (5), 'Water supply and sanitation: the urban poor' (7), Business (8), Water industry (10), Energy (12) and 'Water supply and sanitation' (14).

3. **Enabling mechanisms** – These documents provide an overview of enabling mechanisms that make adaptation possible. The mechanisms selected are: Planning (4), Governance (6), Finance (11), Engineering (15) and 'Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA)' (16).

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

13 Adaptation to climate change – another challenge in the sustainable development of deltas

Mississippi Delta

Ganges Delta

The information contained in this perspective document has been derived to a large extent from a research on deltas in the framework of the Aquaterra 2009 Conference.

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Adaptation to climate change: another challenge in the sustainable development of deltas

Deltas are generally located at strategic locations close to seas and inland waterways. Deltas also provide some of the world's most fertile lands for food production. Attracted by these potentials, large numbers of people live in deltas. The rivers that flow through the deltas are an important source of fresh water and nutrients that create environmental conditions for a unique flora and fauna. Delta and estuarine ecosystems are therefore valuable and among the most productive ecosystems on earth.

1 Trends and issues in the development of deltas

1.1 Deltas: economic and environmental hot spots

The major river systems of the world all have a unique delta region, with their specific challenges and opportunities. But there are also common characteristics. Deltas are usually areas with major economic potential because of their strategic location close to seas and inland waterways. Deltas provide also some of the world's most fertile lands important for food production. That is why navigation and port development, oil production and refinery as well as agriculture and fisheries have always been the engines of economic development of deltas. Attracted by these potentials, large numbers of people live in deltas; a development which has led to the growth of coastal (mega-)cities.

Deltas have been formed by the sediments brought in by their respective river and shaped by the interplay of tides, waves and currents. At the seaside of a delta, these forces tend to erode and disperse the sediments. But as long as the net input of sediments exceeds the rate of erosion, the delta will grow. Such natural processes are crucial in the long-term evolution of a delta. A net deficit in sediment supply, for example, caused by construction of dams upstream, will lead to coastal erosion.

The rivers that flow through the deltas are an important source of fresh water and nutrients that are critical for sustaining life in the deltas. The mixing of salt and fresh water in the estuarine part of the deltas creates environmental conditions for a unique flora and fauna. Delta and estuarine ecosystems are therefore valuable and among the most productive ecosystems on earth.

But, being low-lying areas, deltas are also vulnerable to flooding and have to cope with stagnating drainage. That is why living in deltas has always required human intervention. Land reclamation, irrigation, soil drainage and embankments have made many deltas a safe place to live and work.

Box 1

Opportunities of deltas	Challenges in deltas
– strategic location close to seas and water ways – high potential for port development and oil industry – fertile soils and rich aquatic environment – large potential for agriculture and fisheries – valuable and most productive ecosystems	– areas vulnerable to flooding and drought – human intervention needed to safely live and work – filter or sink for upstream pollution – areas with high pressure on available space

1.2 Melting pot of drivers and trends

Population growth, economic development and climate change are the main drivers for change in deltas. These developments pose extensive demands on the available natural resources of deltas. In addition to these drivers there are a number of societal trends, which affect the organization and outcome of planning of delta development.

Box 2

Drivers for change	Trends in society
population growth: the global population still grows with some 2% per year, although there are distinct regional differences. The number of people to be served and to be protected against natural hazards will increase.	*decentralization*: brings delta issues closer to the stakeholders involved. Due to lack of national coordination there is, however, a genuine risk of uncontrolled and/or chaotic developments.
economic development: despite the current economic recession, economic growth may be expected over larger periods of time, resulting in larger demands to be met, higher values to protect, more energy to be generated and more goods to be transported.	*privatization*: public-private partnerships are becoming the modus operandi for new infrastructural projects and services. Increased efficiency of taxpayer's money is a key motive. The risk of privatization, however, is a focus in the short term as well as a neglect of the public interest.
climate change: although the extent of climate change may be subject to debate, there is general consensus that the rise in global temperature is inevitable, with its associated (local) impacts on sea level rise and the hydrological cycle (larger and more frequent droughts and floods).	*participation*: involvement of stakeholders and citizens is important to promote societal support of development projects as well as maintenance of infrastructure; planning may benefit from the tacit knowledge of stakeholders.
technological development: innovations may open opportunities to enhance the functionality of infrastructural solutions, to extend the life time of infrastructure and/or to develop more cost-effective designs.	*environmental concerns:* worldwide concern over a changing climate and environmental degradation has raised environmental awareness, influencing the valuation of impacts and the choice of measures.
	risk aversion: acceptance of risk is decreasing in our modern societies; hence considerable efforts are made to further reduce or control the risks of natural hazards.

Of these trends decentralization and privatization may be viewed as autonomous developments. The challenge is to utilize the advantages of both trends, while minimizing their undeniable drawbacks. This calls for a selective enhancement of governance structures, reflecting the regional scale, integrated nature and long-term perspective of delta development.

1.3 Overview of delta issues

The characteristics, which make deltas attractive areas to live and work, are under stress. Available space is under pressure, vulnerability to flooding is increasing and fresh water resources are threatened. Population growth, economic development and climate change will cause additional stress on deltas, unless appropriate measures are taken.

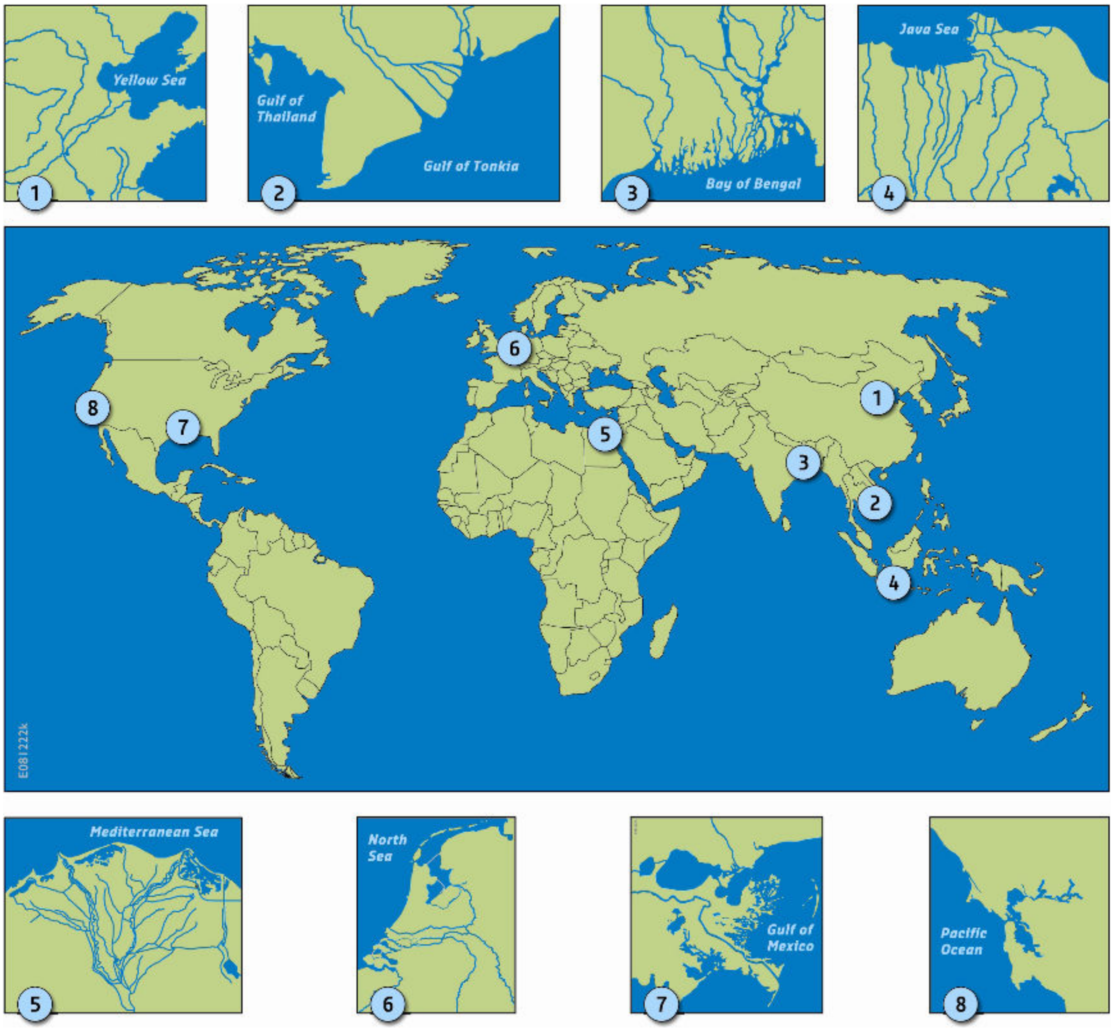


Figure 1: Eight selected deltas from the Aquaterra 2009 Conference.

Box 3 – **Main issues at stake in deltas**

Pressure on available space: being a focal point of economic development, population density is generally high and is rising. Coastal mega-cities have developed and their size and number are growing.

Vulnerability to flooding: being low-lying areas, deltas are vulnerable to flooding. Subsidence of soft soils adds to this vulnerability. Accumulation of people and wealth, as well as loss of resilience of soil and water systems, will further increase the vulnerability with respect to climate change.

Shortages of freshwater resources: many deltas in the world currently face water shortages. Climate change may result in more frequent and prolonged periods of low river discharges. This will have profound repercussions on the delta agriculture, as well as on delta and coastal ecosystems.

Ageing of infrastructure: many deltas have inadequate flood protection schemes or schemes that require major upgrading. Other deltas have irrigation and drainage systems which require an upgrade or major revision to improve their effectiveness.

Erosion of coastal areas: many deltas face a sediment shortage. This sediment shortage is often caused by regulation works in the upstream river. The sediment shortage causes coastal erosion problems. Sea level rise will aggravate these erosion problems.

Loss of environmental quality: ecosystem functioning and biodiversity in deltas are under very high pressure worldwide. Main causes are a high population density and concentration of agricultural, industrial, harbor and mining activities. Deltas are also the receptor of pollutants from upstream.

1.4 Issues of selected deltas from the Aquaterra 2009 Conference

In preparation of the Aquaterra 2009 Conference a quick assessment has been made on the nature of delta issues in eight selected deltas. The table displays to what extent issues play a role. The classification distinguishes four types of problems. Problems are judged minor if they are either unimportant, small in magnitude or well controlled (•). A minor problem can become bigger in the future (e.g. due to climate change or delta developments) in which case it is given two bullets (••). An issue is classified as a current big problem if the issue is requiring significant management attention and is not (yet) controlled (•••). If the problem is likely to increase in the near future it is given four bullets (••••).

The outcome of this assessment is summarized here in a comprehensive table. The main report on trends and responses provides some short explanations for the assessments, whereas the delta descriptions provide further background on the issues at stake in the eight deltas. The assessment is certainly subjective and reflect our understanding of the issues at stake in the eight deltas. Within the short time span of the research we may have overlooked certain aspects, so individual assessments may need revision. The main purpose of the overview is, however, to show that there is a large variation between the eight deltas. For example vulnerability to flooding is a major issue in most deltas but not in all. The table also shows that some deltas have to deal with a range of major issues, whereas in other deltas most issues are minor or at least under control. A few revisions of individual assessments will not alter this overall picture.

Box 4

Delta	**Issues** Pressure on space	Flood vulnerability	Freshwater shortage	Ageing or inadequate infrastructure	Coastal erosion	Loss of environmental quality and biodiversity
Yellow River Delta (China)	••	•	••	•	•••	•••
Mekong River Delta (Vietnam)	••	••••	••••	••	•	•••
Ganges–Brahmaputra Delta (Bangladesh)	••••	••••	••	••	••••	••••
Ciliwung River Delta (Indonesia)	••••	••••	••	••	•	••••
Nile River Delta (Egypt)	••••	•	••••	••••	••	••
Rhine River Delta (The Netherlands)	•••	••	••	•••	••	•
Mississippi River Delta (USA)	•	••••	•	••••	••••	••••
California Bay (USA)	••	••••	••••	•••	•	•••

Legend:

- • relatively minor problem, now and in the near future
- •• currently a minor problem, but is likely to increase in the near future
- ••• currently already a big problem, future trend uncertain
- •••• currently already a big problem, likely to increase in the near future

1.5 Impact of climate change on delta issues

Climate change has an impact on most of the delta issues presented in Box 3. The vulnerability to flooding may increase substantially due to sea level rise. Shortages of freshwater resources are another important impact. The frequency and extent of such shortages will be influenced by prolonged periods of low river discharges, as well as by a reduction in local precipitation. Climate change may also impact the lifetime of infrastructure, because the physical conditions may become more severe compared to the conditions for which the infrastructure has been designed. Coastal erosion problems may aggravate because of sea level rise. Climate change may also result in a reduction of freshwater supply to the delta, which in its turn may jeopardize the ecological integrity of delta ecosystems.

2 Planning of delta development

2.1 Dealing with drivers and trends

The drivers and trends pose tremendous challenges to delta management. Existing management approaches and tools are not always adequate as they tend to tackle these challenges in a piecemeal and sector wise way. For example, in many countries a full-fledged Environmental Impact Assessment legislation is operational. Although this is a great improvement over past practices that neglected the negative consequences of development projects, it mostly does not account for multiple and cumulative impacts. Also planning regulations and limitations do not always serve an optimal spatial development. It has been long standing-knowledge that nature conservation by means of protective areas or reserves has significant limitations. Endangered species get trapped in those isolated havens as their habitat becomes unsuited due to climate change.

These are but some examples of the difficulties delta management is confronted with. As a way out, a more holistic and integrated view on delta management is taking shape. We see this, for instance, in integrated water management, coastal zone management and at the scale of entire river basins. But there is more: ideas to reconcile human development with nature are emerging in various fields. 'Building with Nature' is practiced already in the form of beach nourishments as opposed to hard structures to control erosion. Multifunctional use of infrastructure is being implemented in densely populated deltas to save space and money. Restoring the natural purification capacity of wetlands and estuaries are being considered in highly modified deltas, such as in the Netherlands.

To promote sustainable development of deltas, a clear vision has to be developed on how to respond to the various drivers of change as well as on how to play along with the various trends in society. A strategy for sustainable development of deltas should comprise a sensible combination of different kind of responses. This should include measures for management and restoration of natural systems, for development and adaptation of land and water use and for extension and revitalization of infrastructure. Furthermore enhancement of the governance structure is required to enable implementation of these responses. The perspectives of these responses will be discussed in the next sections of this document.

2.2 Conceptual view on planning of delta development

The sustainable development of a delta may be analyzed and managed using the so-called 'layer model'. The layer model divides the space in three physical planning layers, each with their own dynamics. These layers are the base layer (water and soil), the network layer (infrastructure) and the occupation layer (physical pattern arising from human activities: living, working, recreating; in short: land and water use). The essence of the layer model is the difference in dynamics and vulnerability between the layers, which results in a logical order in planning the various layers. The layers enable and/or constrain activities in another layer.

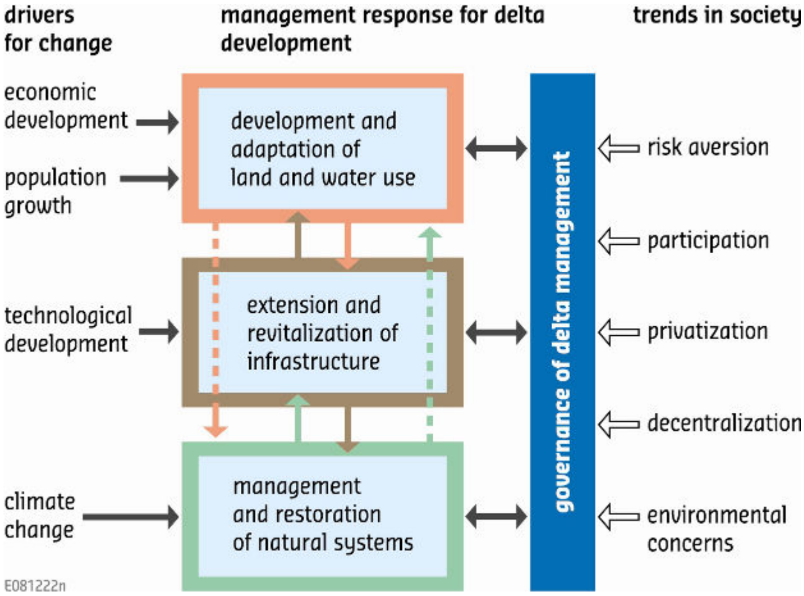


Figure 2: Linking responses to drivers and trends.

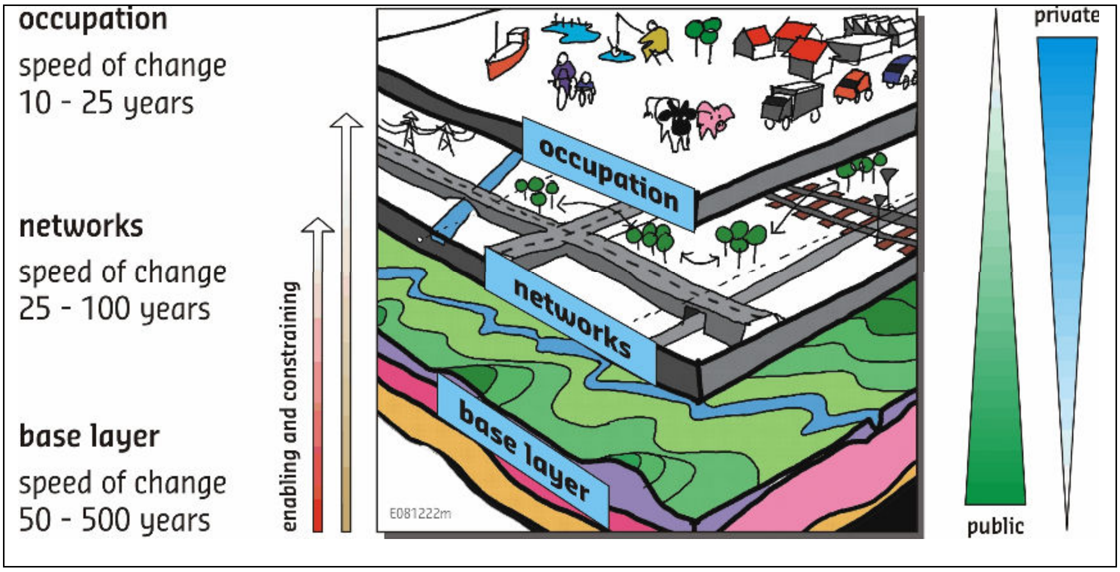


Figure 3: Layer model for planning of delta development.

The layer model may be instrumental in, for example, the design of strategies for adaptation to climate change. The key to adaptation to climate change (climate proofing) lies in the base layer. If the structure of the base layer is climate proof, then the other layers follow suit. This is not a matter of hierarchy or dominance but of logical order- the base layer first. The climate proofing of the base layer is the sole responsibility of government. The way to act is to make maximum use of the large adaptive capacities of natural systems. Moving to the occupation layer the role and influence of government becomes more restricted and the influences of private parties and citizen's interests become more dominant.

2.3 Perspectives on development of deltas

Basically there are two different ways to respond to the different drivers and trends. The first perspective is very much driven by the (liberal) economic perspective: the role of the (central) government is reduced through privatization and decentralization. Also there is less government influence in spatial planning, etc. The balance between central and de-central is a political issue. It is a response to a growing complexity in society and therefore a trend. The word privatization indicates that there is an existing public service that can be given to the market. There are also many new services to be developed which require a vision on private sector development and involvement. The challenge is to find the right balance between governmental supervision and control, and the dynamics, innovation of free market forces. The conflicts that could arise out of the market-driven and less top-down controlled focus are generally solved in a technocratic way, i.e. by further development of infrastructure. This perspective reflects a high belief in our capabilities to engineer the world to our needs. The long-term sustainability, however, is not guaranteed. Changing environmental conditions will require a regular upgrading of the infrastructure, as infrastructure does not adapt naturally.

The second, environmental perspective, is driven by global concerns on climate change and environmental degradation. It reflects a growing awareness that nature poses limits to development. These limits may be stretched to some extent through the development of infrastructure but at increasing costs. In this perspective land and water use should instead be adapted to changing environmental conditions through spatial planning regulation and adaptive designs. Natural processes should be utilized as much as possible to adapt to changing environmental conditions. The environmental perspective aims to make better use of the inherent adaptive capacities of nature.

The first perspective is visible in most deltas of the world. The second perspective is, as yet, less visible, but is gaining momentum. The two perspectives are basically conflicting. The main challenge therefore is to combine elements of both perspectives into a strategy which is both economically viable and ecologically sound. It requires among others harmonizing and balancing on the government axis – market, and on the central axis – de-central.

2.4 Development of adaptation strategies

Making deltas climate proof requires new adaptation strategies which are timely, technically and environmentally sound, economically feasible and socially acceptable. However, both climate change and socio-economic developments come with large uncertainties. In order to develop adaptation strategies for climate-proof deltas, fundamental questions need to be answered, such as:

- What are the requirements which the key economic sectors (e.g. agriculture, transport, energy, tourism, industry) and nature put on water management and spatial planning in deltas?
- Under what circumstances do current strategies for water management and spatial planning fail to meet those requirements (when, where, how often)?
- What are the adaptation options that will allow us to keep on living and working in the deltas?
- How much time is available to implement these adaptation options for water management and spatial planning?

To answer such questions an integrated method is required to assess the vulnerability of deltas and to determine adaptation paths for the different sectors in deltas. One of the key elements in such method is the so-called adaptation tipping point. An adaptation tipping point is a level where natural (physical) boundary conditions exceed technical, economic, spatial or societal acceptable limits. Figure 4 presents an example on the suitability of a delta for human settlement as a function of sea level rise. The straight line represents conditions for the present adaptation capacity, the dotted line represent conditions under new adaptation strategies. The adaptation tipping points are indicated as an (*). The risk of coastal flooding might at first be reduced to an acceptable level by intensified shoreline management. If that strategy reaches its limits it may be followed by the construction of new super levees. An adaptation tipping point identifies the point where a policy on water management or spatial planning needs to be revised and where a new strategy needs to be implemented.

The adaptation tipping points method (Deltares, 2008) takes the requirements of key sectors of water management and spatial planning as a starting point to identify the need for adaptation to climate change. The degree of climate change to which each key sector can cope is determined. Climate change scenarios are then used to determine in which time period those adaptation tipping points may be reached. This provides insight into the vulnerability to climate change of deltas. Combining the adaptation tipping points with local scenarios will identify the vulnerability of a sector and the possible need for new adaptation strategies.

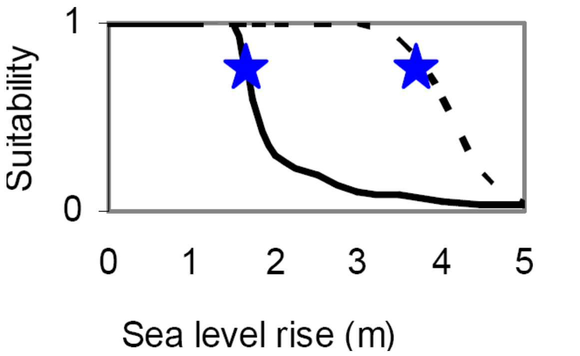


Figure 4: Examples of the relationship between natural boundary conditions and the suitability of a delta.

The timing of adaptation tipping points is crucial knowledge for decision-makers. Knowing how long it will take before adaptation tipping points are exceeded makes the timeframe for decision-making explicit. The timeframe for a certain adaptive measure can be estimated by using climate change scenarios and socio-economic scenarios. Some adaptive measures will have to be implemented soon, and others in the next 20 or 50 years or even later.

The method may also help to develop a sequence of adaptations strategies, so-called 'adaptation paths' (Figure 5). Replacing Strategy 1 by Strategy 2 will happen at a certain level of climate change. It could even lead to a higher efficiency of use of the delta area. When the efficiency of the final strategy becomes too low, retreat from the deltas becomes unavoidable.

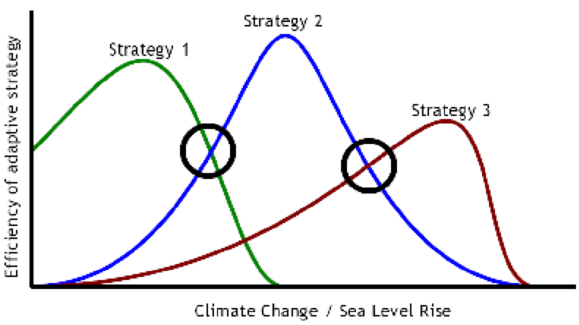


Figure 5: Adaptation paths to climate change for water management in delta areas.

The adaptation tipping point method has been successfully applied to the water resources system of the Dutch Delta to support the analysis and recommendations of the Delta Committee (see Box 5).

Box 5 – **Adaptation tipping points analysis for Delta Committee**

Research findings adopted in the report of the Delta Committee include:

- Fresh water supply will be severely hindered through salt water intrusion, but it will not be an issue before 2040;
- Speed of sea level rise (the higher scenarios) will come close or exceed the natural adaptive capacity of the Wadden Sea;
- The Maeslant storm surge barrier in Rotterdam, has been designed for sea level rise up to 50 cm, hence this will not be an issue before 2060;
- Current strategy for nature conservation will not be sustainable under climate change;
- Salt water upward seepage through the ground water is a minor effect;
- Coastal flood defense maintenance through sand nourishment will not be an issue, provided that sand can be taken from the North Sea bed;
- In general it was concluded there are no limitations to technical adaptation measures, although these measures become increasingly expensive and space consuming.

3 Perspectives of restoration of natural systems

Deltas are relatively young landforms shaped by the interplay of coastal and riverine processes. These natural processes are crucial in the long-term evolution of a delta. The delta estuaries and its marine environs have the highest biological production of all natural areas in the world. Estuaries have also the highest economic value of all ecosystems. The most important direct drivers of change in ecosystems worldwide – and probably also for delta ecosystems – are habitat change, overexploitation, invasive alien species, pollution and climate change (in particular sea level rise).

Delta ecosystems can be relatively easily restored, because the delta environment is highly dynamic. Delta nature has a remarkable adaptive and resilient capacity. In contrast to, for instance, tropical rainforests which require centuries to reach a climax succession stage, delta ecosystems, such as salt marshes, mangroves and dunes develop quickly into rich habitats once the environmental conditions are favorable. All over the world we see restoration ideas turning into reality. Of course not every initiative is an immediate success. There is much trial and error. But the most important thing is that people see the need to protect their environment and to work with nature instead of against it.

3.1 Restoration of resilience

Deltas are often confronted with coastal erosion, salt intrusion, subsidence, extreme high and low river discharges and changes in precipitation and evaporation. All these processes are affected by climate change, which make deltas vulnerable to climate change. In many deltas the developments over the past few decades have modified soil and water systems. The area of surface water has become less, and so has the water storage capacity. Changes of land use, including the creation of impervious surfaces, have accelerated the rainfall-runoff process, making these areas more vulnerable to flooding. The resilience of natural systems (the capacity of systems to adapt to other conditions through natural processes) has generally deteriorated.

Adaptation to these changing conditions is a major challenge. Adaptation strategies should focus on restoration of resilience. Such strategies should include measures to enhance infiltration, retention and/or storage capacities of water systems. Adaptation in densely populated deltas may also include multifunctional use of areas, e.g. giving a water storage function to nature areas. Reducing the vulnerability of land use through adaptive designs is another important pillar of adaptation strategies, for example through urban flood management.

3.2 Wetlands restoration for natural coastal protection

There is ample evidence that coastal protection can greatly benefit from a resilience-based approach. Many of the world's coastlines are highly dynamic by nature through the forces of winds, waves and currents. Hard engineering structures have more often than not led to increased erosion, either on the location itself, or at nearby, unprotected beaches. Instead, coastal practitioners are increasingly applying soft engineering measures, such as beach and foreshore sand nourishments.

Besides - and in addition to - these sand nourishments, ecological engineering is being practiced. Based on the notion that mangroves can provide effective storm protection, there is increased attention to restore these coastal forests. Great potential exist to reverse the loss of mangrove forests worldwide through the application of basic principles of ecological restoration using ecological engineering approaches. Mangrove restoration can be successful, provided that the hydrological requirements are taken into account, which means that the best results are often gained at locations where mangroves previously existed.

3.3 Building with nature

Environmental considerations play a major role in the sustainable development of deltas. Concerns on environmental degradation have been institutionalized into environmental regulation. Almost no infrastructural development takes place without a proper environmental impact assessment. It is, however, not always easy to specify the environmental requirements to be met. These requirements are often subject to debate, and are sometimes hard, if not impossible to meet. That is why a different approach is being advocated: not to try to minimize the negative environmental impacts, but instead to make better use of the forces, interactions and materials present in nature. This approach reflects a shift in paradigm from building against nature to 'building with nature'.

The emphasis of the concept of building with nature is on sustainable development in densely populated coastal and delta areas. In implementing the method a new flexible dynamic equilibrium coastline is created using sand from the sea. The emphasis is on flexible soft structures in harmony with the sea, such as dunes and beaches. Building with nature has shown to be an environmentally friendly and economically advantageous concept. It offers inherent flexibility and adaptability, important for adaptation to climate change. The concept is applicable in many settings and supports long-term sustainable solutions for the restoration of coastlines and habitats and in new approaches for land reclamation.

4 Perspectives of adaptation of land and water use

One of the trends in the development of deltas is an increasing awareness that occupation should be adapted to changing environmental conditions. Due to climate change, but also population growth and economic development, the demands of land and water use will change. In particular the threat of climate change is an important trigger for the adaptation of land and water use. This threat may be countered to some extent by regulation of spatial planning: promoting (new) activities in low-risk areas to minimize the (increase in) vulnerability to climate change. If spatial planning offers little solace, solutions may be found in restructuring an area, for example, in the reconstruction of urban areas so that more space may be created for storage of excess rainfall. Urban flood management is another example. Finally at the lowest scale, vulnerability may be reduced through adaptive designs and construction methods. This may include amphibious housing, shifts to more salt-resistant cropping patterns, etc. This section describes a few examples of adaptation options.

4.1 Spatial planning and zoning

Historically environmental conditions played a major role in the spatial 'planning' of land and water use. The available natural resources as well as the transportation potential were major reasons to occupy deltas. Infrastructure development was necessary to take full advantage of the benefits deltas had to offer.

Due to the debate on climate change as well as the occurrence of some major floods in the past few years there is a trend to take better account of the limitations and risks posed by the natural system. For example, there have been scenario studies in The Netherlands on spatial development. One of these scenarios included diverting new investments and urban development to areas with less or no flood risk. The new Delta Committee in its report, however, concluded that there is insufficient ground for such strategy. Even under severe unfavorable climate change scenarios, The Netherlands will be able to keep the water out with its flood control system, albeit with some additional measures.

The awareness that deltas are potentially risky areas is nevertheless growing, and more so in view of climate change. But in practice there are as yet few examples of formal risk based spatial planning. The UK, however, has regulations for spatial development and flood risks, the Planning Policy Statement 25 (PPS25) on Development and Flood Risks.

4.2 Urban (re)development and urban flood management

Economic development and population growth drive expansion of built up areas. The augmenting rate of built up areas in cities leave less space available for water storage functions. This is an unfortunate situation in deltas as it increases the vulnerability for floods and droughts. Urbanization leads to an increased tension between land and water development.

Over the last decades there is a growing number of floods in urban areas. Climate change and rapid urbanization will exacerbate this trend. Flooding incidents in urbanized catchment areas can lead to great public concern and anxiety, and the economic impacts are often severe. Besides structural measures aiming at a reduction of the probability of flooding, new integrated approaches are being developed and implemented. Urban flood management aims to incorporate flood risk into urban (re)development and tries to increase robustness as well as the adaptive capacity towards future flood impacts.

4.3 Adaptation to salinity problems

Salt accumulation in delta soils, resulting from intense irrigation and/or seepage, reduces agricultural productivity. Hence alternative practices are introduced to adapt to changing environmental conditions:

- desalting of agricultural soils;
- cropping of salt tolerant species;
- mixed farming practices.

Brackish agriculture using salt-tolerant crops is considered a promising strategy for over 100,000 ha of arable land below sea level in the Netherlands. Due to increasing seepage because of sea level rise, the soil in these areas will become increasingly salty. The return on normal crops will consequently falling sharply. Cultivation systems and market opportunities for salt-tolerant crops therefore provide new perspectives for agriculture in these regions.

In the Mekong Delta of Vietnam some 800,000 ha (20% of the total area) is affected by saline water with predominant freshwater in the rainy season and brackish water in the dry season. As saline water intrusion in the dry season is a major constraint to rice farming, many farmers develop an alternating rice-shrimp farming system. This system produces shrimp in the dry season and rice in the wet season on the same plot. In this farming practice saline water is used to flood the rice fields in the dry season to raise shrimp. At the beginning of the wet season, farmers flush salinity out of their fields using rain and fresh river water to plant rice. The integrated farming systems increase farmers' income and improve the living standards of the local community.

5 Perspectives of infrastructure development

5.1 Towards more robust infrastructure

There is a trend in how societies deal with risks, including those from natural hazards. Many societies show a growing aversion of risk. Although zero risk is impossible many countries are adopting strategies which aim at a (further) reduction in the probability of failure as well as the impacts of failure. For example, the Delta Committee in The Netherlands recently recommended to raise the level of safety with a factor 10. The increase in safely level responds to the increase in the number of people and assets to be protected.

The trend of risk aversion, together with the expected impacts of climate change, has triggered a demand for more robust flood defence works. The super levees in Japan are a good example of such robust works.

Similar to the concept of super levees in Japan, Dutch engineers and landscape architects have developed the concept of climate dikes or Delta dikes. These Delta dikes, thanks to their height, width or structural reinforcements should be so strong that uncontrolled flooding is practically excluded. The Delta Committee has recommended adopting this concept particularly in those dike ring areas which are most vulnerable to flooding.

In addition to the trend of more robust infrastructure there is a need for more flexible systems. These are systems that are able to cope with uncertainties and will hence have the capability to adapt to new, different, or changing requirements. To develop these flexible systems, new design approaches and techniques are needed that recognize the value of flexibility and promote a more modular approach to water management.

5.2 Securing future water supplies

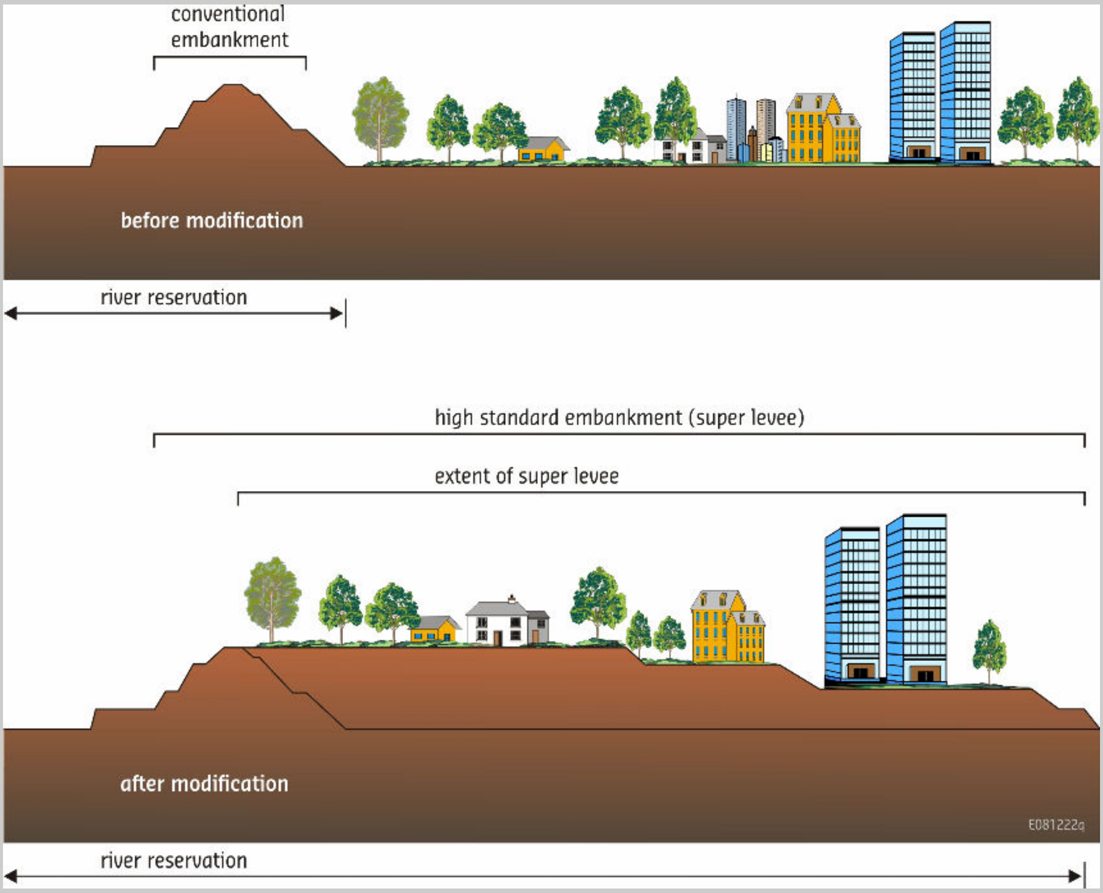
Due to climate change, prolonged and more frequent periods of drought are expected. At the same time water demands in deltas are increasing because of population growth and economic development. As a consequence water shortages will grow in magnitude and frequency, unless land and water use will be adapted or future water supplies will be improved either by storage or transfer.

In many countries shortage of fresh water is viewed as one of the most serious challenges in water resources management. Even in a country such as the Netherlands, with generally an abundance of water, droughts occasionally occur. Due to climate change, water shortages are expected to become more likely and counter measures are being considered. In fact, the Delta committee has proposed to raise the target water level of Lake IJssel by some 1.5 m to increase the amount of water being stored. The water from this lake constitutes a source of water supply to other parts of the country in periods of drought.

The expected increase in water shortages is also a major trigger for adaptation to climate change. Although in some countries such as Spain, the drought problems are so acute that emergency measures are taken.

Box 6 – **Super levees: Japan's response to increasing flood risks**

To respond to increasing flood risks with its devastating consequences to society, Japan had developed the concept of super levees. A super levee is a river embankment with a broad width which can withstand overflow. It prevents uncontrolled flooding due to a dike break. The slope of the embankment is made very gentle. In the unlikely event that the river rises above the embankment, the water would spill 'gently' down the slope. The embankment is protected from destruction and serious damage to assets along the river is minimized. The super levee differs from the conventional embankment, which is basically a wall separating the hinterland from the river.



The adaptation of conventional dikes to super levees offers a number of benefits. A super levee is better resistant to overflow, seepage and earthquakes. In addition it provides usable land and space for urban developments and it restores access to the riverfront. The concept of super levees is also a good example of multifunctional use of infrastructure.

5.3 New impulses for hydro energy

Economic development, unless serious energy saving programmes are implemented, may imply a growth in energy consumption. In line with mitigation policies for climate change there is a growing interest in the potential of deltas for renewable energy. Specifically in deltas there are a number of ways in which water may serve as a source of sustainable energy, waiting to be tapped. These include energy from tides, from waves and from salinity gradients.

The opportunities of water for energy generation have been explored in an innovation programme in The Netherlands. The study looked into the potential of the various sources, and the perspectives for actual generation from both a technical and societal point of view. The perspectives of energy generation from tides and waves in the Netherlands were found to be rather limited. Most potential is in the generation of energy from fresh-salt gradients using Pressure Retarded Osmosis (PRO) and/or Reversed Electrodialysis (RED). The Closure dam which separates the fresh water of Lake IJssel from the Wadden Sea might be a suitable location for the application of this technology. Its application may become part of the required rehabilitation of the Closure dam and would comprise a good example of multifunctional use of infrastructure as well.

Box 7 – **Water shortages and adaptation to climate change (example from Spain)**

The drought problem in Spain is treated rather separately from the adaptation to climate change, despite the obvious and recognized link between the two. In general, drought is regarded as an emergency issue and many ad-hoc actions are taken. This happens often on a short timescale, which does not necessarily fit with the long-term adaptation to climate change. Many activities aim at solving particular bottlenecks caused by drought, especially in the irrigated agriculture. Examples of such measures are the implementation of interbasin transfers, a much disputed issue in Spain, as well as the continuous inauguration of desalination plants, especially close to the major coastal cities such as Barcelona. These kind of drought-driven activities are sometimes included in plans for adaptation to climate change, but tend to be implemented independent as a kind of 'no-regrets' measure.

5.4 Rehabilitation of infrastructure

Due to climate change the physical conditions for which the infrastructure has been designed will become more severe, such as larger droughts to overcome, higher water levels to counter and larger loads to withstand. Climate change, without adaptation or counter measures, will result in damage or a loss of functionality of the existing infrastructure. The adequacy of the infrastructure may be further challenged by physical / mechanical ageing of the infrastructure. Also inadequate maintenance may play a role. Some infrastructure which has already been present for decades or centuries is in (urgent) need of replacement or rehabilitation. Such rehabilitation will require large investments in the near future. Hence it is important to anticipate such expenditure.

6 Perspectives of enhancing delta governance

In the past few decades the development and management of deltas has become increasingly complex and often an issue of societal debate. A number of trends have added to this complexity, including decentralization of government and larger involvement of the private sector. Also interest groups and citizens have a stronger voice in development. Sustainable development and management of deltas has to deal with this increased complexity; it calls for a strengthening of the governance structure. Good governance is in fact a permanent search for a proper balance between public and private interest, between efficiency and equity, between different regions and sectors, between economic development and environmental stewardship.

Box 8 – **Foundation of a Delta Council in the Southwestern Delta of the Netherlands**

Some years ago the provincial managing authorities have drafted a vision for the future. This vision deals with both the ecological side effects of the Delta Works and the expected impacts of climate change. Restoration of estuarine dynamics has a prominent place in this vision. To promote and facilitate its implementation the Delta Council was founded at the end of 2004. Members of the Delta Council are the provinces of Zeeland, North Brabant and South Holland, as well as the Ministry of Transportation and Water Management, the Ministry of Agriculture, Nature and Food Quality, and the Ministry of Housing, Spatial Planning and the Environment. Municipalities, water boards and interest groups are involved through an advisory group.

First step in the implementation of the vision is the determination of a Delta programme. The Delta programme aims to protect and reinforce the 'delta values' at risk. The programme is being prepared by a so-called 'Programme Bureau', which consists of experts and representatives of the parties which make up the Delta Council. The main challenge of the bureau is the determination of the programme of measures for a sustainable and climate proof development of the Southwestern Delta and its implementation in close cooperation with the parties involved.

In the context of this perspective document, governance is related to creating the proper conditions for a sustainable development of deltas. Good governance should ensure that visions for delta development are brought into practice through development and adaptation projects. Governance should also provide adequate arrangements for maintenance of infrastructure preventing early deterioration of the infrastructure.

6.1 Multi-level governance of deltas

Lack of cooperation between different levels and sectors of government are a major impediment for implementation of development projects or adaptation strategies. Deltas are mostly governed by multiple governing layers, e.g. international, national, regional and local. The fact that there is no legal entity for deltas adds to the complexity, hence the interest in multi-level governance to overcome these impediments. The trend of decentralization constitutes a major trigger for the strengthening of the governance structure through multi-level governance.

Planning of delta development requires harmonization of different interests. Often trade-offs have to be made between different regions and/or sectors. Given the regional scale of deltas and their role in the development of national economies, there is also the need for (national) coordination of development activities. The actual implementation of a programme of measures requires the cooperation of different levels and sectors of government as well as the private sector, hence the need for a platform for structured communication and negotiation between all parties involved in delta development. The foundation of the Delta Council in the Southwestern Delta of the Netherlands offers a good example of such multi-level governance (see Box 8).

6.2 Linking river basin management and coastal zone management

Since the UNCED Conference in Rio de Janeiro, the link between river basins and coastal areas has been increasingly highlighted in several fora. Two key management approaches have been developed in the post UNCED years to promote sustainable development of river basins and coasts: Integrated Water Resources Management (IWRM) and Integrated Coastal Zone Management (ICZM). The concepts of IWRM and ICZM have been developed rather independently from each other by separate management organisations, frequently with different objectives and modes of operation. Often estuaries and coastal areas were not considered to be part of the river basin. In deltas the coastal zones and river basins do meet. Linking the management of river basins and coastal zones is needed to maintain or improve the ecological integrity and socio-economic viability of coastal and marine areas.

The past ten years have made clear that the advancement of coastal or river basin issues cannot be solved by ICZM and river basin management (RBM) programmes working in isolation. Linked management is often the only realistic way to maintain or improve the ecological integrity and socio-economic viability of the coastal and marine areas. Recently, the linked management of river basins and coastal and marine areas is recognized to be a characteristic feature of an ecosystem-based management.

6.3 Adaptive management to deal with uncertainties

Adaptive management may be defined as an iterative process of optimal decision-making under uncertainty. It has the aim of reducing uncertainty over time via system monitoring. Adaptive management is often characterized as 'learning by doing' although it is more about deliberate experimentation. Examples can be found in the large-scale beach nourishment strategy proposed by the Dutch Delta Committee. This strategy is facing important uncertainties with respect to the effectiveness of large scale sand nourishment as well as the extent of sea level rise. The type of measure, however, lends itself good for adaptation based on the findings of monitoring. The Thames Estuary 2100 project in the UK is another example of adaptive management: the strategy for flood risk management will vary depending on the expectations of sea level rise (see box 9).

Box 9 – **Thames Estuary 2100: flood protection adapting to sea level rise**

Climate change will cause sea levels to rise and will also affect the scale and frequency of tidal surges, but there is uncertainty on the nature of this change. Thames Estuary 2100 is looking at how to manage tidal flood risk through the century. It includes an assessment of the useful life of the existing defences as well as the development of an understanding of the 'drivers' for change in the estuary (i.e. climate change, urban development, social pressures and the environment). The plan will be adaptable to climate change and to a changing estuary. Depending on the scenario for sea level rise, various types of measures are being considered, including the raising of existing embankments and construction of a new barrier.

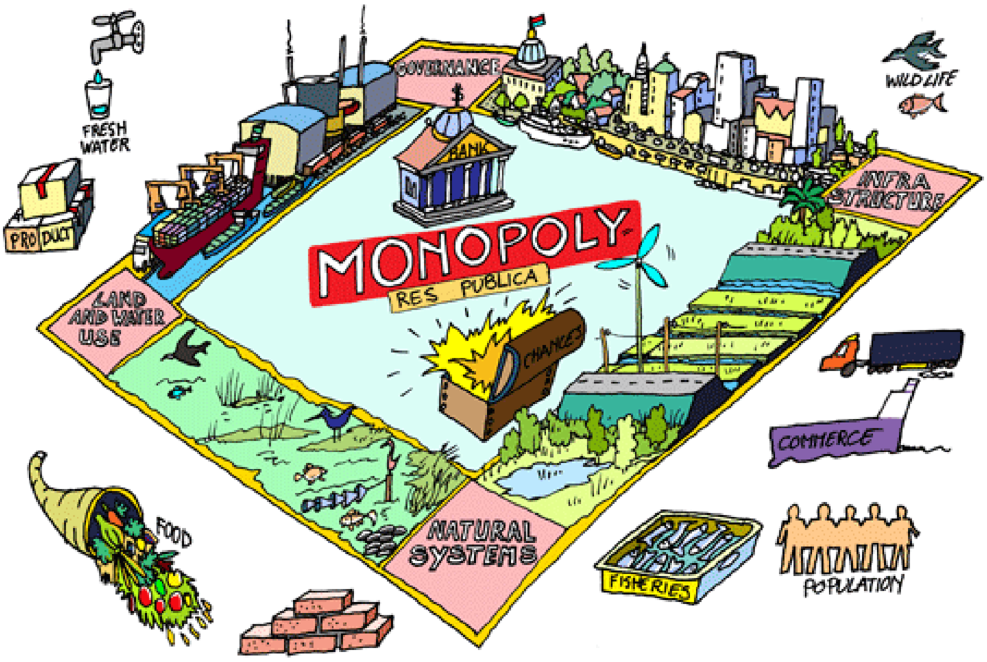
7 Way forward?

The characteristics, which make deltas attractive areas to live and work, are under increasing stress due to population growth, economic development and climate change. The management of delta development has also become increasingly complex, due to - among others - decentralization and privatization. Worldwide concern over a changing climate and environmental degradation has raised the environmental awareness that nature poses limits. A more sustainable development of deltas, however, requires not only acceptance of the limits posed by the natural system but also making use of or even enhancing its enabling conditions. To promote sustainable development of deltas, a clear vision has to be developed on how to best respond to the various drivers of change as well as on how to play along with the various trends in society.

7.1 Delta vision: a shared view on sustainable development of deltas

A shared vision on sustainable delta development should deal with all drivers for change in a delta (population growth, economic development and climate change) as well as with the relevant societal trends (decentralization, privatization, participation, growing environmental concerns and risk aversion). Such a vision should be developed in close cooperation with all parties that have a stake or a say in the development of the delta. A good example of such vision is 'Delta in Sight' which was developed for the southwestern delta of the Netherlands and which presents an integral view on problems and possible solutions for the Dutch Delta waters.

Next, the delta vision should be elaborated into a policy or delta programme. Such a programme should comprise a sensible combination of different kind of responses, including measures for restoration of natural systems, adaptation of land and water use, extension of infrastructure as well as measures to strengthen the governance structure. Establishing the most suitable combination of measures requires



a strategic analysis of the potentials and limitations of the different types of measures. Strategic Environmental Assessment (or Strategic Impact Assessment) may constitute a suitable instrument for the development of the shared delta vision and the associated delta programme.

7.2 Delta technology: innovations in science and technology

Sustainable development of deltas requires innovations in the knowledge of natural systems behavior as well as in the approach to planning and design. For example we should move from an engineering approach to an 'integral approach'. Important 'sources' of innovations are developments in information and communication technology. Advances in sensor and simulation technologies may promote the development of more accurate warning and forecasting systems. These technologies also support the development of local- and global-scale monitoring and diagnostic systems.

7.3 Delta governance: social and institutional innovations

For development of deltas to be more sustainable, it is important to obtain societal acceptance and support for this development. Good governance should promote that shared visions are developed on the basis of sustainable development of deltas. Moreover proper conditions should be created for the actual implementation of such a vision through development projects and adaptation strategies. Governance should also provide adequate arrangements for maintenance of infrastructure to prevent early deterioration of the infrastructure.

Societal trends have to be taken into account in creating these conditions, in particular the trends of decentralization and privatization. Decentralization and privatization may be viewed as autonomous developments. The challenge is to utilize the advantages of both trends, while addressing their undeniable drawbacks. This calls for a selective enhancement of governance structures, reflecting the regional scale, integrated nature and a long-term perspective of delta development.

7.4 Delta dialogue: establishing best delta practices

Sustainable development of deltas is an increasingly complex field which requires the contribution and cooperation of many parties. Although there is no general recipe on how to best deal with many delta issues, it is important to learn from experiences elsewhere. To this end, exchange of knowledge and experiences should be stimulated. Such exchange may take various forms:

- The draft National Water Plan of The Netherlands (December 2008) proposes to set up an active and longstanding cooperation on water safety and water quality with some four delta areas in the world. This cooperation may serve as a vehicle for exchanging experiences in planning and design approaches.
- The Aquaterra Conference has the ambition to develop into a biannual forum on delta and coastal development. The Conference may offer a platform to discuss the various challenges in deltas and the possible approaches to deal with these challenges. Through a process of dialogue, these approaches may be elaborated into best delta practices.

Box 10

Emerging 'best practices' for dealing with delta issues?
Deltas have characteristics in common, but there is much diversity in physical conditions, governance structure and cultural background. Hence, there is no general recipe on how to deal with delta issues. Nevertheless, some broad perspectives may be distinguished on dealing with these issues, such as emerging 'best practices' for deltas, and enhancement of the governance structure as an important component of such practices.

Relieving the pressure on available space
Spatial planning regulation may relieve some of the pressure by redirecting urban development and economic activities to less 'crowded' and/or low risk areas. In cases where spatial planning offers little solace, land reclamation has proven to be an effective way to relieve some of the pressure on space. Land reclamation offers also good opportunities for implementation of the Building with Nature concept meanwhile easily applying new safety considerations. Multifunctional use of areas, e.g. giving a water storage function to nature areas, may further assist in relieving the pressure on space.

Improving resilience of delta areas
Vulnerability of societies to future climate change (such as flood risks, droughts and salinity intrusion) should be reduced, preferably by making societies more resilient. Resilience can be improved by: preparedness, coping strategies and adaptation to changing conditions. This requires a combination of willingness to change, appropriate technology and community participation. Increasing the robustness of infrastructure is another promising way to respond to the increase of the vulnerability of delta areas and the growing aversion of risk.

Securing fresh water supplies
Many deltas in the world currently face water shortages which may aggravate due to climate change and pollution. Adaptation of land and water use will be an important way to respond to these shortages. This may include more efficient water use and/or changes in cropping pattern and fertilization in agriculture. Pollution reduction programmes and establishment of environmental flow requirements for deltas are needed. Their implementation may benefit from involvement of river basin agencies.

Upgrading of ageing infrastructure
Many deltas have irrigation and drainage systems as well as flood protection works, roads, water supply and treatment facilities which require upgrading. Public private partnerships could provide a solution in those cases where farmers, industries and communities directly benefit from these infrastructure investments. But for protection schemes against floods and storm surges other options could be more appropriate, such as introducing financing mechanisms. Rehabilitation of infrastructure offers also opportunities for multifunctional use of infrastructure.

Coastal erosion management
Many deltas experience coastal erosion problems due to a sediment shortage Solutions should preferably include a restoration of the sediment balance. If this is not feasible, sand nourishments are preferred over hard engineering structures. Also other 'Building with Nature' options should be looked into, e.g. mangrove restoration. This is primarily a task for coastal management agencies, who should work closely together with local stakeholders and the private sector.

Biodiversity protection and restoration of ecosystems
Worldwide estuarine ecosystems and biodiversity in deltas are under severe pressure. Effective action must be taken to protect nature areas from local habitat destruction, external disturbance and adverse inputs (pollutants). This requires adhering to the national and international obligations, such as the Habitat Directive, and the Ramsar and Biodiversity Conventions. Biodiversity protection should be effectuated at the local level through cooperation and involvement of all stakeholders. Ecosystems in deltas can be relatively easily restored. An integral approach and early involvement of stakeholders contributes to the success of restoration efforts, The integrity of (modified) estuarine ecosystems may be enhanced through reconnection with rivers and seas.

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Perspectives on water and climate change adaptation

Climate change and WASH services delivery – Is improved WASH governance the key to effective mitigation and adaptation?

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

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

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

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

Participants were invited to contribute perspectives from three categories:

1 **Hot spots** – These papers are mainly concerned with specific locations where climate change effects are felt or will be felt within the next years and where urgent action is needed within the water sector. The hotspots selected are: Mountains (number 1), Small islands (3), Arid regions (9) and 'Deltas and coastal cities' (13).

2 **Sub-sectoral perspectives** – Specific papers were prepared from a water-user perspective taking into account the impacts on the sub-sector and describing how the sub-sector can deal with the issues. The sectors selected are: Environment (2), Food (5), 'Water supply and sanitation: the urban poor' (7), Business (8), Water industry (10), Energy (12) and 'Water supply and sanitation' (14).

3 **Enabling mechanisms** – These documents provide an overview of enabling mechanisms that make adaptation possible. The mechanisms selected are: Planning (4), Governance (6), Finance (11), Engineering (15) and 'Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA)' (16).

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

14 Climate change and WASH services delivery – Is improved WASH governance the key to effective mitigation and adaptation?

Charles Batchelor, Ton Schouten, Stef Smits, Patrick Moriarty and John Butterworth

Climate change and WASH services delivery – Is improved WASH governance the key to effective mitigation and adaptation?

This paper attempts to identify and discuss the nature and scope of possible climate change impacts (negative and positive) on WASH services delivery. Rather than consider these impacts in isolation, the paper considers climate change as one of many important and uncertain external factors that can have a profound direct or indirect effect on WASH services delivery. Although the paper does not attempt to provide an exhaustive assessment of the state of climate change knowledge, recent literature is summarised and specific attention is given to the high levels of uncertainty in this knowledge and in recommendations resulting from it.

Taking a WASH practitioner's perspective, the paper discusses whether climate change is very different in nature from other challenges facing the WASH sector and, more specifically, whether a new set of interventions, methods, tools or approaches is needed to address climate change challenges. The paper notes that many of the solutions in the fast-developing climate change literature fall neatly under the heading: 'Business as usual – but better'. It is worrying that some solutions, that are being identified and strongly recommended in the literature, have been shown to have major limitations and/or negative tradeoffs when implemented at scale.

Similar to above, the paper discusses the scale and immediacy of climate change in relation to WASH services delivery in different regions of the world. It is argued that, even in the absence of climate change, the WASH sector is struggling to meet WASH-related MDGs. Of equal concern, is the widespread *slippage*[1] in WASH services levels in many parts of the world. When these are taken into account, immediate WASH challenges (regardless of a climate change overlay) become even more daunting.

Finally, the paper discusses the potential roles of improved WASH governance and *integrated water resources management (IWRM)* as a primary means for the WASH sector to mitigate and adapt to the potential impacts of climate change. This level of attention to WASH governance and IWRM is prompted in part by general agreement in the literature that improved governance and IWRM are needed to tackle immediate WASH challenges (e.g. Moriarty et al, 2007). Lessons are drawn from ongoing attempts to implement IWRM and improve WASH governance and specific practical recommendations are made for overcoming institutional obstacles that have been identified.

Climate change and water: current state of knowledge

The opening statement of the IPCC's Sixth Technical Report on Climate Change and Water (IPCC, 2008) asserts that: "Observational records and climate projections provide abundant evidence that freshwater resources are vulnerable and have the potential to be strongly impacted by climate change, with wide-ranging consequences for human societies and ecosystems". Specific findings and recommendations in this report, relevant to WASH services delivery, are summarised below. Please note that the text in brackets refers to the IPCC's system for classifying uncertainty[2]:

- **Climate model simulations for the 21st century are consistent in projecting precipitation increases in high latitudes (very likely) [3] and**

[1] *Slippage* refers to WASH services that have slipped back from being acceptable (e.g. in excess of government norms) to being unacceptable. The can be many different cause of slippage (e.g. poor O&M of WASH infrastructure, increases competition for limited water resources, insufficient finance for proper design of institutional capacity building etc).

[2] A detailed explanation of the IPCC uncertainty classification system can be found in IPCC (2008).

[3] Where uncertainty in specific outcomes is assessed using expert judgement and statistical analysis of a body of evidence (e.g., observations or model results),

parts of the tropics, and decreases in some sub-tropical and lower mid-latitude regions (likely). Outside these areas, the sign and magnitude of projected changes varies between models, leading to substantial uncertainty in precipitation projections. Thus projections of future precipitation changes are more robust for some regions than for others. Projections become less consistent between models as spatial scales decrease.

- **By the middle of the 21st century, annual average river runoff and water availability are projected to increase as a result of climate change at high latitudes and in some wet tropical areas, and decrease over some dry regions at mid-latitudes and in the dry tropics.** Many semi-arid and arid areas (e.g. the Mediterranean Basin, southern Africa) are particularly exposed to the impacts of climate change and are projected to suffer a decrease of water resources due to climate change (high confidence)[4].
- **Increased precipitation intensity and variability are projected to increase the risks of flooding and drought in many areas.** The frequency of heavy precipitation events (or proportion of total rainfall from heavy falls) will be very likely to increase over most areas during the 21st century, with consequences for the risk of rain-generated floods. At the same time, the proportion of land surface in extreme drought at any one time is projected to increase (likely), in addition to a tendency for drying in continental interiors during summer, especially in the sub-tropics, low and mid-latitudes.

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then the following likelihood ranges are used to express the assessed probability of occurrence: virtually certain >99%; extremely likely >95%; very likely >90%; likely >66%; more likely than not >50%; about as likely as not 33% to 66%; unlikely <33%; very unlikely <10%; extremely unlikely <5%; exceptionally unlikely <1%.

4 Where uncertainty is assessed more quantitatively using expert judgement of the correctness of the underlying data, models or analyses, then the following scale of confidence levels is used to express the assessed chance of a finding being correct: very high confidence at least 9 out of 10; high confidence about 8 out of 10; medium confidence about 5 out of 10; low confidence about 2 out of 10; and very low confidence less than 1 out of 10.

- **Water supplies stored in glaciers and snow cover are projected to decline in the course of the century**, thus reducing water availability during warm and dry periods (through a seasonal shift in streamflow, an increase in the ratio of winter to annual flows, and reductions in low flows) in regions supplied by melt water from major mountain ranges, where more than one-sixth of the world's population currently live (high confidence).
- **Higher water temperatures and changes in extremes, including floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution** – from sediments, nutrients, dissolved organic carbon, pathogens, pesticides and salt, as well as thermal pollution; with possible negative impacts on ecosystems, human health, and water system reliability and operating costs (high confidence). In addition, sea-level rise is projected to extend areas of salinisation of groundwater and estuaries, resulting in a decrease of freshwater availability for humans and ecosystems in coastal areas.
- **Globally, the negative impacts of future climate change on freshwater systems are expected to outweigh the benefits (high confidence).** By the 2050s, the area of land subject to increasing water stress due to climate change is projected to be more than double that with decreasing water stress. Areas in which runoff is projected to decline face a clear reduction in the value of the services provided by water resources. Increased annual runoff in some areas is projected to lead to increased total water supply. However, in many regions, this benefit is likely to be counterbalanced by the negative effects of increased precipitation variability and seasonal runoff shifts in water supply, water quality and flood risks (high confidence).
- **Climate change affects the function and operation of existing water infrastructure – including hydropower, structural flood defences, drainage and irrigation systems – as well as water management practices.** Adverse effects of climate change on freshwater systems aggravate the impacts of other stresses, such as population growth, changing economic activity, land-use change and urbanisation (very high confidence). Globally, water demand will grow in the coming decades, primarily due to population growth and

increasing affluence; regionally, large changes in irrigation water demand as a result of climate change are expected (high confidence).

- **Current water management practices may not be robust enough to cope with the impacts of climate change** on water supply reliability, flood risk, health, agriculture, energy and aquatic ecosystems. In many locations, water management cannot satisfactorily cope even with current climate variability, so that large flood and drought damages occur. As a first step, improved incorporation of information about current climate variability into water-related management would assist adaptation to longer-term climate change impacts. Climatic and non-climatic factors, such as growth of population and damage potential, would exacerbate problems in the future (very high confidence).
- **Climate change challenges the traditional assumption that past hydrological experience provides a good guide to future conditions.** The consequences of climate change may alter the reliability of current water management systems and water-related infrastructure. While quantitative projections of changes in precipitation, river flows and water levels at the river-basin scale are uncertain; it is very likely that hydrological characteristics will change in the future. Adaptation procedures and risk management practices that incorporate projected hydrological changes with related uncertainties are being developed in some countries and regions.
- **Adaptation options designed to ensure water supply during average and drought conditions require integrated demand-side as well as supply-side strategies.** The former improve water-use efficiency, e.g., by recycling water. An expanded use of economic incentives, including metering and pricing, to encourage water conservation and development of water markets and implementation of virtual water trade, holds considerable promise for water savings and the reallocation of water to highly valued uses. Supply-side strategies generally involve increases in storage capacity, abstraction from water courses, and water transfers. Integrated water resources management provides an important framework to achieve adaptation measures across socio-economic, environmental and administrative systems. To be effective, integrated approaches must occur at the appropriate scales.
- **Mitigation measures can reduce the magnitude of impacts of global warming on water resources, in turn reducing adaptation needs.** However, they can have considerable negative side effects, such as increased water requirements for afforestation/reforestation activities or bio-energy crops, if projects are not sustainably located, designed and managed.
- **Water resources management clearly impacts on many other policy areas**, e.g., energy, health, food security and nature conservation. Thus, the appraisal of adaptation and mitigation options needs to be conducted across multiple water-dependent sectors. Low-income countries and regions are likely to remain vulnerable over the medium term, with fewer options than high-income countries for adapting to climate change. Therefore, adaptation strategies should be designed in the context of development, environment and health policies.
- **Several gaps in knowledge exist in terms of observations and research needs related to climate change and water.** Observational data and data access are prerequisites for adaptive management, yet many observational networks are shrinking. There is a need to improve understanding and modelling of climate changes related to the hydrological cycle at scales relevant to decision making. Information about the water related impacts of climate change is inadequate – especially with respect to water quality, aquatic ecosystems and groundwater – including their socio-economic dimensions. Finally, current tools to facilitate integrated appraisals of adaptation and mitigation options across multiple water-dependent sectors are inadequate.
- **Global mean sea level has been rising and there is *high confidence* that the rate of rise has increased between the mid-19th and the mid-20th centuries.** The average rate was 1.7 ± 0.5 mm/ yr for the 20th century, 1.8 ± 0.5 mm/yr for 1961–2003, and 3.1 ± 0.7 mm/yr for 1993–2003. It is not known whether the higher rate in 1993–2003 is due to decadal variability or to an increase in the longer-term trend. Spatially, the change is highly non-uniform; e.g., over the period 1993 to 2003, rates in some regions were up to several

times the global mean rise while, in other regions, sea levels fell.

Complexity aside, three important conclusions can be drawn from this summary: i) there are good reasons for the WASH sector to be concerned about the potential long-term impacts of climate change; ii) the WASH sector should become more actively involved in climate change research and debate; and iii) there is a great deal of uncertainty in the findings that increases as spatial scales decrease to those at which most WASH planning processes take place.

As will be discussed later in this paper, although raising awareness of climate change issues in the WASH sector will take time, it is a fairly straightforward task. Similarly, given sufficient resources, a more active involvement of the WASH sector in climate change can easily be achieved. Therefore, the fundamental challenge facing the WASH sector is to ensure that the uncertainty linked to climate change is effectively considered during WASH governance processes. This is in a situation where WASH governance systems are already struggling to take proper account of and adapt to societal, economic and environmental conditions that, in the absence of climate change, are already characterised by high levels of uncertainty, variability and change.

Finally, this paper assumes that there is considerable scope for improving WASH governance worldwide and, thereby, for taking better account uncertainty, variability and change regardless of the root causes. This requires development and/or strengthening of water governance capacity (e.g. in the use of: information systems, stakeholder platforms, legal and regulatory mechanisms, executive capabilities, conflict resolution systems and techniques such as scenario building) to enable society to respond and adapt to uncertainty, variability and change that could be local or regional, short or long term, political, economic, or environmental.

2 Potential impacts of climate change on WASH service delivery

According to the World Health Organization (WHO) and UNICEF Joint Monitoring Programme, the state of water-supply and sanitation services worldwide is a source of concern in several respects (WHO-UNICEF, 2009):

- Globally, 1 billion people are currently without access to improved water supply and 2.6 billion have no form of improved sanitation services. Most of these people live in Asia and Africa. In Africa, for example, 2 out of 5 people lack an improved water supply;
- Significant disparities exist between rural and urban services, which continue to contribute to the burden of life in rural areas. People who live in the informal, overcrowded peri-urban settlements spawned by urbanization, also have especially low coverage;
- Increasingly, surface and groundwater sources are being polluted by pesticides, and by industry and untreated household waste water;
- The over-extraction of water for agriculture and manufacturing, which causes the water table to decline, is another bad practice, which threatens the sustainability of these resources in many parts of the world.

Placing the potential impacts of climate change within this undeniable context supports the argument that climate change has not been a major contributory factor to the unacceptable WASH service levels that currently exist in many parts of the world. The fundamental causes of current WASH sector challenges are more closely linked to factors that include: poor governance, lack of capacity, urbanization, increasing population, increasing competition for limited safe water resources, lack of accountability and insufficient expenditure on, for example, O&M. As the recent GLAAS report (WHO 2008) indicates, the capacity of the WASH sector to even carry out its core mandate of service provision is very poor, particularly at the decentralised (local government) level. A similar view is expressed in the draft Climate and Water Report from the 2008 World Water Week. This report states: “The relative impact of climate change needs to be considered against the demands and threats to water resources from increasing wealth and consumption, and growing populations.” Figure 1 summarises potential direct and indirect impacts of climate change on the different components of water supply systems as represented by a Resources, Infrastructure, Demand and Access (RIDA) framework schematic. The RIDA framework has been used because it highlights the fact that water sources (i.e. resources) are linked to the demands of users

Resources /Natural environment		Infrastructure		Demand		Access	
Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
* Rainfall increases in high latitudes and parts of the tropics, and decreases in some sub-tropical and lower mid-latitude regions. * Increased precipitation intensity and variability increases the risks of flooding and drought in many areas. * Water supplies stored in glaciers and snow cover are reduced. * Higher water temperatures affect water quality and exacerbate many forms of water pollution. * Global mean sea level rises and contributes to saline intrusion in to coastal aquifers. * Frequency of extreme temperatures (hot and cold) increases.	* Land use change and agricultural intensification lead to changes in hydrology at local and basin scales. *In areas of lower rainfall, water quality of rivers and groundwater decreases as a result of reduced dilution of pollutants. * Risk increases unsustainable use of surface and groundwater resources. *In areas of groundwater-level decline, increase in groundwater pollution from natural contaminants (e.g. fluoride, arsenic) *Warmer and damper conditions increase the incidence of many water-borne diseases.	*Major investments are needed in flood protection and re-engineering of dam spillways. *Major investments are needed to increase the capacity of storage, supply and treatment systems. *Major investments are needed to supply WASH services to people migrating from flooded coastal areas or areas of absolute water scarcity. *Destruction of WASH infrastructure and contamination of groundwater occur as a result of localized flooding. *Increased energy costs and a shift to low-carbon policies lead to major increases in the operating costs of WASH systems.	*Anarchy leads to water theft and major damage to reticulation systems. *Break down in law and order occurs at water supply points as a result of conflict between migrants and existing users. *Major increases in investment in irrigation infrastructure to increase food supplies leads to less water for urban use. *High levels of expenditure on WASH infrastructure to meet WASH crises are accompanied by low levels of financial accountability.	*Contribution to increased demand for safe water results from prolonged drought, increasing temperatures etc. *Demand increases for MUS activities using water from WASH infrastructure e.g. for livestock as a result of failure of traditional water sources. *Increased demand for irrigation and for rainfed farming (including demand for irrigated biofuels) increases competition between WASH and agricultural sectors.	*Reallocation of water from agricultural to urban use leads to social unrest in rural areas and to decreased food production. * Interest increases in all types of demand management, regulatory instruments etc. *Increased demand leads to increased concerns over maintenance of ecological flows and protection of rare habitats. *Increased demand leads to increased challenges of water treatment and sewage sludge disposal.	*Increasing challenge of ensuring access to WASH services is consistent with established norms during periods of drought. *WASH service provision to poorer social groups, especially in areas affected by flooding or sea-level rise, is a major. *The poor increasingly rely on unregulated provision of water by private vendors. *Allocation of water for aquatic ecosystems and maintenance of rare habits is less than required.	*Many kinds of livelihood problems result from rapid climatic change to which adaptation may be difficult or even impossible * Possible increased risk of capture of water resources by elite social groups * There is a possibility failure on the part of regulatory systems and/or legislation aimed at protecting rights of individuals or community to access water for different uses.

Figure 1: Potential direct and indirect impacts of climate change.

by supply (and water treatment) infrastructure. The access component is used to emphasise the fact that user access to water services is often less than the demand quantified in terms of politically-acceptable norms. Figure 1 draws attention to several important points:

- Climate change has the potential to impact on all the components of a water supply system (i.e., not just the sources of water) and that these potential impacts can be varied in nature;
- Some potential impacts are likely to be direct and very obvious (e.g. increased incidence of extreme floods that damage WASH infrastructure), whereas others are likely to be indirect and more uncertain in nature and severity (e.g. sea level rise leading to migration away from coastal areas);
- Given the range and uncertainty of climate impacts, there will not be unique strategies for mitigating or adapting to climate change. The challenge will be development of water governance systems, which ensure that strategies are based on a solid understanding of the impacts of climate change on the different components of individual WASH services delivery systems.

How should the WASH sector prepare for potential climate change impacts?

Clearly, a first step is for the WASH sector to engage more effectively with climate change researchers and in relevant research programmes. The benefits of this approach are twofold. First, this will ensure that discussions on the potential impacts of climate change on the WASH sector avoid the shortcoming of considering these impacts in isolation of all the other challenges currently facing the sector. Second, this will also ensure that development of new recommendations draws upon lessons (both positive and negative) learnt through past and ongoing attempts to meet existing WASH challenges. This will increase the likelihood of new initiatives being successful and reduce the risk of mistakes being repeated.

The next step should be to decide whether there are specific actions, changes of practice or interventions that are required to mitigate and adapt to potential climate change impacts. Review of climate change literature (e.g. IPCC, 2008) suggests that most of the proposed solutions to climate change fall neatly under the heading of 'Business as usual – but better' (e.g. increase storage, manage demand, improve governance, adopt principles of IWRM etc). Obviously, potential impacts of climate change might require an increased emphasis on certain actions or interventions (for example, recognition of potential impacts of climate change could add weight to arguments for increased funding for drought preparedness or for enforcing stricter planning regulations against siting WASH infrastructure in areas prone to flooding). Nonetheless, it is clear that rather than try to develop innovative technologies or quick fixes for tackling climate change impacts, the WASH sector should put the bulk of its long-term effort into:

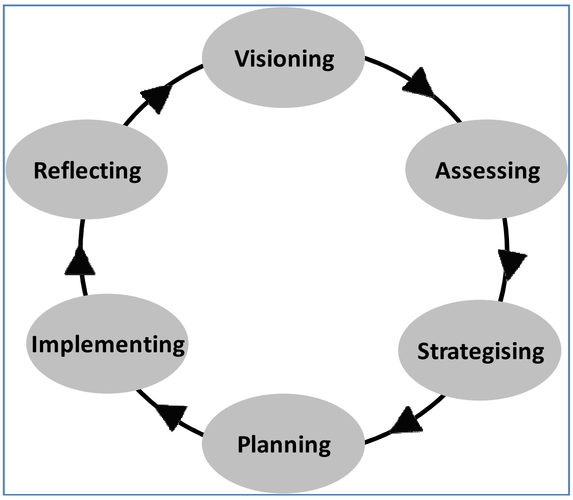
- **Improving WASH governance systems** so that they are better able to take account of the increased uncertainty that can be attributed to climate change. Also governance systems are required that explicitly match actions and interventions to specific contexts and take explicit account of potential externalities;
- **Adopting and implementing IWRM** so that there is better alignment of plans across the whole water sector and other sectors that have an influence on water supply (e.g. the power sector) and demand for WASH services (e.g. planning departments);
- **Adopting principles of adaptive management**. Adaptive management is based on the recognition that in a complex and rapidly changing situation there can never be sufficient information to reach a settled 'optimum' decision. Hence, the WASH sector should put effort into planning approaches that are and supported by strong monitoring and information management systems, which allow for constant adaptation and the upgrading of plans and activities;
- **Strengthening capacity** within the WASH sector, particularly at the intermediate and local levels.

Improved WASH governance

Improving WASH governance is not a trivial matter as indicated by the fact that ongoing attempts to improve WASH governance are having very mixed results. What is clear is that achieving good WASH governance cannot be undertaken hastily using blueprints from outside any given county or region. Good governance needs to be developed to suit local conditions. Incremental improvement and flexibility is key. WASH sector reforms do not have to be implemented in a comprehensive or fully integrated way. However, they do have to workable and doing a few things well to demonstrate that new approaches work. This approach is both pragmatic and likely to generate public and political support.

A practical generic means of improving WASH governance is to adopt project cycle management (PCM) as a framework for stakeholder dialogue, decision making and adapting to change. PCM emphasises the need to put decision making within a clearly defined set of iterative steps that ensure that the decisions reached are based on evidence and a clear and logical flow of thought.

PCM acknowledges that there will always be multiple paths to resolving problems and achieving visions[5]. In other words, there is no 'objectively' 'best' or 'optimum' strategy for achieving a vision. Deciding between different strategies is always a political issue. Such decisions should, nonetheless, be based on a reasonably thorough identification of externalities and sources of uncertainty; which in turn should, as much as possible, be based on a clear and logically consistent interpretation of existing and likely future conditions.



Although many versions exist, a typical project cycle[6] is made up of the following phases:

Visioning – Initial problem identification, visioning, and scenario building
Assessing – Targeted data collection and analysis; creation of a shared information base
Strategising – Development of strategies to meet the vision under different scenarios
Planning – Detailed planning based on most likely scenarios and related strategies
Implementing – Execution of plans
Reflecting – Analysis of monitoring information and process documentation to inform further cycles to promote institutional learning

The PCM approach ensures that explicit account is taken of risk and uncertainty, and that decisions are based on a cycle of continuous adaptation or learning. Another generic means of handling risk and uncertainty is using scenario building as an integral part of planning processes. In the context of WASH governance, the main purpose of scenario building is to identify, evaluate and take explicit account of a whole range of uncertain factors that might either support or derail strategies aimed at improving WASH service provision. Equally important, the approach helps stakeholders think creatively about important and uncertain factors over which they have no or very limited control (e.g. climate change). The net result should be that stakeholders are less likely to fear or ignore these factors and are more likely to consider how they could thrive in a range of future settings. Some of these future settings may be strikingly different to anything that they have ever experienced.

Integrated water resources management (IWRM)

IWRM is being promoted by many organisations, implemented in some areas and piloted in others. A huge effort involving the reform of water laws, institutions and capacity building is underway based upon the IWRM 'recipe'. However, in much of the world, it remains business as usual (Moriarty et al, 2004).

A definition of IWRM, that is in common usage, is as follows: "IWRM is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an

[5] In this context, a *vision* is a concise description of a desired future state.

[6] For a detailed discussion of PCM please see the EMPOWERS Water Governance Guidelines: www.empowers.info.

equitable manner without compromising the sustainability of vital ecosystems (GWP, 2000)". In one form or another, the three concepts of equity, efficiency and sustainability are present in almost all definitions of IWRM. IWRM aims to:

- Promote more equitable access to water resources and WASH services;
- Ensure that scarce water is used efficiently with priority going to meeting basic human needs;
- Achieve more sustainable utilisation of water including for a better environment.

A fourth key concept is that of process. IWRM is a process of getting from some existing state to some envisaged and preferred future state, by achieving commonly agreed principles or best practice in managing water through the involvement of all relevant stakeholders.

The political naivety of IWRM has been denounced by Biswas (2004) because of discrepancy between the concept of integrated management and actual political institutions and property rights. The Global Water Partnership toolbox on IWRM (GWP, 2003) also states that when social actors try to put IWRM into practice, "they are faced with the apparently insurmountable difficulty of bringing together a very intricate socioeconomic reality, the legacy of the past and its ingrained practices and beliefs, and the apparently non-reconcilable conflicting demands". Yet the vagueness of the means by which IWRM might be achieved does not remove all utility from the IWRM concept nor should it be used as an excuse to regress into out-dated technocratic governance. IWRM continues to inspire many adherents amongst international agencies and, like the equally elusive concept of 'sustainability', it has inspirational value as an ideal goal or direction for improvement of water governance.

Strengthening WASH sector capacity

Capacity, or rather lack of capacity in the WASH sector, is a key issue and often a limitation to tackling both immediate and longer-term challenges. Any attempt to improve WASH governance must grapple with operational realities of capacity and other resource constraints, particularly at the intermediate and local levels, and with reluctance or resistance to change. In some cases, unwillingness to change may be for valid reasons, in others the reasons may be linked to issues of integrity and accountability. It is clear, however, that significant improvements in the WASH sector worldwide will not be achieved without strengthening capacity. Clearly, in the context of climate change, a carefully-targeted awareness campaign is needed. This should to be informative and recognise that climate change is just one of many important and uncertain challenges faced by WASH professionals working in the public and private sectors. Similarly, carefully-targeted capacity strengthening programmes that are appropriate to WASH professionals working in different roles and at different institutional levels need to be developed and implemented.

Those involved in climate change research have a very important role to play in capacity strengthening. This includes presenting information in forms and formats that can be easily understood by non-specialists. It is also important that information be provided at scales relevant to typical decisions made in the WASH sector, so that information can be used, for example, in scenario building at the local and intermediate institutional levels.

Conclusions and recommendations

The current state of 'climate change and water' knowledge can be summarised simplistically as follows:

- Precipitation will increase in high latitudes and parts of the tropics, and decrease in some subtropical and lower mid-latitude regions;
- Annual average river runoff and water availability are projected to increase in high latitudes and in some wet tropical areas, and decrease over some dry regions at mid-latitudes and in the dry tropics;
- Increased precipitation and variability intensity will increase the risks of flooding and drought in many areas;
- Water supplies stored in glaciers and snow cover are projected to decline as will dry-season river flows based on snow melt;
- Higher water temperatures and changes in extremes, including floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution;
- Global mean sea level has been rising;

- Climate change challenges the traditional assumption that past hydrological experience provides a good guide to future conditions

There is a high-level of uncertainty in climate change predictions that increases at the scales at which WASH decisions are generally made. It is recommended, therefore that the WASH sector focuses its attention on improving WASH governance and, more specifically, on methods, approaches and tools that support and improve decision-making processes by enabling groups of stakeholders to take explicit account of risk and uncertainty.

Solutions to climate change tend to be the same as those advocated for tackling more immediate WASH challenges. However, solutions being advocated with particular evangelical vigour in the climate change literature have already been shown to have limited scope for tackling WASH challenges, and/or to have significant negative tradeoffs when implemented at scale. It is recommended that WASH professionals become more involved in climate change research so that a more rigorous vetting of 'solutions' takes place.

Finally, it is recommended that a climate change thematic network be established within the WASH sector for better exchange of views on climate change and to promote a more active engagement of the sector in climate change research programmes, workshops and policy fora.

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World Water Council
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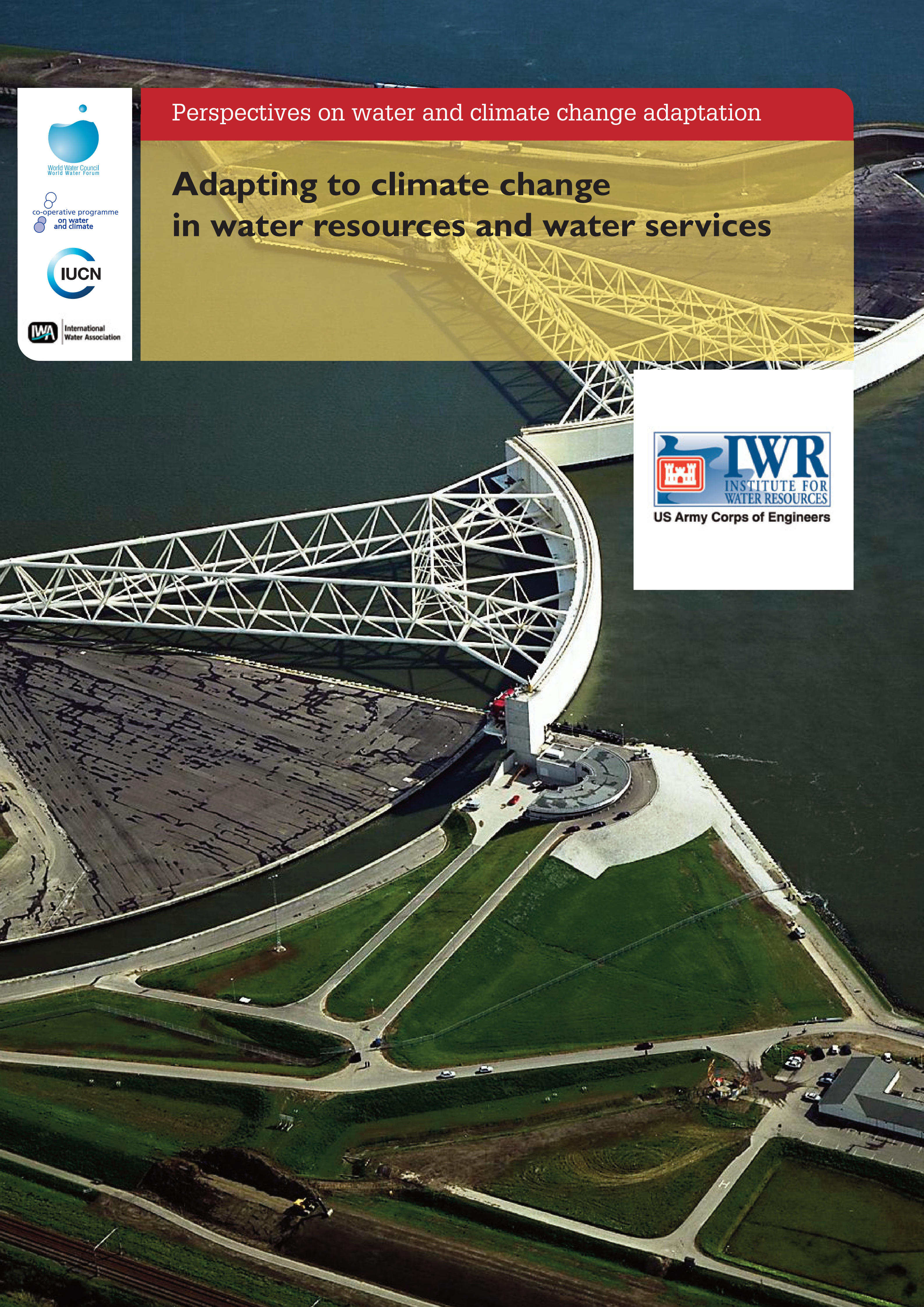
co-operative programme on water and climate

IUCN

IWA International Water Association

Perspectives on water and climate change adaptation

Adapting to climate change in water resources and water services



IWR INSTITUTE FOR WATER RESOURCES
US Army Corps of Engineers

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

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

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

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

Participants were invited to contribute perspectives from three categories:

1 **Hot spots** – These papers are mainly concerned with specific locations where climate change effects are felt or will be felt within the next years and where urgent action is needed within the water sector. The hotspots selected are: Mountains (number 1), Small islands (3), Arid regions (9) and 'Deltas and coastal cities' (13).

2 **Sub-sectoral perspectives** – Specific papers were prepared from a water-user perspective taking into account the impacts on the sub-sector and describing how the sub-sector can deal with the issues. The sectors selected are: Environment (2), Food (5), 'Water supply and sanitation: the urban poor' (7), Business (8), Water industry (10), Energy (12) and 'Water supply and sanitation' (14).

3 **Enabling mechanisms** – These documents provide an overview of enabling mechanisms that make adaptation possible. The mechanisms selected are: Planning (4), Governance (6), Finance (11), Engineering (15) and 'Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA)' (16).

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

15 Adapting to climate change in water resources and water services

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Adapting to climate change in water resources and water services

Access to potable water, sanitation and water for irrigation is already a serious problem in the developing world, especially in the vast semi-arid regions of Central Asia and Africa, and is expected to become even more serious as population growth and climate change exacerbates existing inadequate delivery systems and dysfunctional management institutions. The Millennium Development Goals (MDGs) have set very ambitious targets. The principles and practices of contemporary water management are well known and have adapted reasonably well to technological advances, institutional prerogatives and public preferences in the developed world. Yet the gap between water resources availability and needs grows inexorably in the developing world. Is it the failure of water managers, or the lack of adequate investment or failure to adopt new technologies, or is it a failure at a more elemental level; the failure of institutions and the technical capacity to implement solutions and to manage those investments wisely? There is a consistent storyline in the recent literature, such as the reports of the Intergovernmental Panel on Climate Change (IPCC; Bates et al, 2009) that: 'current water management practices may not be robust enough to cope with the impacts of climate change on water supply reliability, flood risk, health, agriculture, energy and aquatic systems.' The issue is whether it is water management that is not robust enough or the socio-political institutions within which water managers operate?

It stands to reason, based on the predictions of the Fourth IPPC (2007), that water resources will be among the most affected sectors by changes in climate. When coupled with population growth and serious economic circumstances, climate change is an additional, highly uncertain and variable factor that exacerbates the difficulties that developing nations have in achieving the MDGs, not even speaking of sustainable development. In order to set out on the glide path that is sustainable development, one must first climb out of poverty. Widespread poverty is perhaps the greatest barrier to systematic adaptation. The combination of high population growth and global economic disruptions, coupled with endemic poverty comprise an extraordinarily difficult set of barriers to overcome. A recent report that provides the status of 16 Sub-Saharan African countries in meeting the MDGs on water and sanitation (2006) clearly demonstrates how far these countries need to go simply to achieve the needs of the current population. Climate change, associated with global warming merely adds to those difficulties.

Water resources management, which has evolved with its core principles of adaptive management – i.e. adapting to the risk and uncertainty of considerable climate variability – has employed a variety of tools in different combinations to reduce vulnerability, enhance system resiliency and robustness and provide reliable delivery of water-related services. These tools consist of many technological innovations, engineering design changes, multi-objective watershed planning, public participation, regulatory, financial and policy incentives. However, well-functioning institutions are needed to effectively administer this broad array of fairly complex, dispersed and expensive combinations of management measures. Hence, tackling the central issue of 'governance' is a key aspect of any strategy that intends to deal with climate change adaptation. IWRM is the management framework for achieving sustainable development. Governance and IWRM are the principal means for resolving competition among multi-sectoral demands on a fixed water resources base. Each sector (environment, water supply, sanitation, agriculture, hydropower, navigation/transportation) fashions its own set of management principles, rules and incentives that are maximized, often in conflict with one another.

Hence, the fundamental issue is not *whether* adaptation ought to occur, because it is already an integral part of water resources management, but when and how we must adapt more effectively. Those questions can be responsibly answered only by consideration of the costs and ultimate benefits of the adaptive measures, the risks and uncertainties inherent in any strategic planning initiative, and the availability of innovative technologies that can be brought on line in the near future through increased investments in research and development. Many problems exist today because water is misallocated, wasted and priced incorrectly. These defects are being slowly but steadily rectified in all aspects of water management. The deficiencies in the current water management systems should not be confused with an inability to adapt technically feasible solutions to changing conditions. The availability, relative effectiveness, and technical implementability of virtually all water management options is very well known. That is because water resources managers have been conducting economic and financial analyses of their projects and systems for nearly 50 years. Of course, the ultimate success depends on the capacity of any individual country to adapt the wide range of existing management resources.

This failure to differentiate between the technical feasibility of various adaptive measures and the relative capacity to implement well-known, accepted and relatively conventional water management practices, has lead to considerable confusion in the debate about the relative susceptibility of societies to the socioeconomic consequences of climate change. Ironically, developing nations in water-rich areas often have a more difficult time implementing conventional water supply measures to meet rapidly increasing water demand due to rapid population growth, than those countries in arid or semi-arid areas that are constantly faced with scarcity. In most countries that already have a water delivery system in place for irrigation, a reduction of 10 per cent of the water currently going to agriculture would meet the increasing demands of cities and industries through to the year 2025. In countries where such water delivery systems are poorly developed because of the abundance of naturally available surface water supply, their susceptibility may increase because of water pollution, increased demands and poor management practices.

Even without climate change, most developing nations will not be able to provide for the water resources needs of their growing populations because of lack of technical capacity, economic resources and socio-political instability. Clearly, we have to focus our attention on the developing world with strategies that fall into four basic categories:

1. Develop large-scale water infrastructure that will provide the needed buffering capacity, robustness and resilience to withstand the vagaries of climate variability and change;
2. Focus on 'small is beautiful' (and inexpensive) strategies for villages and remote rural areas, using appropriate technologies;
3. Concentrate on upgrading technical and institutional management capacities at all levels;
4. Continue to focus on developing and transferring technological innovations that, hopefully, will keep pace with population growth and provide an extra degree of resiliency to help coping strategies.

Ongoing efforts

Literally hundreds of efforts are underway at many levels of government, and within numerous international institutions devoted to preparing for adaptation to climate change (Heinz Center, 2006), especially in the water resources sector (e.g. Hashimoto Action Plan and the High-Level Expert Panel on Water and Disaster of the UN Secretary-General's Advisory Board on Water and Sanitation (UNSGAB)). These initiatives, coupled with a strong emphasis on IWRM offers considerable impetus for implementing effective adaptation. Since the 'Dialogue on Water and Climate' (Kabat et.al, 2003), followed by the report of the Intergovernmental Panel on Climate Change (IPCC, 2007), there has been a sea change in attitude and realization that, regardless of how effective mitigation efforts might be in reducing greenhouse gases, the various water resources management sectors must at least engage in preparatory initiatives to cope with the anticipated adverse changes associated with predicted climate change impacts. Such influential institutions as the World Bank (2008) and the U.S. Army Corps of Engineers (2008) have initiated substantive programmes to review their existing infrastructure and pending investments with respect to adaptability to increased climate variability and potential changes. These institutions along with many other countries, such as the Netherlands and Japan, and the European Union and UN agencies, such as UNESCO, FAO, and UNDP, are engaged in a concerted and coordinated effort to provide technical advice for their own institutions, and client agencies and ministries, as well as providing the basis for capacity building for the rest of the world.

One such clear example was the United States response to Hurricanes Katrina and Rita, which exposed and highlighted the monumental challenges in responding to large-scale disasters. It has motivated the Corps of Engineers to take serious stock of its planning and engineering methods, and standards for evaluating, managing and responding to extreme events, and how they might be dealt with as part of climate scenarios that reflect different degrees of change from our historical expectations. It is often the case that great catastrophes, such as floods, droughts and infrastructure failures, catalyze both political and technical changes in attitude and performance and serve as the platform for a new generation of approaches. Because climate change, like drought, is a 'creeping', slowly evolving phenomenon, it will not serve to catalyze actions. Hence, the Secretary of the Army (2007) adopted a pragmatic 'proactive adaptive management' approach, comparable to the 'no regrets' philosophy espoused by many advocates of climate change adaptation, consisting of the following elements:

- Risk-based planning and design of infrastructure to account for climate uncertainties;
- Development of a new generation of risk-based design standards for infrastructure; responding to extreme events (floods and droughts);
- Life-cycle management of aging infrastructure;
- Vulnerability assessment of water infrastructure;
- Increased inspections, oversight and regulation of infrastructure during operation and maintenance;
- Increased research and development oriented towards climate change and variability;
- Develop improved forecasting methods for improved reservoir and emergency operations;
- Strengthen interagency collaboration for developing joint procedures and applied research for adapting to climate change;
- Strengthen emergency management and preparedness plans for all Corps projects and assist local communities in upgrading their plans and participation.

The World Bank's (2008) Strategic Framework on Climate Change and Development (SFCCD) recognizes water as the sector that will be most significantly affected by climate change. Each Bank region is likely to face a unique set of water-related climate change challenges, deriving from such impacts as: accelerated glacier melt; altered precipitation, runoff and recharge patterns and rates; extreme floods and droughts; water quality changes; saltwater intrusion in coastal aquifers; and changes in water uses. Potential adaptation strategies to the impacts of climate change on water resources have become central to the dialogue on water policy reforms and investment programmes with client countries. In order to complement regional efforts already underway, and to support future regional initiatives, the World Bank has undertaken a multi-year effort on Climate Change and Water. The main objective is to provide the analytical, intellectual and strategic assistance to regions for incorporating adaptation to climate variability change in their work programmes. The work focuses on water and water-related issues and investments, while addressing relevant linkages with other sectors. A particular focus will be on reducing the vulnerability of sector investments in both water delivery services and water management to the impacts of climate change. Final products will also include adaptation options for increased robustness and resiliency of water systems to climate variability/change, numerous case studies, and a series of thematic papers on water and climate change. It is hoped that this work will help enhance knowledge and understanding of both Bank water staff and client country professionals for making better-informed decisions regarding water investments.

As part of the Bank's assessment of its water portfolio, it conducted a review of the Bank's investments in water over the period 2006–09 taking into account the potential linkages to climate variability and change. More specifically, the objective was to:

1. Assess the World Bank's current portfolio and pipeline in the water sector, identifying the financing directed to the different water systems (services and resources);
2. Analyse how many Bank projects acknowledge climate variability or change in the project documents, including any mitigation or adaptation mentioned in project documents at the project design stage;

3 Identify the Bank's water portfolio and pipeline that may be exposed to the hydrologic aspect of climate change.

These three efforts alone, coupled with those of the European Union and individual nations such as the Netherlands and Japan, will serve as the backbone of a rapidly evolving practical adaptive management strategy.

Elements of adaptation to climate change

Many excellent reports and studies exist on adaptation to climate change for each of the sectors that are expected to be affected (water resources, forestry, ecology, agriculture, urban areas, etc.). Among the best, providing sensible advice on adaptation to climate change in the water resources sectors is the 'Dialogue on Water and Climate' (2003). Within these reports, a consensus has been reached that global warming will generate a series of foreseeable but highly uncertain hydroclimatic consequences, which will have impacts on water availability and, consequently, on water management.

From a technological and engineering standpoint, water managers have routinely dealt with the uncertainties and vagaries of historical climate variability fairly well, but have had much greater difficulties with the institutional and policy aspects of water management, particularly in developing countries. Water availability and vulnerability to natural hazards and uncertainties is more of an institutional failure than it is of engineering design or coping with hydrologic uncertainty. Water managers are used to dealing with risks, hydrologic uncertainties and competing demands. They can build new infrastructure, upgrade and rehabilitate existing infrastructure, as well as reduce vulnerability and increase resiliency and robustness. But water managers are not the policy-makers and politicians who are responsible for establishing the enabling environment and providing the resources within which integration of different water-using sectors can be coupled with the economic and financial incentives to 'climate-proof' communities. Much of the available academic literature routinely confuses the two issues, while dismissing the confounding and more dominant effect of population growth, indirectly suggesting that water managers cannot keep up with the combination of reduced supplies and increased demands.

What can be done by water managers to prepare – i.e. set the stage for adaptation with the resources and options that are under their control? In fact many steps can be taken, based entirely on conventional methods and ideas. One does not need to resort to or depend on IWRM, even though the various approaches rely on concepts and elements that are comparable to the principles of IWRM. In the long term, having the institutional infrastructure that supports IWRM would clearly assist the implementation and sustainability of climate adaptation efforts, and ensure that they are compatible with and complement the broader goals of sustainable development. It is important to begin the pursuit of both initiatives, IWRM and climate adaptation, even though both are very complex and difficult even for developed nations to implement. The pursuit of a perfect complementary system should not divert the implementation of a series of useful preparatory 'first steps' in climate adaptation.

Integrated Water Resources Management (IWRM)

IWRM is the long-term institutional basis upon which climate change adaptation can be sustained through the coordination of numerous adaptive management strategies in water-related sectors. The ideal IWRM framework advocates a few essential components/prerequisites:

1 National water management plan, and/or river basin management plan;
2 National water policy/ water code;
3 Harmonization of the policies, regulations and decisions at all levels of government;
4 Institutional infrastructure that can make consistent decisions and assure progress; manage and monitor resources and effectively deliver services;
5 Establishment of river basin management authorities.

The essential purpose of IWRM is to manage water more efficiently (use less water, more value per drop, conserve) and effectively (delivery of reliable services, improved performance in each sector). IWRM requires the harmonization of policies, institutions, regulatory frameworks (permits, licenses, monitoring), planning, operations, maintenance, and design standards of numerous agencies and departments responsible for one or more aspects of water and related natural resources management. Water management can work effectively (but not efficiently) in fragmented institutional systems (such as the federally-based systems of the United States, Brazil and Australia, for example), where there is a high degree of decision-making transparency, public participation, and adequate financial support for planning and implementation. It does not work well in most other cases where these prerequisites do not exist. Setting up the proper institutional framework is the first step towards IWRM.

Long-term, sustainable adaptation to climate change will require a series of progressively integrated measures to be implemented, consisting of infrastructure, policy instruments, economic adaptation and behavioral changes. These measures will vary with the degree of development in a particular country, and present anticipated vulnerability to the effects of climate variability, expressed as the change in the frequency and magnitude of floods and droughts. IWRM is the organized, orderly process by which adaptation to changes in population, demands, economic conditions and climate change can be addressed in a comprehensive manner. The foundations of IWRM not only serve contemporary problem-solving, but comprise the platform for adaptation in the future. However, having a well-developed IWRM infrastructure in place is *not a prerequisite* to initiating an adaptation strategy with the tools and resources at hand. The reality is that most advances in any human endeavor are made incrementally – in response to major events. Adaptive management is the more relevant and pragmatic approach that will serve most of the problems associated with contemporary water resources management.

Coping mechanisms and adaptation strategies

There is no single, clearly superior set of coping mechanisms and adaptation strategies for water management – whether for contemporary climate variability or for adaptation to climate change. The choices of specific coping measures together with a long range strategy depends on the culture of decision-making, specific problems, societal management objectives, and the relative scarcity of available resources (natural, human and financial capital), along with the relative susceptibility and vulnerability to natural hazard threats. Governments and water managers must first deal with the identified foreseeable needs of contemporary society before they can move on to preparing for the more uncertain demands associated with climate change.

As far as specific management measures are concerned, as a general rule, reservoirs provide the most robust, resilient and reliable mechanism for managing water under a variety of conditions and uncertainties. However, other combinations of nonstructural measures (conservation, pricing, regulation, relocation, etc.) may provide comparable outcomes in terms of gross quantities of water supply, but not necessarily in terms of system reliability. The choice of alternatives depends on the degree of social risk tolerance and perception of scarcity as well as the complexity of the problem. The permutations for coping with the uncertainties of climate change and variability are limitless – both in the number of strategies and in the combinations of management measures that comprise a strategy. There is no single 'best' strategy – each depends on the factors listed above. However, depending on the criteria used to determine the 'best' choices (economic efficiency, risk reduction, robustness, resiliency, reliability) it is clear that an emerging technology, which has the potential to improve virtually all forms of water management, is short-term mesoscale weather and hydrologic forecasting for 15-, 30-, and 90-day periods. Substantial advances are being made in applying this technology in the USA. More reliable short-term weather forecasting for water management purposes represents a key example of how scientific breakthroughs can aid real-time water management and operations, which in turn improve the overall responses to climate variability and greatly increase the efficiency of water management and use, especially for irrigation – by far the largest user of water globally. Also, rapid breakthroughs in biotechnology are anticipated, greatly increasing crop yields while reducing water use. This has great potential in water-stressed areas and in areas of salinized and brackish water. The combination of these two imminent technological breakthroughs alone, forecasting and biotechnology, would play a major role in aiding societal adaptation to climate change around the world, especially in developing nations.

An essential adaptation mechanism is the formalization of transboundary water allocation rules and existing storage reallocation. Both require an institutional framework for IWRM, since allocation deals with the most fundamental issue of water use priorities in times of crises, and how much water is assigned to the various purposes within each country, region and specific reach of the river. Agreeing on the terms for water allocation leads to the development of the more basic water management rules and operations for each reservoir and river. These rules require a full analysis of the water balance and withdrawals, which in turn require monitoring and data collection. Water allocation is a prerequisite for the efficient and effective implementation of all other water management measures and is, therefore, the fundamental component of any adaptation strategy to climate change at the regional, national and river basin scales.

Adaptive management of existing infrastructure

There are two dimensions to adaptation: the numerous changes that can be implemented readily as part of an ongoing adaptive management approach, and which will serve to increase the resiliency and robustness of existing water management systems, and; the fundamental design changes that are needed to accommodate highly uncertain future climate scenarios for new hydraulic infrastructure. There are numerous adaptive management functions that can be carried out relatively easily using conventional methods that would be associated with operational changes in the existing water infrastructure, coupled with changes in demands and processes for water service delivery. The emphasis would be in the two sectors that are most vulnerable to climate change and are critical to human settlements and food security – agricultural irrigation and flood plain management and flood hazard/damage reduction.

The functions that are dependent on a sound knowledge of flood and drought frequencies - as part of highly uncertain climate change scenarios as the basis for changes in hydraulic and hydrologic design criteria for planning new long-lived hydraulic structures - will require a fundamentally new approach to adaptation that requires a substantial investment in research and collaboration among the principal practitioners around the globe.

Adaptive management is a decision process that 'promotes flexible decision-making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood' (National Research Council, 2004). Adaptation to climate change is a merely a cousin of adaptive management – a continuous process of adjustment and flexible adaptation that attempts to deal with the increasingly rapid changes in our societies, economies and technologies. Adaptive management is perfectly suited to much of the immediate efforts needed for operational adjustments in the current infrastructure; changes in processes and demands, and maintenance and rehabilitation of existing infrastructure – particularly for irrigation systems and flood risk management in the floodplains of river basins. These are the two water management sectors that would provide the largest and most immediate payoffs in climate change adaptation, by reducing the vulnerabilities of existing systems, improving productivity and water use efficiency, and reducing flood damage losses.

For adaptive management to be successful, however, a necessary prerequisite is a well-positioned monitoring network to collect the requisite information to track the incremental changes that are implemented and test their viability and performance, so that the necessary adjustments can be made in a timely manner. The establishment of new floodplain zones that are coupled with flood insurance or crop insurance schemes, levee certification and new operating rules for reservoirs during flood periods is just one example of modular or incremental adaptation that would be enhanced by a monitoring network and information feedback.

Another critical aspect of the success of adaptive management strategies is social acceptability of the changes that will be introduced as part of the incremental, and essentially experimental programmes that comprise this approach. Informed, consensus-based decision-making and public participation are at the heart of introducing changes to the status quo. Stakeholder involvement is essential in these planning processes, and a well-thought out and continuous process of facilitated negotiations and conflict resolution among competing interest groups is crucial to the changes that are anticipated in response to climate change.

The fact is that the foundation of climate adaptation rests in the hydrologic methods that are currently used to plan, design, operate and maintain the present hydraulic infrastructure. Hence, the water resources sector is inherently better prepared than most to respond to climate change, notwithstanding the fact that the capacity and capabilities to apply these methods in the developing world are lacking. The only new dimension that is added to what is typically an inherently uncertain water management system, is the added uncertainty of climate change impacts and its influence of hydrologic extremes. Long-term climate predictions of 20-, 50- and 100 years hence are simply unsuitable to the contemporary needs of planners, designers and water systems operators. What is needed today are methods that can provide more reliable short-term, inter-annual forecasts of 30-, 60- and 90-day hydrologic variability.

However, little progress has been made in developing new practical techniques for analysing hydrology under climate uncertainty, which are the foundations of all water management – reservoir operations, water allocation, risk and reliability analysis, design of water infrastructure, and flood insurance and floodplain management. The fundamental mission of any water management agency is to protect its customers from the extremes and uncertainties of climate variability. Climate change adds another dimension of uncertainty, for which we have few operational tools. It is of paramount importance that water management agencies, throughout the world, deal with the practical ramifications of climate change impacts, and that we collaborate across national, federal and state agencies to develop sensible strategies that anticipate various scenarios where these trends are expected to intensify. Even within the bounds of historical climate variability there are difficult decisions surrounding basic questions whose complexity will inevitably be compounded with global warming. At any given region or location, planners and designers have to determine:

- How high should a levee be, and what is the risk to those living and working behind it?;
- How to characterize and identify a 100-year floodplain?;
- How to adaptively manage a reservoir to accommodate an increasingly uncertain spring runoff?;
- How much storage in a reservoir should be allocated to future irrigation versus other competing future needs?;
- What criteria should be used to 'recertify' flood mitigation structures where the flow frequencies have changed or are in the process of changing; and,
- How should our contemporary ideas on life-cycle infrastructure management and performance accommodate our evolving scientific understanding of climate change?

Water resources management is essentially bounded by how the extremes – floods and droughts – are defined, and methods for reducing the risks to society. Virtually all major infrastructure requires some estimate of what the extreme events have been historically, as the probabilistic basis for design, setting flood insurance rates, crop insurance, hurricanes, etc. In many cases the extremes and changes we are experiencing are still within the 'norms' of natural climate variability, within which our existing water resources infrastructure was designed to accommodate such an order-of-magnitude of variability. Yet, the climate change modeling community is convinced that there are 'signals' of a shift in the climate means and trends. As a preparatory action, the operating agencies and the science community need to engage their researchers, planners and reservoir operators with those of other agencies, to try to better understand the nature of these changes and to start to develop methods that could help our planners and operators begin to deal with these shifting trends. The water resources public works planned today must be robust and resilient to future extreme events and designed with an added degree of uncertainty in their re-occurrence frequency and/or magnitude due to global warming. The inventory of infrastructure that we manage today must likewise be maintained and, perhaps, upgraded to provide an extra degree of safety, resiliency and reliability to address these uncertainties. We need a 'paradigm shift' and a new class of tools and techniques for planning, designing and operating our water infrastructure if we are to be successful in adapting to climate change.

Though a majority of water management decisions are made at the local project level, requiring fairly specific design standards and models that can address climate uncertainty, there is an additional important aspect to this effort which can deal with watershed and river basin planning and evaluation issues (including transboundary water allocations). This regional level of analysis requires a higher order level of hydroclimatic analysis (through regional GCMs) which will establish the likely range of regional changes, in terms of discharges, probable maximum floods, probable maximum precipitation, flood and drought frequencies, and new ranges for flood plain management purposes and safe yield reliability calculations for water supply and irrigation. This level of analysis is essential as part of IWRM, so that all the subsidiary decisions made at the watershed and local levels are using the same baseline for planning and evaluation of alternatives, along with reservoir operations in a complex river basin system.

For example, the Corps of Engineers has long known that Category 5 hurricanes of the magnitude of Katrina were anticipated, even within what we consider 'normal' climate variability, but no one could predict the frequency of such events, and still more difficult is how the magnitude and frequency will be altered under different climate change scenarios. Society and the engineering profession, through a historical accumulation of experience, laws, engineering practices and regulations, have defined a narrower acceptable range of 'expected' events to which it chooses to adapt – hence we have the 100-year floodplain for flood insurance purposes, we design our urban drainage systems for smaller but more frequent events, and we ensure dam safety by designing spillways for very low-probability floods, roughly of a 10,000-year return period. These are societal judgments made on the basis of many factors, including affordability, relative population vulnerability, and national and regional economic benefits. They are not determined criteria made on the basis of empirical or simulation modeling. Neither GCM models nor IPCC reports can provide such a determination. Defining social risk tolerance and service reliability is part of a 'social contract' to be determined through the political process coupled with public participation – a continuing 'dialogue' within each society – whether it be for new drugs, nuclear power plants or water infrastructure.

While a formal, systematic approach to climate change adaptation (CCA), coupled with IWRM is an ideal goal, the reality is that any major event in a nation – any large damaging flood or drought or infrastructure failure - can and should serve as the catalyst for a series of organized incremental changes in water management to bring it closer to a systematic adaptive management footing for climate change. Even if only some of the essential components of the IWRM institutional infrastructure are in place, there are opportunities to begin CCA at almost any level of government or entry point in the existing water management infrastructure. There is an impressive array of perfectly sound and workable water resources management measures that are routinely used and can be mobilized into a more coherent and 'proactive adaptive management' preparatory approach. This is comparable to a 'no regrets' strategy suggested in many studies. The difference is that adaptive management has a specific definition and rationale, the principles of which should be applied to climate adaptation. It is preparatory, because it is not clear yet that climate change can be detected in the hydrologic record. Even though the GCM models predict certain changes, the actual evidence for such changes is still ambiguous – many long-term observational records, upon which water management decisions are based, do not yet support evidence of non-stationary trends. Hence, an adaptive management strategy is the pragmatic way to deal with this evolving and highly uncertain phenomenon, based on models that are yet in their infancy.

If societies cannot deal with contemporary and foreseeable water management needs, they most certainly will not be able to cope with highly uncertain climate change consequences. Contemporary adaptation is a necessary prerequisite for dealing with climate change uncertainty. Adaptation can effectively begin with existing conventional methods, tools and resources. Most systems can achieve quite a bit of adaptive efficiencies by rethinking and reorganizing existing methods, practices and processes. As climate change and variability becomes more extreme, newer, more innovative technologies, economic incentives and financial instruments and institutional arrangements will have to be introduced. There are essentially five ways that water managers have of adapting to climate change:

1 Planning **new investments**, or for capacity expansion (reservoirs, irrigation systems, levees, water supply, wastewater treatment);
2 **Operation, monitoring and regulation** of existing systems to accommodate new uses or conditions (e.g. ecology, climate change, population growth);

3 Maintenance and **major rehabilitation** of existing systems (e.g. dams, barrages, irrigation systems, canals, pumps, etc.);
4 Modifications in **processes and demands** (water conservation, pricing, regulation, legislation) for existing systems and water users;
5 Introducing new **efficient technologies** (desalting, biotechnology, drip irrigation, wastewater reuse, recycling, solar energy).

Coupled with the basic set of adaptation strategies and options, there are a series of sensible principles to guide contemporary water resources managers in the evaluation, selection, and implementation of appropriate adaptive response strategies. These adaptation strategies should be undertaken when they:

- are beneficial for other reasons and justifiable under current evaluation criteria;
- are economically efficient and cost-effective;
- service multiple social, economic, and environmental purposes;
- are adaptable to changing circumstances and technological innovation;
- are compatible with the concept of sustainable development; and
- are technically feasible and implementable.

Monitoring systems

Long-term monitoring networks are essential for detecting and quantifying climate change and its impacts. The effectiveness of adaptation strategies and actions – i.e. adaptive management – requires continuous feedback and adjustments based on the information provided by these networks, including improved sensors deployed in space, the atmosphere and the oceans, and the earth's surface. To be useful for water management, a good part of the monitoring networks need to be emplaced in locations relevant to water managers – i.e. in watersheds important to municipal water supply, or in especially hydrologically-sensitive areas.

Monitoring networks are essential for hydrologic trend analysis and improvements in the accuracy of forecasting methods. Detecting statistical shifts in trends of precipitation and streamflow are key to the management of existing water resources systems and the design of new systems. The state of General Circulation Model projections are such that they are significantly inconsistent with observations, and as such cannot be used as reliable information for water management needs – neither current operational needs nor design of future infrastructure (Brekke et al, 2009).

Operational changes

Operational changes are inherently oriented towards improving the use and performance of the existing water resources delivery systems for all of its designed and de facto uses. Most reservoirs in the USA undergo periodic reviews of their operating rules, either as part of new and expanded hydrologic records, or as new uses or purposes are added (e.g. recreation, environmental flows, protection of endangered species, etc.). These are the opportunities for updating the drought and flood contingency plans based on new information that could improve the overall resiliency, robustness and reliability of the system. These revisions may take into account changes in peak flood periods, snowmelt timing or updating flood and drought frequency analyses based on new methods and extended data, along with scenarios based on GCMs that would test the robustness of the operating system.

Operational flexibility could be enhanced by introducing new risk-based forecasting methods and decision criteria, such as El Niño forecasts coupled with likely runoff forecasts. Better forecasts can increase water delivery and hydropower production at most reservoirs if the reliability of the forecasting methods could be improved. Conjunctive use of groundwater and surface water as apart of a more sophisticated water management strategy is another aspect of operational changes that can be implemented now with fairly conventional methods and techniques, associated with an adaptive management plan (monitoring, feedback and adjustment to operating rules).

Vulnerability assessment

It is useful to differentiate hydrologic runoff *sensitivity* to climate change from that of water management *vulnerability* and societal *susceptibility* to economic disruptions and dislocation as a consequence of climate change. Hashimoto et al. (1982a, 1982b) introduced a taxonomy to account for risk and uncertainty inherent in water resources system performance evaluation. It is clear that the five terms listed below simply represent a set of descriptors that characterize and extend the key components of more traditional engineering reliability analysis, i.e. they focus on the sensitivity of parameters and decision variables to considerations of uncertainty, including some aspects of strategic uncertainty. The terms are:

Reliability – a measure of how often a system is likely to fail;

Robustness – the economic performance of a system under a range of uncertain conditions;

Resiliency – how quickly a system recovers from failure (floods, droughts);

Vulnerability – how severe the consequences of failure may be;

Brittleness – the inability of optimal solutions to accommodate unforeseen circumstances related to an uncertain future.

The relative *vulnerability* of a water resources system is, therefore, a function of hydrologic *sensitivity* (as input to the managed system) and the relative performance (robustness) of a water management system as it affects the delivery of services required by society. This is more of a technically defined management function, which can be quantified according to various scenarios of climate change. Societal *susceptibility* to climate change, on the other hand, depends on numerous factors outside the control of water managers, such as land use regulations, proper allocation of water supplies and population growth and economic policies related to water uses. Without an integrated water management capability, society becomes increasingly susceptible both to population-driven increases in water demands, as well as climate change variability. In other words, susceptibility and vulnerability increases not so much because of increased hydrologic variability, but more as a function of an inadequate institutional infrastructure required to manage those resources. In many cases, upgrading the institutional capacity of developing nations to implement sound water management practices is the most effective way of reducing vulnerability due to climate change. These processes include:

- Assess existing statutes, policies and regulations for dealing with extremes and contingencies – who has the authority and responsibility for what?;
- Who is responsible for climate adaptation planning?;
- Who operates and maintains existing water infrastructure? Is it at capacity? Can it serve projected needs? What is needed over next 10–20 years?;
- Assess socioeconomic scenarios of growth and development – what does the future look like? How will future demands for resources be met? What is role of water?;
- Assess vulnerability to current climate variability – floods and droughts. How will this change under future climate scenarios, and growth in 2050?

Emergency preparedness and response

In the end, political will and substantial financial resources will be needed to catalyse the actual implementation of the series of preparatory measures, strategies and plans that need to be developed. But one must be prepared for the next 'big event', whether it be a devastating drought, flood, typhoon or hurricane. Emergency preparedness and response is both the 'leading edge' and core of proactive climate adaptation. Every dam, levee system, water supply system and irrigation system needs to have an emergency response plan – to deal with events that are beyond the design criteria (spillway flood, dam failure, levee overtopping, etc.) or firm yield of the system. Every unforeseen or catastrophic event is an opportunity for reform and implementation of adaptive solutions and strategies. Water managers must lead the way and become more proactive in promoting the basic elements of adaptive management that are under their control, and that are inherently technical in nature. That is the essential starting point for adaptation.

Technological advances

One of the obvious investments in technological development that is expected to have immediate payback is improved forecasting techniques that will undoubtedly improve operation and management of existing water delivery systems, and open up possibilities for the trading of water rights and other risk-sharing programmes. But forecasting requires much more investment in scientific research, as well as installing and maintaining hydroclimatic monitoring systems in each river basin. Recent advances in genetic engineering and biotechnology are expected to have the greatest impact on food security and agriculture, alleviating some of the stresses on fresh water supply, as the vast reservoirs of brackish groundwater might be used for certain forage crops. Advances in fusion energy and cheaper solar power would alleviate water supply problems for the large urban areas on the coasts, making desalination an economically-competitive option. Cheaper solar energy would do the same for small villages and remote rural areas, making subsistence much easier by making available groundwater sources for water supply and small farm irrigation water for livestock, while reducing the costs of water treatment and sanitation. These technological advances are essential for climate change adaptation, yet do not require complex institutional systems for implementation – i.e. they can be implemented without a fully organized 'integrated water resources management' (IWRM) strategy and institutional infrastructure.

The way forward

The focus of climate change studies must begin to shift from generic global impact assessments to more focused adaptation and response mechanisms, and deal with the socioeconomic and political dimensions of difficult resource management trade-offs. No individual water management agency and affiliated research institute can deal with the problem of developing a suite of new principles and tools that water managers and design engineers can use effectively to adapt to climate change. The issues are too complex and the problems are too diverse, ranging from agricultural engineering to spillway design. At the global level, every institution from the World Bank to the Global Water Partnership is struggling with comparable issues, which are intertwined with sustainable development and IWRM.

An internationally coordinated and collaborative applied research and development effort needs to be undertaken by a few select water research centres that routinely deal with practical implementation issues for water management. It is important that the research institutions engaged in this effort be associated with operating issues of water management agencies, rather than approaching this as an academic exercise or an IPCC-type effort. The issues that confront water managers and infrastructure designers require quite pragmatic approaches and tools – even if they are transitional in nature. It is important that the methodologies developed be as useful as possible, derived from existing conventional methods for risk and uncertainty analysis, and which could be used by mid-level career practitioners in a typical agency. The methods must strive for uniformity and consistency.

A new 'paradigm shift' is required in the methods that are used for justifying new water resources investments and projects, which includes very different economic decision criteria. The planning and design of new hydraulic infrastructure requires not only new hydrologic tools for dealing with a non-stationary climate, and mechanisms for incorporating very uncertain and qualitative climate change scenario information, but also a new economic decision framework that can absorb this information as the basis for deciding among very costly options – from a social, economic, environmental and equity standpoint. The current economic criteria are based on stringent benefit-cost tests or maximizing the internal rate of return. New economic evaluation and decision rules for infrastructure designed to cope with climate uncertainty – i.e. be more robust and resilient – need to apply different decision rules, such as maximizing risk-cost effectiveness or minimizing risk-cost.

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World Water Council
World Water Forum

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IUCN

IWA International Water Association

Perspectives on water and climate change adaptation

Integrated Water Resources Management and Strategic Environmental Assessment joining forces for climate proofing

co-operative programme on water and climate

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Netherlands Commission for Environmental Assessment

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

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

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

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

Participants were invited to contribute perspectives from three categories:

1 **Hot spots** – These papers are mainly concerned with specific locations where climate change effects are felt or will be felt within the next years and where urgent action is needed within the water sector. The hotspots selected are: Mountains (number 1), Small islands (3), Arid regions (9) and 'Deltas and coastal cities' (13).

2 **Sub-sectoral perspectives** – Specific papers were prepared from a water-user perspective taking into account the impacts on the sub-sector and describing how the sub-sector can deal with the issues. The sectors selected are: Environment (2), Food (5), 'Water supply and sanitation: the urban poor' (7), Business (8), Water industry (10), Energy (12) and 'Water supply and sanitation' (14).

3 **Enabling mechanisms** – These documents provide an overview of enabling mechanisms that make adaptation possible. The mechanisms selected are: Planning (4), Governance (6), Finance (11), Engineering (15) and 'Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA)' (16).

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

16 Integrated Water Resources Management and Strategic Environmental Assessment – Joining forces for climate proofing

This paper is initiated by the Co-operative Programme on Water and Climate (CPWC) and the Netherlands Commission for Environmental Assessment (MER).

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Integrated Water Resources Management and Strategic Environmental Assessment – Joining forces for climate proofing

This paper serves as an input for the thematic, regional and political processes of the 5th World Water Forum and focuses on the challenges related to water, climate change and food security. Recent publications related to the anticipated impacts of climate change on water and agriculture are comprehensive, but a global analysis of specific impacts remains limited. The paper summarizes recent food production and food security trends and provides an overview of how climate change, through impacts on global hydrology, could impact food production, and consequently food security, in some key farming systems. However, as climate change is but one of many drivers of agriculture, climate change impacts need to be appreciated in relation to specific farming systems in order to identify appropriate adaptation measures. The paper highlights key drivers and presents possible responses, emphasizing that the scope of policy response will need to be broad if water institutions are to be effective in coping with climate change.

1 Introduction

Global warming and climate change are real. The international community is concerned about the consequences of climate change for the world population, especially for particularly vulnerable groups in developing countries. The IPCC, in its 4th Assessment Report, states that a high priority should be given to increasing the capacity to adapt to climate change in ways that are synergistic with wider societal goals of sustainable development. Progress has been made in this respect. The most vulnerable countries and regions have been identified, information and experience on possible adaptation options is accumulating and capacity is being built. There is, however, a disconnect between awareness and the full coordination and integration of climate change adaptation into planning at all levels and across all sectors.

Climate change adaptation is obviously in its early stages. For example, some 33 developing countries have completed National Adaptation Programmes of Action, identifying over 300 project ideas. However, only a few have reached the GEF funding stage. Challenges are faced in terms of follow-up actions, implementation of priority projects, integration with national policy and planning frameworks, and effective stakeholder involvement. The challenge is to have adaptation integrated in the overall planning, and to define guiding principles for this integration (Dialogue on Climate Change Adaptation for Land and Water Management, not dated).

A key message provided by the Global Water Partnership (GWP, 2007) is that, if our global energy habits are the focus for mitigation, the way we use and manage our water must become the focus for adaptation. It is generally agreed that the supply of and demand for water resources will be substantially affected by climate change. The recent Intergovernmental Panel on Climate Change Report (IPCC, 2007) puts it in different wording: “water is in the eye of the climate management storm”.

In this paper two mechanisms, available to support the integration of climate change adaptation in overall (water resources) planning, will be discussed: Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA). Strengths and weaknesses are discussed. The complementary nature of both mechanisms is highlighted, considering the need for a more effective approach to the incorporation of climate adaptation in (water resources) planning.

2 Climate change and the water sector

Global warming and related climate changes are increasingly better understood and there is growing consensus on their likely scale. It is also clear that, irrespective of the scale of mitigation measures, adaptation measures are necessary. This implies an integrated approach to climate change that embraces both mitigation, which addresses the drivers of climate change, and adaptation, which considers the measures necessary to accommodate such changes. Ultimately, adaptation is an exercise in damage limitation and deals with the symptoms of a problem that can be cured only through mitigation (OECD-DAC, in prep.).

Urgency is provided by the expectation that relatively small temperature changes of a few degrees Centigrade will see average river flows and water availability increase by 10–40% in some regions while, in others, they will decrease by 10–30%. An important message is that changes in climate will be amplified in the water environment (GWP, 2007).

An overarching message is that the best way for countries to build the capacity to adapt to climate change will be to improve their ability to cope with today's climate variability. Adaptation to seasonal and inter-annual time scales will be critical in adapting to the impacts of longer term climate change as well. In other words, improving the way we use and manage our water today will make it easier to address the challenges of tomorrow.

Better water management will thus be essential to adapt to climate-induced changes in water resources. A combination of 'hard' infrastructural and 'soft' institutional measures is needed. The future resilience (or vulnerability) of human communities to climate change related impacts will depend on their success. The Global Water Partnership (GWP, 2007) suggests that Integrated Water Resources Management provides the best approach to manage the impact of climate change on water. In this paper it is argued that by joining forces with SEA, IWRM will more effectively achieve its objectives.

3 Integrated Water Resources Management

Integrated Water Resources Management (IWRM) has been the accepted management paradigm for efficient, equitable and sustainable management of water resource since the early 1990s. The development and sustainable use of water resources requires the allocation of these scarce resources among competing human activities. This implies decision-making in complex situations, often with conflicting interests. Careful planning and analysis are required to support such decisions, taking into account technical, economical and environmental aspects in a specific social, cultural and institutional context. Intensive and timely consultation of all stakeholders is of utmost importance.

IWRM is an approach to support decision-making in such complex situations. It is defined as a process which promotes the coordinated development and management of water, land and related resources in the river basin in order to maximize the resultant economic and social welfare in an equitable manner, without compromising the sustainability of vital ecosystems.

As such, IWRM has to deal with all natural resources, not only water but also soils, surface water and groundwater, water quantity, quality as well as water ecological aspects. Next to the natural resource system the socio-economic system, the people living in the area, their water using activities and related economic, social and cultural aspects have to be dealt with. Finally, the administrative and institutional (control) system is of importance.

Generally, water resource management uses both an analytical framework, explicitly identifying the components and different steps in the analysis process, and a computational framework, establishing a capacity for data processing and quantitative comparison of alternatives. Based on scenarios for climate change, demography, economic development and spatial planning, projections of the water demand for irrigation, drinking water supply, industrial water supply and environmental requirements are made. Hydro-meteorological data (measured data and results from hydrological analyses, taking into account climate change scenarios) are used to establish the availability of water as well as its spatial distribution and variation over time. Next, projected future demands are checked against projected available future resources with a river basin simulation model. In case of imbalance, water resources management strategies (logical and/or promising combinations of structural and non-structural measures, allocation rules and water sharing options) are designed to improve the situation. Finally, the performance of the strategies, in terms of impacts on the water resources system, the socio-economic system and the environment, is assessed.

While there are no set IWRM 'rules', the approach is founded on the Dublin principles, which assert that: (i) fresh water is a finite resource; (ii) a participatory approach is needed in water planning and management; (iii) women play a central part in the provision, management and safeguarding of water; and (iv) water is an economic good. It seeks to ensure that water is used to advance a country's social and economic development goals in ways that do not compromise the sustainability of vital ecosystems or jeopardize the ability of future generations to meet their water needs (GWP, 2004).

IWRM is not just about managing physical resources; it is also about reforming human systems to enable people – women as well as men – to benefit from those resources. For policy-making and planning, taking an IWRM approach requires that:

- Policies and priorities take water resources implications into account, including the two-way relationship between macro-economic policies and water development, management, and use;
- There is cross-sectoral integration in policy development;
- Stakeholders are given a voice in water planning and management, with particular attention to securing the participation of women and the poor;
- Water-related decisions made at local and river basin levels are in-line with, or at least do not conflict with, the achievement of broader national objectives;
- Water planning and strategies are integrated into broader social, economic, and environmental goals.

The benefits of IWRM arise from the process as much as from the end product. The increased understanding arising from sectors working together, the gathering and sharing of knowledge and information during the study, and the consideration of catchment-wide uses and impacts and the debates about alternative options themselves result in benefits for water resources management.

Strengths and weaknesses of IWRM

IWRM is a well-developed and highly-structured approach, supported by computational frameworks capable of providing quantitative information on dynamic systems, and capable of working on the basis of alternative scenarios.

IWRM is able to cope with the multi-functionality of water its many uses and users, addressing the issues from a biophysical, socio-economic and institutional systems perspective.

In practice, however, the benefits that can be obtained from an IWRM approach are often not exploited to the full. For example, in World Bank client nations with weak environmental policies or laws, environmental considerations in IWRM play little role in decisions about water allocation, water quality management, source protection, or the protection of water dependent ecosystems (World Bank, 2007). IWRM itself is not embedded in any legal procedures and consequently cannot be 'enforced'.

Similarly, in practice the intention of creating a participatory, multi-stakeholder process is usually not implemented to its full extent. Consequently, the potential benefits of such as approach do not always materialise.

Even though IWRM looks beyond sector boundaries, its implementation is limited by sector boundaries. Sectors outside the water sector may be totally ignorant of the principles of IWRM. For example, energy supply, tourism, or agriculture all have to adapt to potential water stress or water-related hazards as a result of climate change. Yet, there are few mechanisms to get a foothold for IWRM in these sectors (OECD-DAC, in press).

4 Strategic Environmental Assessment

The World Bank (2007) argued, based on a literature review analysis of ten global case studies, an in-depth pilot study at a country level and review of four national and state water resources policies, that IWRM has, at best, been implemented in a disjointed way in developing countries. According to this study, Strategic Environmental Assessment (SEA) offers an additional planning tool for introducing environmental considerations into water resources management.

The principle behind environmental assessment is deceptively simple: it directs decision-makers to 'look before they leap'. An environmental assessment should bring into focus what the likely environmental (and related social) effects of a project or plan could be, before decisions on that project or plan are made. When there is a clear insight into the consequences and stakeholders' visions on those, decision-makers are in a better position to direct development into a more sustainable course.

Of course, decision-makers do not direct development on their own. Most plans or projects concern a range of actors, from government to the business sector and the public arena. For this reason, environmental assessment does not merely provide information, but brings the various parties together to discuss this information. It provides a process for them to come to a shared understanding of the possible effects, and to determine what this knowledge should mean for the plan or project at hand.

In general, environmental assessment is centred around four core values:

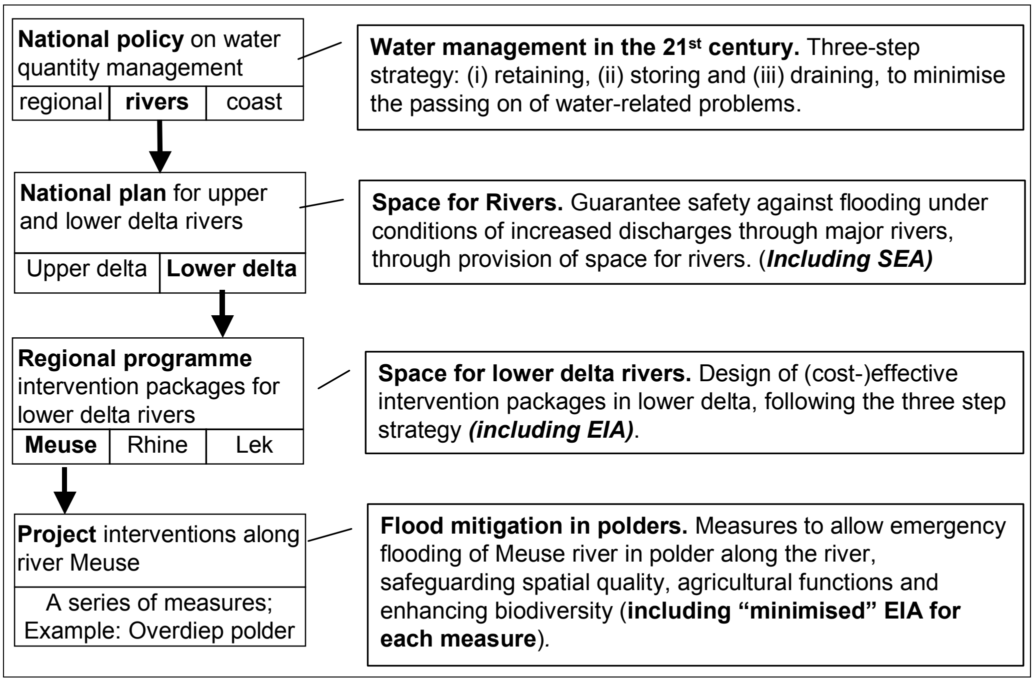
- Good quality information, geared towards the decision-makers needs;
- A participatory approach in which stakeholders can bring their concerns forward during the assessment and planning process;
- Transparency in decision-making based on publicly available information;
- An institutional framework, which is capable of performing the necessary tasks, both in the assessment process and in the implementation plan.

Since its early beginnings in the 1960s, the field of environmental assessment has expanded, both in scope and in application. Practitioners now recognize two levels of environmental assessment: Environmental Impact Assessment (EIA) that is applied at the level of individual projects, and Strategic Environmental Assessment (SEA) which is applied to plans, programmes and policies.

By 1997, over 100 countries had a legally-embedded EIA system in place. Practice with EIA showed that cumulative and large-scale effects could not be addressed adequately at the project level. Furthermore, it was realized that many relevant planning decisions have usually already been taken at higher strategic levels before a project can be conceived. This severely limits the potential range of alternative solutions, so a new instrument was needed to assess such effects at the appropriate strategic level: that of policies, plans and programmes.

In the 1980s a distinct SEA practice was gaining momentum. Canada, New Zealand and the Netherlands were among the first countries to develop a regulatory basis for SEA (Dalal-Clayton & Sadler, 2005). In the 1990s many more developed countries and some developing countries embedded SEA into regulation. A very recent expansion of the application of SEA is the European Union SEA directive, which came into effect in 2006 (European Council, 2001). All 25 EU Member States are now faced with the legal obligation to apply SEA to plans and programmes.

Box 1: Hierarchy of policies, plans and programmes: an example from the Netherlands.



Box 2 – **SEA and the water sector**

The UNECE Protocol on SEA, adopted by the Parties to the Espoo Convention (1979) on Environmental Impact Assessment in a Transboundary Context, requires that contracting countries conduct domestic and transboundary SEAs during the elaboration of programmes and plans in a number of sectors, including water management. These include dams, inter-basin transfers, wastewater treatment plants, irrigation schemes, and groundwater abstractions.

The EU Directive on Strategic Environmental Assessment requires that all plans and programmes that are likely to have an effect on water need to be assessed with an SEA closely related to the EU Water Framework Directive. It contains many IWRM principles including managing water quantity and quality for surface and groundwater, treating water as having an economic value, and enhancing consultation and participation. Its key requirement is the production of river basin management plans by all EU Member States.

The South African Department of Water Affairs and Forestry (DWAF) considered SEA as a tool for use in catchment management and planning when it became clear that a wider frame of information was needed by decision-makers with the introduction of the National Water Act 1998. Although SEA was not subsequently used as a specific approach in other catchments, the ideas behind SEA have been influential in guiding IWRM in other catchments.

A SEA pilot study in the Palar Basin in India proved to be a successful method for developing a framework for IWRM, and the SEA process is being extended to other sub-catchments in Tamil Nadu State, India.

The 2004 Tanzanian Environment Management Act 2004 identifies water developments as one of four types of developments where an SEA is specifically required at a pre-project stage.

The Netherlands Commission for Environment Assessment has summarized experiences with valuation of ecosystem services in SEA (Slootweg & Van Beukering, 2008). Of 20 cases, 10 were water sector related, showing that SEAs have successfully promoted IWRM.

It is important to point out that SEA is not EIA, because it is necessarily different in nature. At project level, decision-making is about a concrete set of activities. EIA then concentrates on the activity-effects relationship. EIA very often is a responsibility for private sector investors. In practise the focus often lies on the mitigation of negative impacts. EIA is organized in an internationally accepted procedure, following a legally embedded series of steps.

As EIA aims at better projects, SEA aims at better strategies, ranging from legislation and countrywide development policies to more concrete sector and spatial plans. Strategic decision-making is less about concrete impacts but more about identifying, assessing and comparing the different ways in which a policy, plan or programme can achieve its objectives. Planning usually is a government responsibility. The more changeable and politically charged development of a plan or policy is less easily structured. Ideally, SEA is applied at each planning tier, and higher-level SEAs inform those at a lower strategic level so that there is no overlap in the assessments. See Box 1 for a water sector example of tiered planning and the position of environmental assessment in this process.

In 2002, the International Association for Impact Assessment published SEA performance criteria (IAIA, 2002). In 2006, the SEA Task Force of the OECD Development Assistance Committee brought together a wide range of SEA experience to draft SEA guidance. The diverse group adopted a definition of SEA, which states that SEA is “a family of tools that identifies and addresses the environmental consequences and stakeholder concerns in the development of policies, plans, programmes and other high level initiatives” (OECD, 2006). This definition makes clear that SEA is not one single tool. SEA can, moreover, be considered as a procedural framework, for which the right tools have to be selected, depending on the sector for which it is applied, the level of decision-making, and the information needs at that level.

Consequently, there is no ‘one-size-fits-all’ approach. SEA needs to be applied flexibly and even when SEA is captured in a formal procedure in legislation (e.g. the SEA Directive of the European Union) there will still be great differences in how the SEA activities are undertaken, when and with whom. However, there is general agreement about the activities that make up an SEA process (OECD, 2006). There is a logical sequence to these activities, but logic is certainly not the only, nor necessarily the dominant, principle governing a given planning process. Realistically then, the activities outlined here may take more or less effort, may follow each other sequentially or not, and some may be repeated or combined.

- First phase – creating transparency and joint objective setting.
  - Announce the start of the SEA and assure that relevant stakeholders are aware that the process is starting;
  - Bring stakeholders to develop a shared vision on (environmental) problems, objectives, and alternative actions to achieve these;
  - Check in cooperation with all agencies whether objectives of the new policy or plan are in line with those in existing policies, including environmental objectives (consistency analysis).
- Second phase – technical assessment.
  - Make clear terms of reference for the technical assessment, based on the results of stakeholder consultation and consistency analysis;
  - Carry out a proper assessment, document its results and make these accessible for all;
  - Organize effective quality assurance of both SEA information and process.
- Third phase – use information in decision-making.
  - Bring stakeholders together to discuss results and make recommendation to decision-makers;
  - Make sure any final decision is motivated in writing in light of the assessment results.
- Fourth phase: Post-decision monitoring and evaluation.
  - Monitor the implementation of the adopted policy or plan, and discuss the need for follow-up action.

Strengths and weaknesses of SEA

A planning exercise can be characterized by three elements: (legal) procedure, process and content. From a procedural point of view, SEA is rapidly becoming a strong, internationally acknowledged, legally embedded tool, with clearly demarcated roles and responsibilities. Regulations ask for an assessment of new plans and programmes, and sometimes also policies, that potentially have environmental and related social consequences when implemented. This provides a formalized foothold for SEA to influence the planning process, referred to as entry points for SEA (see Table 1).

Even though the SEA process is not as strictly defined in legal procedures as the EIA process, there is a common understanding of what good SEA practice is. Transparency and stakeholder participation are core values, supported by an increasing evidence base of good practices.

Table 1: Entry points for government-led SEAs (OECD-DAC, 2006).

Lead authorities	**Focus area**
National government and cross-sector ministries (e.g. Departments of Finance / Planning)	National-level strategies
	Policy reforms, budget allocations and financial mechanisms
Sector or line ministries (e.g. Mining, Health or Agriculture)	Sector specific policies, plans or programmes, e.g. energy or health sector reform
	Infrastructure investments plans and programmes
Sub-national, regional and local governments	Spatial development plans and programmes
International/ transboundary agencies	Cross-border or multi country plans and investment programmes

Nevertheless, SEA is relatively new and practice shows that many government authorities are still struggling with the level of transparency and participation they are prepared to accept. The level of stakeholder involvement is not always practised at project level EIA (where regulations usually are more strict).

SEA in itself has relatively little content. Apart from the decision whether the SEA should address biophysical consequences only, or should also include social and economic consequences (environment only versus integrated assessment), the content has to be provided by the sector specialist involved in the process. SEA provides, so to speak, the procedural umbrella under which a variety of tools have to be used.

SEA is principally 'sector-neutral'. Any plans with potential environmental or social consequences can be subjected to SEA, ranging from spatial and sector plans, to new legislation, or negotiations on an international trade agreement. .

5 SEA and IWRM: a win-win combination?

Even though SEA and IWRM originated from different professional interests, they share many concepts and characteristics. Both include the integration of environmental and social considerations into multi-sectoral decisions; both emphasize the importance of participatory and consultative approaches to decision-making; both incorporate monitoring and evaluation of outcomes; both seek to broaden the perspectives of planners beyond immediate sectoral issues; and both stress that the outcome is a product (a policy, strategy or plan) as well as a process.

One could thus question whether we are talking about the same thing, having different names. A further look at the strengths and weaknesses, however, reveals major differences of a complementary nature, grouped under four headings:

a Legal procedure

A strong asset of SEA is the increasing number of countries having legal obligation to do SEA for plans and programmes (irrespective of the sector). IWRN does not have such a legal backing. Much can be said against legal obligations. For example, many of the early adapters have done EIAs and SEAs on a voluntary basis before creating legislation. The voluntary nature guaranteed a genuine interest of participating agencies in the outcome and an intention to learn. Legal obligations without commitment create a less optimal process. Nevertheless, a legal obligation in combination with a government willing to learn from experiences does provide good opportunities to use SEA as a vehicle to convey the messages of IWRM.

Already in 1987, Ortolano et al described six drivers for good impact assessment implementation. Availability of legislation and a procedural framework is only one of these; others are judicial (effectiveness of courts), evaluative (willingness to impose sanctions if quality is considered unacceptable), instrumental (e.g. donor driven assessment), professional (capacity of professional), and public (civil society motivated and confident to respond). In other words, an 'enabling environmental' is more than only legislation.

Transboundary water plans are inherently complex, caused by different enabling environments, different levels of knowledge and skills, and varied objectives of basin countries. Transboundary SEAs can be facilitated through international legal instruments for bi-/multi-lateral cooperation between the countries (e.g. regional agreements for protection of international river courses or the Protocol on SEA to the Convention on Environmental Impact Assessment in a Transboundary Context).

Several environmental conventions have articles on the application of impact assessment and adopted guidance documents (such as the Convention on Biological Diversity, the Ramsar Convention on Wetlands of International Importance, and the Convention on Migratory Species).

***Message*: SEA is a legally established vehicle to convey the messages of IWRM.**

b Process

SEA is sometimes referred to as an organized fighting arena. Stakeholders have to make sure their interests are taken into account in government decision-making. SEA aims at bringing forward these interests in the planning and decision-making cycle, at the right moments, providing the type of information that decision-makers need. This practise of impact assessment is sometimes harsh and complex, as stakeholders have different influence and powers, each trying to influence the process. This explains why the impact assessment community, almost obsessively, focuses on process aspects. How to guarantee that interests of all are taken into account, that decision-making is done in the most transparent manner, and that information is scientifically valid. SEA can significantly enhance the implementation of IWRM principles related to stakeholder involvement and transparency.

The concept of 'tiering' in impact assessment is linked to the nature of decision-making. Higher level decision-making creates boundaries for lower level decisions; impact assessment necessarily has to be adapted to the scope of issues and level of detail required at each tier. A significant body of practical knowledge has developed over the years on do's and don'ts in SEA. Compared to IWRM, SEA has a more structured approach with respect to process aspects and thinking in terms of the most efficient manner to influence decision-making.

***Message*: SEA is better geared toward the practical implementation of the principles it shares with IWRM (stakeholder participation and informed, transparent decision-making).**

c Contents

As explained earlier, SEA is considered to be a family of tools, where the right tools have to be selected in the light of the issues at stake. Here, IWRM undoubtedly fills a void by providing profound understanding of water-related issues, within and beyond the water sector. Where SEA provides more concrete process guidance to influence decision-making, IWRM is better equipped to provide the water-related contents.

Just to mention a few aspects, IWRM, and the underlying Dublin principles, prominently highlight the importance of having a gender-sensitive approach, emphasizing the role (and vulnerability) of women in water-related issues. This is completely ignored in the overarching SEA literature.

Defining water as an economic good greatly enhances the discussion on the valuation of water and water-related ecosystem services. This discussion is only recently being opened in the SEA community (see Slootweg & Van Beukering, 2008). More in general, the economic consequences of policies and plans have not been consistently considered by the impact assessment community.

***Message*: IWRM provides comprehensive and integrated understanding of water sector issues for SEA to inform decision-making.**

d Beyond sector boundaries

The strength of IWRM lies in its strong rooting in the water sector and its subsequent extensive theoretical and practical knowledge of water-related issues. At the same time, this sectoral basis can be a point of weakness when issues beyond the sectoral boundaries have to be addressed. This has resulted in a call to think 'out-of-the-box', meaning something like thinking beyond what is common practice within the sector.

The SEA community is totally unfamiliar with this phrase. Having to work with specialists from different disciplines and sectors is the rule in SEA. SEA provides the procedural framework; specialists have to provide the contents. During what is called the 'scoping' stage of SEA, the relevant issues are defined and specialists are identified that have to address these issues during the assessment. In SEA, every case is dealt with as new and unique, requiring individual scoping. In short, there is nothing like a box.

One of the basic characteristics of SEA is an independent review of the quality of the outcomes before the information is given to the decision-makers. This independent position of SEA, not being linked to sectoral interests, gives it a relative advantage where the interests of sectors clash.

From a climate change adaptation perspective, an SEA at national level may help to identify elements of national plans that are sensitive to – or at risk from – climate change or whose viability in the context of projected future climatic conditions is in question. At sectoral level, climate change considerations within an SEA might be used to screen strategies for sectoral reform, identifying where adaptation interventions will be required to enhance the resilience of the sector in the face of climate change, or to identify which strategies are – and which are not, – resilient under different climate change scenarios. Responsibility of such plans does not necessarily lie in the hands of the water sector. There are limited possibilities to apply

IWRM principles if the 'owners' of the plan are not familiar with it or have no affinity with it[1].

An example is provided by Poverty Reduction Strategy (PRS) processes. These have become key processes for development policy-making and planning. In these countries the PRS processes are therefore essential for climate change adaptation. Mainstreaming thus implies that climate change measures must be incorporated in the PRS framework of development policies, plans, programmes, reviews and implementation systems. SEA provides the entry point for IWRM approaches where it concerns water-related issues.

***Message*: as a sector-neutral, broadly applied instrument, SEA can insert IWRM principles beyond water sector boundaries.**

6 Conclusion

As observed earlier, climate change adaptation has strong linkages with the water sector. An Integrated Water Resources Management approach is considered the best approach to address the impacts of climate change. When implemented properly, IWRM is capable of dealing with ever-changing circumstances. Developments in society such as population growth or economic development are strong drivers of change in water demand. Most climates are characterized by seasonal, inter-annual and periodic variability. Climate change creates yet another, although complex, driver of change. Good IWRM can cope with this, by focusing on robustness and flexibility of solutions.

In everyday practice, however, IWRM is not always effective in addressing the climate change adaptation challenge. For IWRM to become more effective, various sources have suggested linking IWRM with Strategic Environmental Assessment. In this paper a quick reconnaissance of the issue has been made, leading to a number of messages that need further elaboration and discussion.

At first glance, it becomes apparent that IWRM and SEA share the same principles, but that both instruments have a complementary scope of work. Where IWRM provides in-depth sector knowledge and a comprehensive framework to develop relevant knowledge, SEA is best equipped to facilitate a process to influence decision-making. The legal backing of SEA provides the necessary entry footholds in a plan process to get the IWRM message across.

In conclusion, there is clear scope to further elaborate the added value of bringing IWRM and SEA together when discussing the implementation of climate change adaptation. Because SEA and IWRM come from different disciplinary backgrounds, there is a need to bridge their separate, but overlapping perspectives and terminologies. This paper is only a first step.

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1 The Netherlands have created the so-called 'water test' procedure. Each spatial plan has to be assessed on its consequences for water quantity management prior to implementation. In the same manner a 'climate-proof' test could be envisaged.

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