Perspectives on water and climate change adaptation

Don't stick your head in the sand!

Towards a framework for climate-proofing

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Key Messages

The consortium of the Co-operative Programme on Water and Climate, the World Water Council, and the International Union for Conservation of Nature derived the following key messages from a series of 16 Perspective Documents on Water and Climate commissioned for the 5th World Water Forum. It is our hope that these interdependent principles can serve as a guidance to both the water and climate communities by providing the water community with information on how to build climate change adaptation into water work, and by offering the climate community an explanation of why water ought to be at the centre of their efforts.

Water-Related Vulnerabilities to Climate Change

Climate adaptation is water adaptation. Climate change is real and it is already underway. Although global climate change induced changes in water resources and water services have yet to be observed, they are universally anticipated. The negative impacts of climate change are expected to outweigh the benefits. Water resources and water services will be most affected by the expected impacts on drought – flooding, storms, melting ice, and sea-level rise, and water will mediate impacts across sectors. Clearly, water needs to be at the centre of adaptation policy, planning and action.

Climate change impacts on water cut across sectors, so sectoral responses need to be integrated to enable climate proofing. Vulnerability to climate change is largely mediated by water and depends on exposure to hazards, sensitivity to impacts and adaptive capacity. Perspectives on climate change from water utilities, agriculture, energy, business, industry, and environment demonstrate the diversity of actions needed to reduce climate risks. Integrated climate-proofing strategies aim to reduce exposure and sensitivity to impacts across sectors, while increasing adaptive capacity.

Vulnerability to climate change is not evenly distributed and there are geographic hot spots where impacts on water are highest and capacity to cope is lowest. Vulnerabilities of developing countries ought to be given highest priority. In arid regions, low-lying deltas, small islands and mountain regions, water security is already under pressure. These areas should be the priority areas for international and national adaptation policies and investments.

Adaptation Policies and Planning

Climate change is not just an environmental issue. As one of the major drivers of global change, climate change will hinder sustainable development. Adaptation should not be exclusively linked to an environmental agenda; it requires a multisectoral approach.

Identifying high-risk landscapes is a pre-requisite for effective adaptation planning. Assessment of hot spots of risks and vulnerability is instrumental to cost-efficient adaptation. More reliable climate information and a universally accepted vulnerability assessment methodology are needed to determine hot spots in countries and basins. Within the geographical hot spots, the vulnerability at the level of water sectors can be assessed. Once this is accomplished, adaptation plans can be prepared within these sectors.

Climate proofing demands portfolios of actions and enabling mechanisms, tailored to vulnerabilities of geographic hot spots, that integrate priorities across sectors. Utilities, energy and industry take a predominantly control-oriented approach in which response options aim to rectify specific climate-related problems and risks. Agriculture, environment and WASH have a more resilience-oriented approach to adaptation and aim to put in place adaptive systems that will cope best with future uncertainties. Climate proofing uses a complementary mix of engineered tolerances to climate change and water-based resilience.

The magnitude and pace of hydrological changes in hot spots will require new water management thinking. In most hot spots, the coping range of water systems and services is set to be more frequently or permanently exceeded, causing unprecedented and irreversible impacts. In such critical situations, structural and command-and-control adaptation strategies might prove highly costly, or even ineffective, forcing water planners to make a paradigm shift from 'building against' to 'living with climate'. This will have wide-ranging policy implications that need to feature more prominently in the current debate and reasoning on water adaptation.

Water-based climate resilience combines adaptive management, human and institutional capacities and natural river basin infrastructure. Water-based resilience will benefit from investment in no-regrets and best-practice measures aligned to Integrated Water Resource Management (IWRM). These will strengthen the reliability and utility of information, effective water governance and trans-boundary decision making, capacities for adaptive management, and ecosystem-based adaptation that integrates natural infrastructure into planning.

Climate data and information are essential and provide the foundation upon which adaptation measures are developed. Ensuring access to useful information is key. Equally so it is important that the climate information is tailored for its specific use.

Specific climate-justified measures are needed to put in place safe tolerances to climate change impacts and uncertainties in water services, energy and industry. Reconciling water supply and demand is key; as are development and deployment of infrastructure adapted to extremes, including water supply and treatment, drainage, hydropower and shoreline management.

Enabling mechanisms for adaptation must overcome major barriers to coherent and integrated approaches to climate proofing. Climate proofing strategy must incorporate enabling mechanisms for adaptation, including information systems, improved tools for priority setting and cost-benefit assessment, capacity building, adaptive institutions, policy cohesion, and mobilisation of financing.

Water risks are locally specific and cannot be addressed through 'one-size-fits-all' approaches. Response mechanisms in hot spots need to be tailored to local circumstances and capacities. A balanced portfolio of control-oriented and resilience-based adaptation strategies, based on consideration of cost and benefits and bottom-up thinking, is required.

Constructing an overarching financial architecture to finance adaptation to climate change is urgent. Climate change adds additional challenges to the overall development and sustainability agenda resulting in the need for additional external financial resources for developing countries to implement adaptation measures (the 'polluter pays principle').

Developing an Agenda for Water and Climate Change Adaptation

Political commitments are required to focus climate change adaptation on water. Placing climate change impacts on water at the centre of adaptation demonstrates the importance of understanding interdependencies when planning adaptation and developing effective enabling policies. Climate change impacts on water are directly undermining human development because of their linkages to water supply, sanitation, food, energy, health, and, by extension, the Millennium Development Goals (MDGs). Simple sectoral approaches to climate change adaptation are insufficient for both the water sector and other sectors. Decision makers have to learn to think and act beyond sectoral boundaries; in the case of the water sector this means thinking 'beyond the water box'.

Strategic frameworks for climate proofing need to be combined with operational portfolios of practical responses. These need to enable action at the local level, while coping with the effects of water-related impacts of all sectors. The framework and operational responses should be formed around critical enabling mechanisms and must be adaptive and adaptable to the specific socio-economic and environmental context of a country.

Act now and act locally. Capacity building and information for sector professionals is essential, especially for the least developed countries. Waiting for more accurate data to emerge is ill advised because adaptation needs to start now. The real way forward is to educate people to use probabilistic decision making tools, and transfer technology (soft and hard) to low-level water managers and to developing countries.

Cooperation and a concerted focus on water as the medium for adaptation should be promoted at all levels. An international alliance could be established to provide guidance on climate change adaptation to agencies. The alliance should promote coordination mechanisms at appropriate levels (international and national) to mainstream climate vulnerability assessments. IPCC and WWAP could be linked for instance, as could political dialogues taking place under the umbrellas of the UNFCCC and the World Water Forum). Adaptation planning (such as NAPAs and National Communications) could be linked with with sectoral policies and planning, including IWRM processes.

A unified 'water voice' is needed at CoP-15 and other long term international negotiations. This should seek political recognition for water as the fundamental vehicle for adaptation to climate change. The goal should be to secure clear commitments vis-à-vis water as the medium for effective adaptation policies and measures at all levels. This could be accomplished by acknowledging the role of water in adaptation in the long-term agreement on climate change, with Parties agreeing to address water as a priority in their national policies and strategies.

1 Introduction: Climate Adaptation is Water Adaptation

Scientific evidence indicates that in addition to being real, climate change is already underway. With expected impacts on drought, flooding, storms, melting ice and sea-level rise, the hydrological cycle is clearly the aspect of the Earth system that will be most affected by climate change. Many of the impacts of climate change, including effects on climate variability, will be manifested on water resources.

Climate change is often considered an environmental issue. However, the central role of water intimately links climate change to poverty reduction, economic development and human security, particularly as adverse effects on freshwater systems aggravate the impacts of other stresses (e.g., population growth, changing economic activity, land use change and urbanization). Having moved beyond an environmental challenge, climate change will test human resilience.

The world is now locked into a pattern of change, and the opportunity for preventing any warming has passed (IPCC, 2007). Societies must respond by both minimizing any further warming (through mitigation to reduce the concentration of greenhouse gases in the atmosphere) and by finding ways to *adapt* to the impacts that warming will bring – including shifting precipitation regimes, more frequent and severe extreme weather events and sea-level rise. Adaptation policy is a crucial means by which the world can prepare to deal with the unavoidable impacts of climate change. To date, however, it has been under-emphasised, including in the water sector.

The wide-ranging impacts of climate change on local water resources and water services demand tailored responses for specific locations and specific sectors. Climate change impacts will affect the function and operation of existing water infrastructure, including hydropower, structural flood defences, drainage, and irrigation systems, as well as vital services provided by natural ecosystems. Climate change presents very serious water-related risks with implications at the global level, and thus demands urgent global, regional and local responses.

Aim of the Document

This document was prepared to assist in identification of critical elements of a response framework that combines strategy and policy development with prioritisation of practical operational actions. The document is based on a synthesis of 16 Perspective Documents on Water and Climate commissioned for the 5th World Water Forum. The Perspective Documents provide viewpoints and assessments of adaptation needs from three categories of perspectives:

1 Geographical categories – arid areas, low-lying deltas, small islands and mountainous areas
2 Sectors – water utilities, environment, food and energy
3 Enabling mechanisms – governance, finance, planning and vulnerability assessment tools

Together, these perspectives provide a compilation of how water related adaptation priorities are seen from different vantage points. Analysis of these perspectives has enabled identification of critical impacts and key socio-economic vulnerabilities for specific geographical categories and a selection of sectors. This has revealed a number of bottlenecks that limit or slow adaptation responses and helped to identify enabling mechanisms that should be a high priority for policy makers aiming to ensure timely and effective adaptation. In this document, these findings are synthesized into a strategic and operational response framework for water-mediated adaptation to climate change.

This draft document will be presented and discussed in the 5th World Water Forum in Istanbul under Topic 1.1 'Adaptation to Climate Change'.

Quick reading guide

Chapter 2 explains the vulnerabilities and risks associated with climate change. Potential geographical hot spots are described in Chapter 3. Chapter 4 explores sector vulnerabilities and risks in greater detail. Identified barriers and critical challenges are inventoried in Chapter 5, and Chapter 6 lists enabling mechanisms. The document concludes with the strategic and operational responses to climate change in the water sector offered in Chapter 7.

2 Vulnerabilities and risks

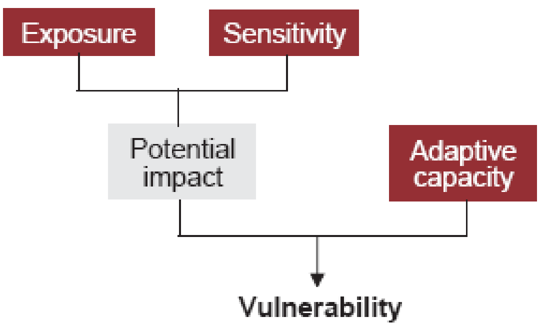
Risk is a function of the probability of an event occurring and the severity of its impacts (IPCC, 2001). IPCC defines vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change impacts, including climate variability and extremes". As depicted in Figure 1, vulnerability to a potential impact is related to the extent of exposure to a hazard and to sensitivity. Vulnerability to flood hazards serves as a good example. When floods occur more frequently, exposure to floods increases. Sensitivity also increases in the form of reduced food security after floods. The resulting impacts of these increases tends to increase vulnerability.

Vulnerability is reduced, however, by capacity to adapt to an impact. Adaptive capacity enables planning and implementation of adaptation measures to reduce risk by increasing preparedness or enabling coping mechanisms.

The IPCC Fourth Assessment Report (2007a) described criteria for identifying vulnerabilities of ecological and socio-economic systems. Criteria were based on magnitude of impacts, timing, persistence, the extent to which systems are resilient to external pressures, and reversibility and likelihood, among others. Potential for adaptation, distribution of impacts and vulnerabilities, and importance of the systems were also identified as criteria.

Sectoral perspectives illuminate the importance of systems at risk. The more sectors and water users in the same region are affected by higher frequency or more severe events – such as droughts, floods or coastal inundation – the larger the exposure of populations. The distribution of vulnerabilities relates to geographically-defined 'hot spots' where water especially mediates impacts and where sensitivities are high (e.g. for populations whose livelihoods are based on a narrow range of assets). Potential for adaptation is based on mechanisms that enable responses to climate change at various levels. The more coping mechanisms available and accessible, the greater the adaptive capacity of the countries and communities concerned.

The Bali Action Plan (UNFCCC, 2007) recognises especially vulnerable areas. It addresses the importance of water-related adaptation actions through vulnerability assessments, prioritization of actions, financial needs assessments, capacity-building and response strategies, and integration of adaptation actions into sectoral and national planning, among others. Vulnerabilities of developing countries and small island developing states are given high priority (e.g. countries in Africa affected by drought, desertification and floods).



Exposure: The nature and degree to which a system is exposed to climate change.
Sensitivity: The degree to which a human–environment system is affected, either adversely or beneficially, by climate change.
Potential Impacts (PI): All impacts that may occur given projected climate change, without considering planned adaptation.
Adaptive Capacity (A): The potential to implement planned adaptation measures.

Figure 1: Vulnerability and its components (adapted from Schöter et al., 2004)

3 Geographical Hot Spots of Vulnerability to Climate Change Impacts on Water

3.1 Climate Change Hotspots

As shown in the 4^{th} IPCC report and other publications. (e.g. Giorgi, 2006), the climate signal is likely to be more intense and rapid in certain locations (e.g. the Mediterranean), creating patterns of hazards and threats across the globe. Analysis of the various Perspective Documents reveals a huge geographical and social inequity in the distribution of vulnerability and capacity to cope with climate change shocks and stresses. Depending on where they occur, the impacts of increasing sea level rise, storm surges, floods and droughts will look very different. The developing world and the poorest fringes of societies will undoubtedly be affected most severely.

Areas critically at risk from short and long-term hydrological impacts of climate change will form so-called 'hot spots' of vulnerability. Following the IPCC definition of risks and vulnerability, these may be countries, or locations or communities within a country, where the likelihood of dangerous climate change hazards and sensitivity to their effects are relatively high, and local adaptive capacity to cope is relatively low (Chapter 2; Kabat et al., 2003). Determining the locations of hot spots is a crucial step in adaptation planning, as they provide the basis for raising political awareness, setting priorities and mobilizing adaptation funding in relation to needs.

Geographical categories perceived as potential hot spots include:

- mountains and their rivers – where glaciers retreat and reduction in the size of winter snow packs will increase flood or drought risks and shift the volume and timing of downstream water availability for irrigation, industry and cities;
- small islands – where sensitivity to coastal erosion, inundation and salt-water intrusion will increase;
- arid regions – where susceptibility to more severe or more frequent water scarcity is high;
- deltas and low-lying coastal mega-cities – where higher frequency of flooding and coastal inundation will have the most acute impacts.

Box 1 – Vulnerability Assessment

Assessment of vulnerability and risks are instrumental in identification of hot spots. Significant progress has been made recently on methodologies for vulnerability assessments. International agencies and research centres are now actively contributing to raising the profile of climate change impact assessment tools and protocols, notably through the development of more precise and reliable regional climate models and of downscaling techniques. However, despite these developments, current risk analyses are usually conducted at a very large scale (global to regional) and have very coarse spatial resolution. In most cases, they fail to deliver the level of information needed to support national and local adaptation planning and investment decisions. Moreover, attempts to identify 'climate change hot spot' areas with a special focus on water resources and services remain quite limited. They lack a common and widely accepted framework for vulnerability assessment to enable comparison of results, reduce uncertainties and support cost-effective policy making at various scales.

3.2 Mountains and glaciers

The Perspective Document of ICIMOD (Erikson et al., 2009) stresses that high mountain and glacier areas present unique patterns of vulnerability to the impacts of climate change. Often described as 'the World's Water Towers', they provide 50% of global river runoff and underpin water supply for more than one-sixth of the Earth's population (ICIMOD, 2008). Mountain cryospheres, ecosystems and the nations and communities relying on mountain rivers are extremely sensitive to global warming and its associated changes in temperatures, precipitation patterns (amount, intensity and timing) and evaporation rates. Key climate change vulnerabilities in the Himalayas relate primarily to the reduction of snow pack, and the melting of glaciers and permafrost associated with increased water-related disasters, including Glacial Lake Outburst Floods (GLOFs).

The Himalayan region, which possesses the largest mass of ice outside of the polar caps, is one of the areas at highest risks from global changes in hydrology. In both the short and long term, warming temperatures are severely impacting the amount of snow and ice in the region, which determine natural water storage capacity and downstream water availability. Current observations show that snowmelt is now beginning earlier in winter and that glaciers are retreating at an average rate of 10–15 metres a year (UNDP, 2007) as a result of decreasing precipitation and rising temperatures (UNDP, 2007). IPCC scenarios show that with a 2 °C increase, short term increases in glacial flow will be followed by long-term drying.

Similar processes are affecting mountain regions worldwide, with development and vulnerabilities being closely tied to glacier-fed mountain rivers. This accelerated snow and glacial melt has the potential to affect downstream river regimes, with repercussions for water supply, hydropower, agriculture and infrastructure, particularly in basins which are dependent upon glacial melt in summer. Also, the frequency and magnitude of extreme events such as avalanches, flash floods, landslides and debris flows are likely to rise, causing tremendous damage in densely populated mountainous basins. Similarly, reduced water storage and availability will exacerbate current pressures on water resources and may generate additional tensions and conflicts over water allocation among countries, provinces and sectors.

The Perspective Document on mountainous areas (Erikson et al., 2009) points out that resilience of snow and glacier-fed watersheds cannot be mandated from above. Structural and 'command-and-control' type adaptive solutions can generate benefits only if they are fully embedded into a broader process of mainstreaming climate change risks into regional and local development policies and practices. Consequently, the transboundary nature of mountains and glacial watersheds presents a key challenge to which calls for innovative adaptation governing arrangements and enabling mechanisms. These include:

- improvement of modelling and assessment tools to reduce uncertainty about magnitude and consequences of changes;
- greater quality and accessibility of climate information to support climate-proofing of policy-making and management;
- 'bottom-up' resilience-building strategies through empowerment of local populations and community-based adaptation;
- development of regional cooperation in support of transboundary planning and decision making;
- valuation of watershed services through adequate market-based mechanisms (e.g. PES).

The Perspective Document promotes adaptation measures that build upon traditional flexibility and resilience in livelihood strategies and institutional arrangements in mountain communities, as well as hazard mapping to adapt to future changes through proper planning and design. It also considers the importance of highly specialized adaptation to confront the immediate impacts of GLOFs (through for example retention dams, glacial lakes draining, canalisation works, etc). In the mid to long run, however, such costly and highly specific climate-proofing efforts may need to be balanced against more preventive sustainable development and strategic planning responses as the forces in the glaciers go far beyond what mankind can construct and absorb.

3.3 Small Islands

As highlighted in the perspective paper from the Pacific Islands Applied Geoscience Commission (SOPAC) and Caribbean Environment and Health Institute (CEHI), climate change and sea-level rise (SLR) bring major challenges to water management in small islands. Small Islands Developing States (SIDS) and territories are clearly characterized as climate change hotspots because of their sparse and fragile water resources and supplies, which make them extremely sensitive to shifts in the water cycle. The vulnerability of small islands is driven by a set of natural and anthropogenic factors, which include their small physical size and low land elevation, lack of natural water storage, proneness to water-related disasters and extreme events, high population density and growth, limited infrastructures and scarce financial and human resources (IPCC, 2007). Combined with these baseline constraints, projected changes in temperature, precipitation patterns and sea level are expected to translate into a large array of destructive impacts and risks to water.

In the Pacific, the SOPAC/CEHI's paper shows that higher temperatures, increased evaporation rates and more erratic rainfall are likely to lead to more frequent and more intense drought spells – putting agricultural activities, rural livelihoods and urban water supply at jeopardy. In the Caribbean, climate scenarios indicate a trend of increased frequency and severity of tropical cyclones and hurricanes. These extreme events will be accompanied by exceptionally intense rainfall and storm surges. Under changing climatic conditions, these may result in catastrophic flooding (especially in mountainous and low-lying islands), enhanced costal erosion, semi-permanent submersion and salt water intrusion. Accelerated sea level rise is expected to act as a 'threat multiplier' and will magnify impacts of climate change on small island water systems. Exacerbated flooding can cause significant damage to water infrastructures (intake works, treatment plants, small dams or distribution networks) and may indirectly affect water supply by degrading water quality. Similarly, with over 80% of the SIDS populations located in low-lying coastal lands, costal inundation will have a destructive impact on properties, settlements, water-based livelihoods and human development in general. Moreover, intrusion of salt water is expected to lead to salinisation of soil, aquifers, and estuaries, thus threatening drinking water supplies, irrigation and economically important ecosystems.

Adaptation options proposed in the Small Islands paper fall into the category of best practices and 'no-regret'. The upgrading and integration of watershed and coastal areas management is flagged as top adaptation priority. From this perspective, the way forward in small islands is based on the following enabling mechanisms:

- strengthening of hydrological services in their capacity to develop and apply responsive water monitoring and forecasting systems;
- role-out of risk-based drinking water safety planning and management;
- mainstreaming climate information and disasters preparedness into IWRM frameworks;
- increasing resilience-building investment through enhanced political awareness and regional cooperation.

3.4 Arid regions

As evidenced by the Arab Water Council's document (Arab Water Council, 2009), climate change projections indicate that arid and semi-arid region will suffer the highest decrease in precipitation worldwide (up to 30% by 2100). Already faced by structural water scarcity and fast-growing water demand, climate change has the potential to bring drylands' traditional and conventional water management models to their breaking point. In Middle East and North Africa, already the world's most water-stressed region, climate change could add some 80-100 million people to the population exposed to water stress by 2025 (Warren et al, 2006). This situation will worsen unsustainable depletion of groundwater and may create additional competition for water across sectors (especially from agriculture) and geographic locations. Increased intrusion of salt water into coastal aquifers due to sea-level rise will further reduce the availability of usable ground water (IPCC, 2007).

The resulting decrease in water availability will pose a direct threat to food production and security in drylands. In most arid and semi-arid areas, water, not land, is the limiting factor for agricultural production. With climate change, agricultural yields, especially in rain-fed agricultural areas, are expected to fluctuate more widely over time, and to converge to a significantly lower longer-term average (WB, 2007). In agriculture-dependent countries the decline in production may lead to loss of jobs and incomes and generate serious economic reversals. For example, in Morocco, economic growth for 2005 was downscaled from 3.5 to 1.3 percent as a result of drought (UNDP, 2006). Furthermore, water-related extreme events, such as drought and floods will worsen public health in urban and rural areas, cause loss of life and assets. and may further intensify domestic and international migration, especially in North and Sub-Saharan Africa where numbers of 'climate refugees' are escalating.

In the this context of vulnerabilities and risks, the main enabling mechanisms prioritized by arid and semi-arid regions involve:

- multi-disciplinary approach and trans-global cooperation for information and knowledge management on water and climate;
- effective demand management through use of 'virtual water' and water saving policies;
- systemic and institutional capacity building through targeted training and learning;
- adequate financing strategies for infrastructure and research development;

- multi-stakeholders engagement and good governance of the water sector;

Climate change will primarily manifest itself in arid regions by increasing the pace and magnitude of the already growing gap between water supply and demand. Logically, response measures highlighted in the perspective paper on arid regions overlap to a large extent with best management practices and no-regret options. Thus, demand management measures (such as more efficient water supply and irrigation systems combined with drought-resilient farming practices and importation of water-intensive commodities) are considered as priority measures.

3.5 Low-lying coastal areas and coastal megacities

Because of their strategic position and economic attractiveness, coastal zones face unprecedented population growth and urban expansion. According to Deltares and ICLEI, most of the world's economic wealth and largest megacities (those with 10 million inhabitants or more) are located in low-lying deltas already highly vulnerable to storm surges, flooding and stagnating drainage. Climate change and variability will indubitably create mounting threats to these areas, with developing countries and poor communities being more profoundly impacted. Recent assessments point out that sea-level rise, combined with more frequent and severe flooding, could affect over 70 million people in Bangladesh, 6 million in Lower Egypt and 22 million in Viet Nam (UNDP, 2007). The resultant risks on water will take different forms. Combined with salt water intrusion from higher sea level, more unpredictable and unreliable rainfall and river discharge are likely to increase water scarcity and shortage, especially in summer. Such effects would have harmful consequences on water supply of deltaic agglomerations and agriculture. Increasing storm surges and rains could increase the risks of marine-induced disasters, inundations, water contamination, and water-borne disease. Designed under historic climate conditions, urban water infrastructure (water distribution pipes, sewage and sanitation facilities, storm drainage, etc.) are likely to suffer damage and rehabilitation costs. Furthermore, water insecurity induced by climate change may lead to heightened competition for freshwater. Conflicting demand from urban development, agriculture and the environment are likely to increase, generating challenging social and political tensions.

In view of the these challenges, enabling mechanisms identified for deltas and costal megacities for water management adaptation include:

- integrated spatial and urban planning combined with land reclamation (when relevant) to reduce pressures on land and water;
- management and recovery of natural dynamics and ecosystems to develop resilience and adaptive capacity ('building with nature' concept);
- progressive redesign and multifunctional use of water infrastructures;
- provision of reliable climate change information and risks analysis tools to support adaptive management;
- strengthening of governance and decision-making structures through increased public participation, multi-level cooperation, pro-active thinking and secured financing.

Coping approaches supporting the above mechanisms fall largely under the realm of no-regret options. Responses considered include: nested closed-loop systems for water supply, storm surge control or sewage-treatment; improvement of urban drainage, and costal road systems; stormwater retention ponds and constructed wetlands and shoreline management planning. Specific impact-targeted adaptation actions are also considered and include revised construction standards for flood-defences, high-standard embankment (super levee) within river restoration, salt-resistant farming and cropping systems or relocation of settlements and activities to low-risk areas.

3.6 Conclusion

Some regions such as low lying coastal areas and cities, mountainous areas and arid countries will be more vulnerable to the impacts of climate change on water resources and water services. The Perspective Documents confirm this assumption, arguing that climate change should be considered a 'threat multiplier', magnifying the effects of other drivers of vulnerability and risks, such as population growth, urbanisation and land use change.

Furthermore, the analysis of perspectives has shown that there is no 'one-size-fits-all' approach to cope with the harmful consequences of climate change and variability on water systems and uses. Geographical hotspots all share a common sense of urgency but there are varying perceptions in terms of classification of risks, prioritisation of responses and enabling mechanisms required to facilitate sector-wide transition and societal resilience.

Response mechanisms are thus locally specific and include 'command and control' approaches where defence and protection of lives and economic interests are important (such as coastal and mountainous areas threatened by surge storms and GLOFs) and otherwise more sustainable development measures where optimisation is perceived as a balancing act under paradigms, such as 'living with water' or 'ecosystem-based' adaptation. The former perspective tends to be overly visible in most hotspot areas. The latter is, as yet, less visible, but is gaining momentum as water managers are increasingly realizing that nature poses limits to development and to technology-based adaptation. The main challenge therefore is to combine elements of both perspectives into a strategy that is both economically viable and ecologically sound.

Similarly, adaptation options identified in the various perspectives appear to lie mainly in the range of best management practices and no-regret measures. Specific climate-justified measures, which fall outside traditional water and disaster management practice, remain limited. One important reason for this is that climate change has just started to produce its effects and water managers and policy-makers may face difficulties to differentiate long-term climate change trends from manifestations of 'historic' climate variability. Another possible reason is that climate change targeted measures require new approaches, which prove both costly and politically challenging under the current level of uncertainty.

4 Sector Perspectives on Vulnerabilities and Risks

Water is a key resource for a very large array of economic activities. Given water's central role in mediating impacts, climate change is expected to affect many of these economic pursuits. Each sector has its own specific perspective on climate change and associated vulnerabilities and is, therefore, developing sector-specific coping measures. The systemic nature of water, however, makes boundaries between sectors artificial. Surveying sectoral perspectives reveals opportunities for creating system-wide approaches to climate change adaptation that emerge when response measures from across sectors are brought together in portfolios of actions. The perspectives available from the Perspective Documents are not, however, comprehensive. There are significant gaps in the perspectives currently available, notably with regards to health, tourism and transport. Nonetheless, the available perspectives are sufficient to highlight the advantages of a cross-sectoral, portfolio-based approach to adaptation planning and operational implementation.

4.1 Water Utilities

Due to climate change, water utilities face increasing uncertainty in the design of urban drainage systems, water supply systems and water resources management. Key vulnerabilities of concern to water utilities in a changing hydrology are future limits to groundwater extraction where water tables fall, decreased water quality as a consequence of reduced dilution capacities of water bodies, water scarcity where storage is inadequate and mass destruction of infrastructure following extreme weather events. Specific vulnerabilities relate to river floods, as well as to seawater intrusion causing salinisation of aquifers resulting in degraded freshwater supply. Consequences of these impacts, including increased disease burden and human migration, compound the climate-related pressures on water utilities. Changes in flow seasonality cause uncertainties about water storage capacity needs, particularly in densely populated floodplains.

Response actions identified by the utilities sector include demand management measures through reductions in water consumption by awareness raising, pricing, new technology etc., and by supply measures to increase water availability. The water utilities sector requires flexibility in water resources management to reduce vulnerability to external shocks, including climate change. The sector is also in need of a portfolio approach characterized by adaptation that includes operational measures, strategies for more flexibility in the design and operation of structural provisions, awareness and behavioural campaigns, smart technologies, political awareness raising, institutional adjustments, capacity development, and asset management.

Enabling mechanisms for adaptation identified as priorities in the water utilities sector include:

- modelling of climate change;
- monitoring of climate variability and change, and its impacts, including observational networks;
- development of nimble, adaptive management strategies;
- education and training of all personnel;
- demand driven climate research that is developed with the involvement of the water sector.

4.2 WASH Sector (WAter, Sanitation and Hygiene)

As a first step, the WASH sector must engage effectively with climate change researchers and in relevant research programmes. This will help ensure that discussions on the potential impacts of climate change on the WASH sector consider climate impacts along with, rather than in isolation from, the other considerable challenges currently facing the sector. It will also ensure that recommendations developed take account of the lessons already learned from attempts to meet existing WASH challenges. This will reduce the risk of repeating costly mistakes.

Measures to increased capacity to cope with climate change impacts in the sector include:

- Improving WASH governance systems so they are better able to take account of increasing uncertainty due to climate change. In addition, governance systems that explicitly match actions and interventions to specific contexts and take explicit account of potential externalities are required.
- Adopting and implementing IWRM to better align 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 flexible planning approaches that are backed up by strong monitoring and information management systems, which allow constant adaptation and the upgrading of plans and activities.
- Strengthening capacity within the WASH sector, particularly at the intermediate and local levels.

4.3 Agriculture: Food and Fibre Production and Security

Climate change and changing hydrology have numerous implications for agriculture; these are based on a variety of mechanisms. Changes in evapotranspiration, photosynthesis and distributions of pests and pollinating insects, for example, will have effects on food production that vary strongly according to location, with some regions experiencing benefits, while others will suffer lower production that increases vulnerabilities (e.g. regions where rainfed agriculture dominates and rainfall is projected to decline or where the frequency of drought rises). Expansion of irrigated agriculture is identified as a means of reducing such vulnerabilities, but irrigation systems are themselves vulnerable where climate changes affect runoff and groundwater recharge. Agriculture is vulnerable to losses because of flooding, particularly in coastal deltas, where exposure to coastal inundation and salinisation of groundwater will increase as the climate changes. Sensitivity to climate impacts is especially high in marginal areas such as arid and mountainous regions because of interactions between subsistence farming, water, food production and poverty.

Response options in agriculture focus on modification of farming systems to better account for climate vulnerabilities and changing uncertainties. This includes best practice soil water management in rainfed agriculture. In vulnerable areas, cropping patterns may shift as crops or crop varieties more adapted to the new climate replace those that are less adapted. Best practices and no-regret demand management are needed to reduce the vulnerability of irrigated agriculture, and support new irrigation development that may emerge in response to climate change and variability.

Policies and actions relating water, agriculture and climate change need to be better incorporated into agricultural development processes. Enabling mechanisms for adaptation in agriculture include:

- institutional and managerial flexibility;

- improved responsiveness of future investments in land and water to climate opportunities;
- access to relevant information on water and climate change;
- resilience building in all food production systems, particularly in the most vulnerable farming systems.

4.4 Ecosystems and the Environment

Ecosystem services are the benefits people obtain from nature. They are commonly categorised as provisioning, regulating, supporting or cultural services. By way of example, supply of food and freshwater are provisioning services, flood attenuation and water purification are regulating services, nutrient cycling and soil formation are supporting services, and opportunities for recreation are cultural services. Human well-being can be damaged when these services are degraded, and costs must be borne to replace or restore the services lost. Ecosystems are integral to the benefits people derive from the hydrological cycle and to protection against extremes. Ecosystem services provide vital 'natural infrastructure' needed to reduce vulnerabilities to climate change.

Examples of natural infrastructure in river basins abound, from the uplands through floodplains to the estuary and coastal zone. Deep, upland soils in mountain grasslands and glaciers store and feed water for use by downstream populations in agriculture and to sustain cities. Forests in upper watersheds protect soils and stabilise slopes, and retain water. Lakes, wetlands, and aquifers store water for use during drought and in historically arid regions. Intact floodplains reduce flooding by giving rivers the space needed to dissipate peak flows, especially in low-lying deltas. At the coast, mangroves, coral reefs and barrier islands protect against erosion, buffer saltwater intrusion, and attenuate storm surges. In this context no-regrets measures, such as incorporating vulnerability assessment and dynamic hydrology into integrated water resources management and the ecosystems approach, will be justified by the urgency of maintaining and rebuilding environmental infrastructure in the face of uncertain future changes.

From an environmental perspective, natural infrastructure and conservation of ecosystems and biodiversity are integral to building and maintaining resilient water resources and resilient human societies. Ecosystem-based approaches to climate change adaptation that build on no-regret measures such as restoration of floodplains or conservation of wetlands and upland forests and grasslands support natural infrastructure. They are complemented by coping measures for different sectors that include application of best practices in environmental management to ensure that ecosystem services support the resilience of systems needed to cope with future uncertainties. This entails reconciling environmental concerns with, for example, business and energy perspectives. This is increasingly made possible by application of decision-support tools that enable comparison of the costs and benefits – including valuations for ecosystem services – of alternative investment options. Such tools make it possible to select among climate change response options, including ecosystem-based adaptation, on the basis of future returns on investment that include the benefits people receive from ecosystem services.

Key enabling mechanisms from the environmental perspective include:

- reform of water governance to enable participatory and accountable coordination of water resources development;
- investment strategies based on principles of good governance;
- learning from integrated water resources management;
- integration of natural infrastructure into adaptation planning.

4.5 Energy Sector

All human-devised energy systems or technologies have a water footprint, which, in varying degrees, impacts on the quantity and quality of water available to other uses. The capacity of the energy sector to adapt to climate change stems, in part, from the combined effects of fuel switching opportunities and the uneven distribution of water and energy resources and rates of consumption across the world and within countries. Desalination is a good example of how options for adaptation are strongly related to water-energy linkages. In arid yet oil-rich countries, shortages of water could be economically overcome through desalination regardless of high energy requirements.

Because climate change impacts on hydrological systems are projected to limit water availability overall, energy supply will struggle to keep pace with increasing energy demand accordingly. Biomass is especially vulnerable to the adverse effects of water cycle changes on river catchments. In this respect, it is important to recognise that fuel wood, charcoal, agricultural waste, dung, etc., are still the dominant energy source in the household sector for the poorer segments of global society. In the transport sector, bio fuel crop production is a fast-growing consumptive use of water with potential to compete with other water users, especially where there is water scarcity. Finally, the hydropower sector is vulnerable to changes in seasonal water availability, especially in terms of scarcity and exacerbation of scarcity by evaporative loss from large reservoirs.

The Energy Sector is driven by considerations of risk minimization and costs and benefits. A command-and-control approach is preferred in the sector. However, there is recognition that no single prescription is sufficient and that climate adaptation at the water-energy interface hinges on addressing multiple imperatives including:

- reconciliation of demand and supply to provide climate 'headroom';
- climate-proofing of water, energy and ecosystem services;
- recognition of the dominant role of electricity in low-carbon energy systems;
- better understanding of the water footprint of energy systems;
- appropriate capacity building with knowledge-sharing, technology, industry and finance to move adaptation from policy to practice.

4.6 Businesses and Industry

Key vulnerabilities for businesses are generally associated with reduced resilience in operations. On the one hand, costs can arise as a consequence of damage to physical assets, including insurance or supply disruptions (e.g. EFD Group was forced to redesign a sub-glacial water intake due to accelerated glacier retreat). Facilities may need to be redesigned according to the potential for water and energy savings, and recovery and reuse as well. Water and wastewater efficiency can be achieved through various interventions depending on context based product life cycles and business processes (e.g. through adoption of new crop varieties or heating and cooling technologies). The IPCC (2007) states, with high confidence, that there are viable adaptation options that can be implemented in some sectors at low cost, and/or with high benefit-cost ratios. Negative environmental and social impacts due to excessive groundwater abstractions represent another key vulnerability for the business community when manifested in terms of reputation, market competitiveness, or risk of conflict over licence to operate.

Enabling mechanisms with high priority for business and industry include:

- provision of reliable climate change risk data, models and analysis tools;
- integration between water and energy efficiency in measurement tools and policy;
- delivery of common management practices, education and awareness raising from institutional capacities;
- valuation of ecosystem services within trans-boundary decision-making;
- promotion of best practices through innovation, appropriate solutions and community engagement.

4.7 Sector Perspectives: Conclusions

Perceptions of vulnerability differ among sectors, as do perspectives on priority setting for improving coping capacities and enabling mechanisms. Utilities, energy and industry take a predominantly control-oriented approach, in which options are identified based on the question of how to respond most effectively to specific effects and uncertainties. In contrast, the more resilience oriented WASH, agricultural and environment perspectives are based on putting in place adaptive systems (in terms of management, social-economic and ecological components) that will cope best with future uncertainties. Significantly, these two approaches – one control oriented and the other resilience oriented – are not necessarily mutually exclusive, and within an effective strategic framework are likely to have many complementary elements.

In many sectors, the impact of climate change will result in an increase in the cost of water services and the cost of reliability in service delivery. These costs will be caused more by infrastructure, information and systems needed to cope with climate variability, than by scarcity. Variability under great uncertainty will be a management challenge for all sectors analysed. IWRM theoretically offers the opportunity to build resilience to current climate variability while building capacity to adapt to future climate change. Moreover, it allows balancing of equity, environmental and economic priorities, as well as 'soft' and 'hard' responses with 'hard' responses including both natural and man-made infrastructure at the community, national, and river basin levels).

5 Barriers to Adaptation and Critical Challenges

Perspectives on climate change adaptation from different sectors and contrasting hot spots highlight a wide variety of needs and potential actions. This diversity leads to the possibility of confusion, especially among politicians, policy makers and the general public – all of whom must rely upon advice from experts. With so many legitimate voices speaking on adaptation, finding a coherent way forward in the face of numerous competing policy priorities (whether relating to water, industry, energy, food, or environment) is a major challenge. Nonetheless, recognising the centrality of water to climate change impacts provides an opportunity to use water as the starting point for both action planning and for the development of the adaptation policies needed to mobilise resources and implementation.

Each of the geographic hot spots has different priorities for adaptation depending on its particular vulnerabilities to impacts projected because of drought, flood, melting ice, storms or sea-level rise. Each sector – agriculture, energy, industry, water utilities and environment – offers a set of responses, as well as capabilities for action. In the water services sector, for example, response actions are combinations of demand management, including incentives for water conservation through tariff structures; changes in technical specifications and tolerances for infrastructure; and applications technologies, including desalination, recycling of domestic wastewater or nested closed-loop systems design. In agriculture, concerns about drought, floods and greater climatic extremes provoke worries about weakening of food security. Response actions proposed include more water storage, a new generation of investment in irrigation, application of efficient technologies, and selection of new crop varieties adapted to the new extremes. In the industry and energy sectors, upgrading and updating of infrastructure to increase tolerances to uncertainty and new infrastructure to meet expected storage, supply and flood protection requirements under future climates are called for. From the perspective of environment, restoration and maintenance of the 'natural infrastructure' of river basins is needed to build the resilience of communities and economies. Such responses, and many other potential actions, are prioritised and tailored to local conditions in each hot spot. Which options are chosen in a given location will depend on specific vulnerabilities, the capacities of institutions, knowledge and skills, and economic resources.

Myriad practical response options are available for those who must decide which actions are warranted or need priority attention at either the local, national, or international level. While the diversity of available options demonstrates that practical steps can be undertaken, it confronts decision makers with a long menu of choices. Portfolios of actions that cut across sectors and vulnerabilities need to be formulated to alleviate this problem. It is critical that obstacles to their development be identified and addressed, and that barriers to action in the form of practical responses are understood and overcome.

At this juncture, barriers to action are as prolific as response options. A Minister or policy maker who is asked to give priority to adaptation will confront a huge array of necessary (and possibly disparate) measures, which are accompanied by constraints that severely limit the decision maker's confidence in the available choices. This scenario consistently results in the higher placement of other issues on a Minister's list of priorities.

The major barriers to a coherent and coordinated approach to adaptation include:

- *Lack of information* – In many locations, climate and hydrological information systems are inadequate. Lack of information makes planning and risk assessment difficult. This is compounded by the inadequacy of data on climate change at scales – such as river basin, national and local – that give decision makers enough confidence to make decisions on adaptation.

- *Inadequate tools and analysis* – In addition to simply not having the desired information, the analytical tools needed to support decisions are absent. For example, most locations lack the means of assessing the costs and benefits of adaptation options under uncertain futures and at scales that support practical decision making by local authorities, utility companies or river basin authorities.
- *Lack of knowledge and capacity* – Climate change is full of uncertainty, and is poorly understood among non-specialists. Effective adaptation will require combinations of actions and policies that link international processes, national governments and local actions. At many linkages along this chain, lack of knowledge and understanding prevents development or planning that is appropriate in a changing climate.
- *Inappropriate institutions* – Effective adaptation requires institutions that are structured and managed to ensure that they are adaptive and able to coordinate across sectors. Too often, in water and related sectors, institutions struggle to adequately coordinate among themselves and manage adaptively, even without the uncertainty associated with climate change. This may result in fragmented and poorly integrated planning and action and a failure to coordinate the necessary portfolios of actions.
- *Lack of policy cohesion* – Uncertainty, lack of knowledge, and fragmentation result in the absence of a clear and systematic approach to policy formulation in the midst of competing priorities. This further results in missed opportunities to coordinate action and investment, not just among sectors, but also with other priority issues in public policy (e.g. health, development, and economic growth).
- *Inadequate financing* – In many places, especially in developing countries but also in major cities in developed countries, many response actions cannot be taken until ways to meet the huge potential costs of adaptation are found.

6 Enabling Mechanisms for Adaptation

Coping with climate change requires transformation of the sectoral approach in water management to an approach where water is considered the principal and crosscutting medium for climate resilient development. Mainstreaming climate into water policies and IWRM alone will not accomplish this. Water management will have to go beyond the proverbial ‘water box’ to address evolving complexities and develop innovative governance modalities, financing mechanisms and technologies; in combination with capacity development, structural reform and transfer programmes for vulnerable societies. An understanding of enabling mechanisms and additional instruments is urgently required.

Given the many linkages between the impacts of climate change and social and economic systems, adaptation cannot be implemented efficiently by itself or as a strictly environmental issue, and a sensible combination of different kinds of enabling responses is needed. Sustainable development can be promoted by identifying clear responses to the consequences of climate change on water resources and water services. Though by no means comprehensive, the overview in this chapter emphasizes actions that incorporate the key principle ‘prevent rather than cure’ at the appropriate scale. The responses can be grouped as follows:

- climate and water (hydrological) information;
- tools for planning and assessment;
- technology (including infrastructure);
- natural systems;
- governance;
- finance;
- capacity building.

The process that addresses these enabling mechanisms as a whole is ‘climate proofing’ and can be implemented at the basin, national or local level.

Table 1 qualitatively presents the level of attention given to different enabling mechanisms in the Perspective Documents and clearly indicates that the importance assigned to different enabling mechanisms varies across sectors.

Table 1: Qualitative representation of attention given in Perspective Documents.

PERSPECTIVES AND ENABLING MECHANISMS		Climate information and data collection and sharing	Spatial and economic planning and adaptation	IWMR + SEA	Better engineering and adaptation	Governance and adaptation	Financing of Adaptation	Capacity building
WATER-USE AND SUB-SECTOR PERSPECTIVES	Water supply and sanitation: Water Utilities	+	++	o	++	+	o	++
	Water supply and sanitation: the urban poor	+++	o	+++	o	++	o	+++
	Water and Food	+++	++	o	o	+	+++	+++
	Water and Energy	+	++	++	++	++	++	++
	Water and Nature	++	++	+++	+	+++	+	++
	Water and Business	+++	+	o	o	++	+	+++
GEOGRAPHICAL HOT SPOTS	Arid Regions	+++	+++	+	+++	+++	+++	++
	Small Islands	+++	++	++	++	++	++	+++
	Glacial melt / high mountain areas	++	o	++	+	+++	o	+++
	Coastal Mega Cities	+	+	+	+	+	+	+
	Deltas	+	+	+	+	o	o	+

o	not applicable / not mentioned
+	mentioned as an enabling mechanism
++	mentioned as an important enabling mechanism
+++	mentioned as being an essential enabling mechanism

6.1 Climate and water information

Climate data and information are essential and provide the foundation upon which adaptation measures are developed. While examples of the use of climate predictions at different time scales to improve decision making exist, in some cases available information is not used because of concerns that consideration of such information may not necessarily lead to improved decisions. Ensuring access to useful information is key because the availability of information does not necessarily guarantee its accessibility or appropriate delivery for a specific purpose.

It is generally recognized that decision-making should be guided by an IWRM[1] approach and that climate variability and change play a significant role in water resource decision making. In practice, however, a significant gap in the use of climate information in decision making and in considering the effects of climate change remains. For example, although most of the IWRM plans prepared in response to the Johannesburg target for IWRM plan preparation are based (whether implicitly or explicitly) on climatic considerations, they rarely make explicit reference to climate variability and change. Water professionals are well advised to ensure that climate information, whether for the short, medium or long term, is tailored to serve their needs at national, regional or local levels. Water sector professionals cannot rely on climate specialists to do this work for them, rather, they must take responsibility for specifying this information themselves.

6.2 Tools for planning and assessment

Integrating adaptation in overall planning and defining guiding principles for doing so are important challenges. Institutionalisation of 'integrated

[1] Integrated Water Resources Management (IWRM): the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner, without compromising the sustainability of vital ecosystems

approaches' for land and water requires coordinated decision-making and planning across sectors as well as across administrative boundaries and geographic areas (e.g. upstream and downstream). Organisation of national ministries, government agencies and centralised or decentralised administrative systems along sectoral lines does little to facilitate necessary coordination, because land and water management issues frequently fall under diverse sectoral ministries (agriculture, forestry, fisheries, water, environment, etc.) and corresponding agencies.

A number of conceptual frameworks and guiding principles[2] for integrated land and water management have evolved using livelihoods and ecosystem-based approaches. Among these, Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA) have proven to be of major significance, as both approaches are able to support the integration of climate change adaptation in overall water resources planning.

IWRM has been the accepted management paradigm for efficient, equitable and sustainable management of water resources since the early 1990s. IWRM promotes co-ordinated development and management of water, land and related resources to maximise the resultant economic and social welfare in an equitable manner, without compromising the sustainability of vital ecosystems.

IWRM's strength is a well-developed and highly-structured approach, which is capable of coping with the multi-functionality of water, based on quantified data. Its weakness is a lack of formal procedural requirements for implementation by governments and water institutions, which results in weakly implemented process aspects, such as public participation. The extent to which other sectors are unaware of the principles of IWRM is a further disadvantage.

Strategic Environmental Assessment (SEA) is a family of tools for identifying and addressing environmental consequences and stakeholder concerns in the development of policies, plans, programmes and other high-level initiatives. Under this approach, the definition of 'environment' depends on the scope of the SEA, and ranges from the biophysical environment only, to an all-encompassing scope that includes biophysical, social, economic and institutional environments.

SEA's strength lies in the fact that it is a legally embedded tool with clearly demarcated roles and responsibilities. Furthermore, widespread awareness of SEA is accompanied by a strong common understanding of what constitutes good SEA practice, and core values of transparency and stakeholder participation are supported by an increasing evidence base of good practices. SEA provides the procedural umbrella, under which a variety of tools must be used, but in and of itself SEA has relatively little content; this is its greatest weakness.

The SEA process targets development of better strategies for sustainable development, ranging from legislation and countrywide development policies to more concrete sector and spatial plans. SEA assists in identifying, assessing and comparing the different ways in which a policy, plan or programme can achieve its objectives. SEA is a complementary tool for the IWRM process.

IWRM and SEA share many characteristics including: integration of environmental and social considerations into multi-sectoral decisions, participatory approaches, monitoring and evaluation of outcomes, broadening of perspectives beyond immediate sectoral issues, and emphasis on the product as well as the process. A comparison of the strengths and weaknesses of the two approaches reveals complementary differences, summarised in four messages:

1 SEA is a legally established vehicle that can convey the messages of IWRM.
2 SEA is better geared toward practical implementation of the principles it shares with IWRM (stakeholder participation and informed, transparent decision-making).
3 IWRM is best equipped to deal with climate change adaptation. It provides comprehensive and integrated understanding of water sector issues to inform SEA decision making.
4 Climate change adaptation is a responsibility not only for the water sector, but also for various sectors linked to water (tourism, agriculture, energy, etc.). As a sector-neutral, broadly applied instrument, SEA can interject IWRM principles beyond water sector boundaries.

2 Other integrated frameworks: the Sustainable Livelihood Approach (SLA), Integrated Watershed Development and Management (IWDM); Sustainable Land Management (SLM) and Integrated Coastal Zone Management (ICZM).

As evidenced by this comparison, the value of bringing IWRM and SEA together in the context of climate change adaptation merits further attention.

Other instruments for vulnerability assessment include the Flood Vulnerability Index and the Climate Vulnerability Index. All instruments have their own specificity, their own institutional and legal basis and their own abilities and limitations.

6.3 Technology

Technology provides useful tools, and continuing innovation in a variety of fields will deliver new technologies that increase the effectiveness of adaptation. Although technology is not a panacea for adaptation and won't solve all the uncertainties associated with climate change; alongside other enabling mechanisms it will play an important role in reducing vulnerabilities.

One investment in technological development that is expected to have immediate cost benefits is the application of improved forecasting techniques to enhance operation and management of existing water delivery systems. Such innovation in forecasting will, however, require increased investment in scientific research, as well as installation and maintenance of hydro-climatic monitoring systems in each river basin.

On the demand side, the dominant role of agriculture in water demand highlights the importance of technologies for reducing water use in food production. Wider application of efficient irrigation technologies, including best practice technologies to reduce wastage and leakage, improved varietal selection for crops, and adaptation of farming systems have key roles to play.

On the supply side, advances in energy technologies, including cheaper solar power, could alleviate water supply problems for large urban areas on the coasts, making desalination an economically competitive option. Cheaper solar energy could do the same for small villages and remote rural areas, reducing the effort required for subsistence by making available groundwater sources for water supply and small-farm irrigation water for livestock, while reducing the effort required for subsistence and the costs of water treatment and sanitation.

Due to climate change, in some places the conditions under which infrastructure was intended to operate will be exceeded as a result of anticipated increases in the extremity and frequency of the physical conditions for which it was originally designed. Periods of drought may become longer, precipitation more intense and more erratic leading to more variability in run off, and sea levels higher leading to salinisation of coastal areas and coastal groundwater. Without adaptation or counter measures, existing infrastructure will experience damage or loss of functionality as a result of climate change. Physical and mechanical ageing may further jeopardize the adequacy of this infrastructure. Inadequate maintenance may also play a role. Much infrastructure is already decades or even centuries old and in need of replacement or rehabilitation. These challenges may create opportunities to invest in new developments and new functionalities, including multifunctional use of the infrastructure, as well as retro-fitting of new technologies that assist with adaptation.

6.4 Natural systems

The primary threats to water resources and ecosystems emerge from greater wealth and consumption, and increasing populations. These threats will be exacerbated by climate change and must be addressed together.

Water related concerns are predominant in climate change impacts. In this context, natural systems are critically important 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.

When 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.

6.5 Governance

Governance needs to look beyond water and across institutional and disciplinary divides. Political commitments are required if water is to emerge as the primary medium for climate change adaptation. Adaptation needs to start with water: the benefits will flow across sectors, increasing resilience across the economy and society. This calls for looking outside the 'water box' and crossing sectoral boarders. It has implications for governing arrangements and mandates for coordination of adaptation at both national and international levels and for the role of Water Ministries, as well.

6.6 Finance

The cost of adapting to climate change could exceed USD 100 billion per year and will be sensitive to many factors, including how much and when mitigation takes place. Though exact figures are not known, it is clear that a large amount of new and additional investment and financial flows will be needed to address climate change adaptation. Fortunately, several promising financial initiatives are being launched on adaptation (and mitigation). Nonetheless, it is clear that additional needs cannot be met with present adaptation funding instruments alone.

Though it is a nation's responsibility to finance its national water management programmes, within the overall development and sustainability agenda, climate change may add additional challenges that go beyond national responsibility. These challenges will result in the need for additional (external) financial resources (the 'polluter pays principle') so developing countries can implement adaptation measures.

The option of tapping into other international and multilateral financing sources, as well as other domestic public and private sources, will become a crucial consideration. Private funding sources may also cover a portion of the costs, and public resources are expected to play a dominant role in all sectors. Disbursement mechanisms should be streamlined to guarantee that the most vulnerable can receive necessary support and benefits. Finally, there is a need for an international, overarching financial architecture for current and future bilateral, multilateral and international climate adaptation funds. It is of utmost importance that the UNFCCC COP-15 participants agree on an overarching financial architecture, financing sources, and issues, including (though not limited to) priorities and criteria for disbursement and eligibility.

6.7 Capacity Building

Sufficient institutional and local capacities are prerequisites for adaptation to climate change. Institutional capacities should be able to deliver common management practices, education and awareness raising. Presently, the institutional capacity to establish vulnerability, acquire relevant and tailored climate information, make use of climate information in planning processes, and acquire financial commitments for adaptation programmes are in an early stage of development. This is also the case with capacity building programmes for sector professionals.

Strengthening leadership, professional capacity, and communication on climate and adaptation is equally essential in developed countries, countries in transition and developing countries.

Capacity building and information for sector professionals (particularly Least Developed Countries) is essential. Waiting for more accurate data to emerge is ill advised because adaptation needs to start now: act now, and act locally, with the help of community-based, participatory processes and traditional knowledge. The real way forward is to educate people to use probabilistic decision making tools and to transfer technology (soft and hard) to low-level water managers and developing countries.

Capacity building is needed in the area of vulnerability and adaptation assessment processes (including economic assessments and access to appropriate models, tools and methodologies), and for linking of these processes with the planning and implementation of concrete action.

7 Strategic and Operational Responses

Every day, all over the globe people make key decisions about future investments in water management and land use. Long term changes and increased variability in climate will require that water managers[3] adjust their current water investment strategies and institutional frameworks to adapt to these new conditions.

Within this context, 'climate proofing' is the process that incorporates possible categories of adaptive responses: best management practices, no-regret measures, and climate change adaptation specific investments, including measures that go beyond our current knowledge. At a political level, climate proofing is the strategy of choice because it factors climate change risks and opportunities into decision-making about land and water management interventions. With its inherent scientific and social uncertainties and progressive insights, climate proofing is characterized by a multilayered approach that prevents it from reducing concerns to a single scientifically derived value or relying on a single decision support system.

Strategic Level: Climate Proofing

Climate proofing should be facilitated by trained people (scientists and policy makers) who are able to interpret outcomes, uncertainties and constraints from available decision support tools, such as tailored climate scenarios, in the domain in which they work (i.e. water resources management). The chosen tools should be capable of presenting, complex information (e.g. scientific understanding of the studied water system and statistical uncertainties) in a simplified way (e.g. cascades of uncertainties for future economic developments).

In addition to improved decision support tools and scientific insights, climate proofing requires redefinition and negotiation of the boundaries between science and policy (Tuinstra, 2006; Janasoff, 2004). An important aspect of climate proofing is the mutual construction of problem-defining and research agendas through both science and policy. Climate proofing is a new approach that incorporates scientific expertise on climate change (experts, tools, knowledge) into decision-making processes that extend beyond the traditional domain of water resources management.

Operational Level: A continuum of adaptation responses

Aspects of the scale and timing of likely adverse impacts of climate change remain uncertain. At present, unambiguous answers are elusive, and water managers have to work in a situation of considerable uncertainty. The only way to proceed is on an adaptive and flexible basis that is informed by monitoring and is therefore resilient. Within this context, adaptation measures can be categorized along a continuum of responses, ranging from actions focused on reducing vulnerability to climate (including historic and changing climate) to measures aimed at creating adaptive mechanisms aimed at specific impacts of climate change (WRI, 2007). Three main categories of responses emerge from this continuum:

1 Best management practices

Delivering, up-scaling and replication of what already works, based on the assumption that there

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[3] For the professional water resources manager, water management involves the regulation, control, allocation, distribution and efficient use of existing supplies of water to offstream uses such as irrigation, power cooling, municipalities and industries, as well as to the development of new supplies, control of floods and the provision of water for instream uses. Additionally, all levels of government, and especially the private sector and individual stakeholders, are routinely engaged in the management of water. Hence, technically, every individual who uses water is a water manager, from the water resource professional to the woman in the village who draws water from a well. Nevertheless, water managers typically are considered to be those people who are formally trained and involved in some institutionally organised component of water development, delivery or regulation, and who have responsibility and accountability for the decisions that are made. (Kabat et al., 2003)

exists a technique, method, process, activity, incentive or reward of choice which is more effective at delivering a particular outcome than any other approach. Examples of best management measures include 'baseline' strategies such as extension and upgrading of water supply networks and services, reduction of leakage, and training and capacity building of technical staff.

2 No/low regret measures

Adaptive policies can respond to anticipated changes through conventional approaches, such as introducing no-regrets policies that perform under a range of conditions with little modification (e.g., energy-efficiency policies), and through automatic adjustment of policies when the monitoring of key system indicators indicates that a predefined trigger has been reached (e.g., unemployment insurance policies). A 'no-regret' policy would generate net benefits whether or not climate change occurs. Examples include:

- maintenance and major rehabilitation of existing systems (dams, barrages, irrigation systems, canals, pumps, etc.);
- modifications in processes and demands (water conservation, pricing, regulation, legislation) for existing systems and water users.

3 Climate change adaptation specific measures

Information about climate is integrated into decisions, or additional investments are made to reduce or eliminate clearly attributable climate change risks. Response oriented measures are specifically targeted at the effects of climate change. Typically, this category includes measures such as:

- engineering works aimed at mitigating risks;
- retrofitting, flexible distribution systems, and supply management;
- planning for new investments, or for capacity expansion (reservoirs, irrigation systems, levees, water supply, wastewater treatment)
- introducing new efficient technologies (desalting, biotechnology, wastewater reuse, solar energy, etc.).

The extent to which each of the responses is implemented in a given location is highly dependent upon the national context (i.e., stage of development, culture, governance structures etc.). For example, Least Developed Countries may decide to start with best management practices as a first step towards building resilience. Conversely, in wealthier nations operating under higher management standards, resilience may entail addressing specific and distinct impacts of climate change through additional activities and investments (e.g. development of high-technology flood control infrastructures in The Netherlands).

Policy makers within and outside the water sector should consider a balanced portfolio of vulnerability and impact-oriented responses, based on strong bottom-up thinking and careful consideration of cost and benefits.

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