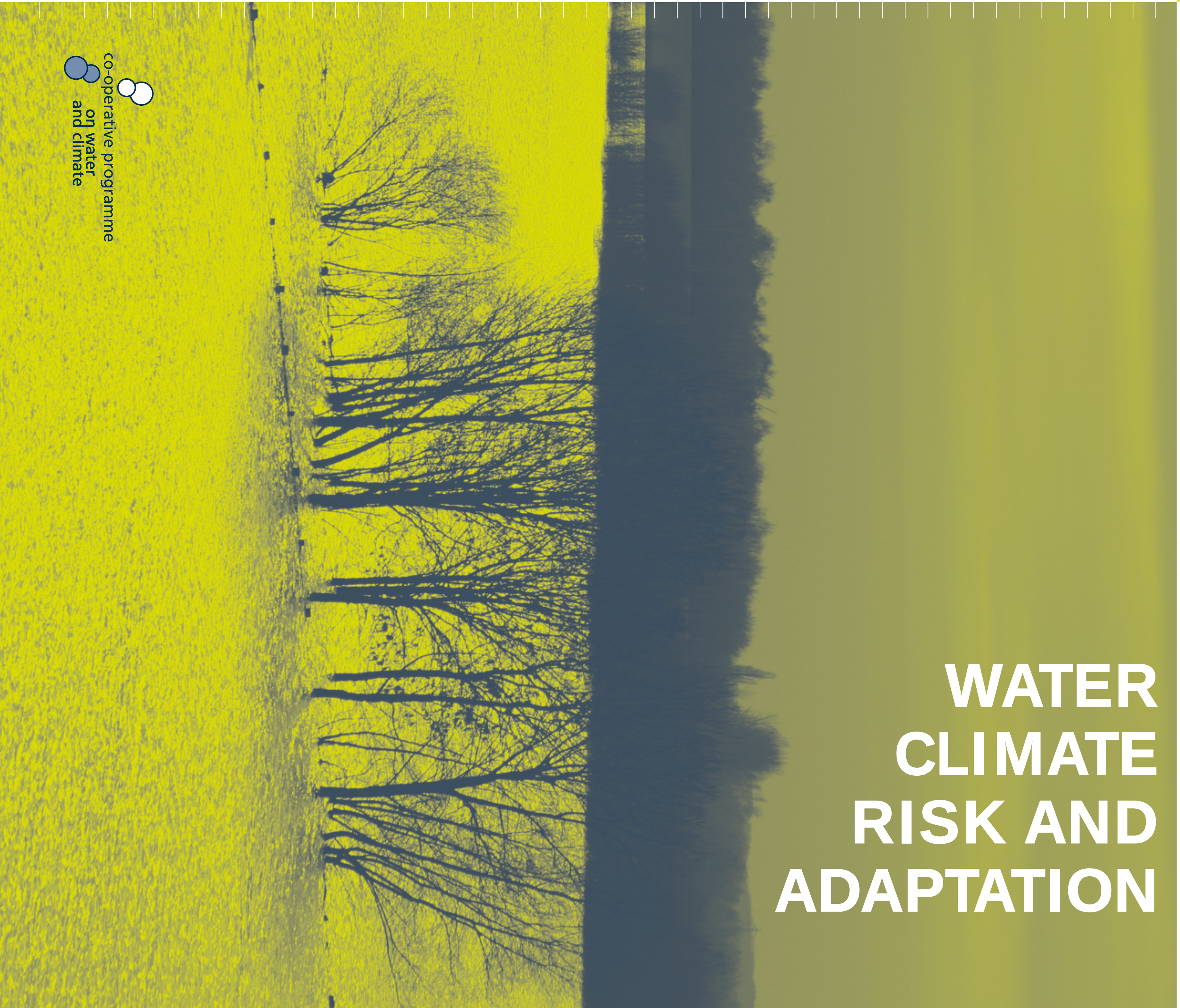

WATER CLIMATE RISK AND ADAPTATION

Working Paper 2007-01

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Co-operative Programme on Water and Climate

The mission of the Co-operative Programme on Water and Climate (CPWC) is to initiate activities within the water sector, that contribute to reducing the impact of climate change and variability in particular for the most vulnerable groups.
The ultimate goal of the Programme is to enhance the preparedness to cope with climate impacts upon water resources and water services and to enhance the preparedness for water-related disasters. For further information see:
www.waterandclimate.org

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Committed to environmentally sustainable development and poverty alleviation. ISET's mission is twofold: (1) to improve understanding and elevate the level of dialogue on environment and development in a rapidly changing global context; and (2) to serve as a framework for equal collaboration between the North and South on programs that address the first mission.
To achieve these objectives we: identify, demonstrate and support catalytic implementation projects; disseminate information; educate key audiences; encourage open exchange of views and ideas; and serve as an enabling framework for development and implementation of new strategies. ISET is known for its work on water resources and adaptation to climate change. We currently lead major research and pilot implementation programs in South Asia. For further information see:
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NeWater

NeWater is an EU-funded interdisciplinary project that develops new methods for integrated water resources management taking into account the complexity of the river basins to be managed and the difficulty to predict the factors influencing them (e.g. climate, socio-economic developments).
The central focus of NeWater is a transition from currently prevailing regimes of river basin water management to more integrated, adaptive approaches that cope with growing uncertainty like climate change. Over 40 partners work together in NeWater. For further information see:
www.newater.info

FOREWORD

The fourth assessment report of the Intergovernmental Panel on Climate Change (4AR of the IPCC, 2007) confirmed stronger than ever before that climate is changing due to human intervention. The report of the IPCC Working Group II on Climate Change Impacts, Adaptation and Vulnerability presents the impacts of climate change on regional and sectoral levels. The 4AR provides substantiated evidence to policy makers at global, regional, national and local levels that the time has come to get prepared.

We are pleased to be able to offer you so soon after the 4AR this first Working Document of the CPWC on Water, Climate Risks and Adaptation. The document was prepared as an initial working document for a more inclusive so called Compendium Document on conceptual advances, tools and adaptation examples. This Working Document has a similar broad scope. It presents and discusses conceptual issues, strategic responses and practical cases, from a risk management perspective. The Working Document is indeed a very valuable input to the Compendium Document which will be published later this year.

The Working Document has been written by Dr. Marcus Moench in cooperation with Sarah Stapleton, to both of whom we like to express gratitude for their perseverance and commitment to complete the assignment in this successful way.

Compiling a Working Document is only a first step. The next step is to see that the lessons in the Document are being applied and made use of. CPWC is committed to distribute the Document to sector professionals and capacity building institutions to ensure that many will benefit from this valuable Document. Copies can also be obtained free of charge from the CPWC, and the document can be accessed through our website www.waterandclimate.org.

Henk van Schaik
Programme Coordinator CPWC

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CHAPTER

PARAGRAPH

SUB PARAGRAPH

THEME

01 INTRO-DUCTION

Scientific consensus now confirms that whatever is done to reduce green house gas emissions, human-induced changes in climate are now inevitable. While reductions in heat-trapping emissions are required to reduce the extent of such changes, adaptation to change will be essential as well.

Water management planning processes rarely account for the likely impacts of climatic change. Most hydrologic modeling, analysis and planning are based on assumptions regarding the stationary nature of key climatic parameters. Such parameters are assumed to fluctuate stochastically around means that can be quantified based on historical conditions. As a result, changes in climate, whether due to anthropogenic or other factors, undermine the scientific assumptions currently used for most decision-making and planning.

The likely impacts of climatic change on variability and baseline conditions are increasingly well documented. Changes in average temperature, the gradual rise in sea level and the global retreat of glaciers represent long-term trends that society will have to respond to at both local and global levels. Such gradual changes are likely to be accompanied by other sudden, less predictable and more dynamic changes. The incidence and economic impact of climate related disasters have increased over recent decades (World Meteorological Organization, Co-operative Programme on Water and Climate et al. 2006). While it is currently difficult to attribute any specific event, such as the record breaking series of hurricanes that occurred during 2005, to human-induced changes in climate, projections suggest that increases in variability and the intensity of extreme climatic events — floods, droughts and storms — are likely outcomes of climate change. Such increases present a particular challenge for society. Planning processes are particularly well suited for responding to trends that can be identified well in advance. Changes in variability and the nature of extremes contain inherent elements of surprise and unpredictability.

Climate changes alter the risk associated with virtually all water management decisions. Hydrologists can no longer assume that estimates of key parameters – such as storm intensity-duration relationships or flood flows – can accurately be assessed based on historical records. As a result, uncertainties in all aspects of water management and the risks associated with such uncertainties will increase.

Risks associated with surprise and unpredictability in the water sector are compounded by wider social change processes. Demographic, economic, political and social changes all influence exposure to the direct and indirect impacts of climate change. Globally, much human settlement is concentrated in coastal areas and river flood plains. Such regions are particularly vulnerable to changes in extreme storms or floods that may occur as a consequence of climate change.
Furthermore poor populations tend to concentrate in marginal areas that are subject to floods, droughts or other climate related extreme events. This was, for example, clearly the case with Hurricane Katrina. According to a recent report on New Orleans (Logan 2006, p. 7):

"The data for the total region show that in several respects the neighborhoods of social groups with least resources were the ones most affected by Katrina. The population of damaged areas was nearly half black (45.8% compared to 26.4% black in the rest of the region), living in rental housing (45.7% compared to 30.9%), and disproportionately below the poverty line (20.9% compared to 15.3%) and unemployed (7.6% compared to 6.0%)."

The report (Logan 2006, p. 14) goes on to point out that:
"These disparities stem from within the City of New Orleans itself, and more specifically from vulnerability to flooding. This is a pattern with deep roots, and although Katrina caused the most extensive flooding in memory, prior studies by historians (such as An Unnatural Metropolis by Craig Colten) have demonstrated that both high ground and public investments in drainage and pumping systems consistently worked to the advantage of certain neighborhoods in past storms."

Similar patterns are common in many parts of the world. Poor residents in urban areas often concentrate in areas that are less desirable – and therefore lower cost — due their vulnerability. The inherent vulnerability of such areas is compounded by the lack of political and economic clout their residents tend to have. As a result, services, and investments in protection tend to be drawn to wealthy regions. The challenge isn't only urban. It is common in rural areas where marginal populations depend on vulnerable, lower income, livelihoods, such as agriculture. As a result, the impacts of climate change are likely to disproportionately affect populations that are already poor and vulnerable. In sum, while it is often complicated

1 HTTP://WWW.CSMONITOR.COM/2005/0912/P01S01-USSC.HTML
HTTP://WWW.CSMONITOR.COM/2005/0912/P01S01-USSC.HTML

2 WEALTH, RACE GUIDING WHICH NEW ORLEANIANS STAY, AND WHICH NEVER RETURN: BY , WASHINGTON POST STAFF WRITER, WEDNESDAY, MAY 17, 2006; PAGE A01

to attribute risks to a single cause, managing the risks associated with multiple changes is central to meeting basic human development goals.

Now to the question of more water-specific issues; water management has always had a major focus on risk. Virtually all water control structures are designed using criteria developed on the basis of assumed maximum and minimum flow conditions. This is also the case with water management institutions. Internationally, arrangements for allocating variable flows are the basis for many international compacts in trans-boundary river systems. At a more local level, flood frequency maps are the foundation of zoning and insurance institutions. All these institutional elements are, at their core, about risk management.

While risk management within the water sector is nothing new, adapting to climate change will require an increased and explicit focus on risk. Climate change increases the probability that conditions will not match the design criteria assumed when structures or institutions were created. Risks of failure will, as a result, increase particularly where design criteria are tailored to a narrow range of conditions. Such risks are compounded by demographic, economic and other changes beyond the water sector. Effective adaptation to climate and other change processes by the water sector will require strategies, institutions and structures that are robust under uncertainty. These are likely to be very different from the processes and responses that can be mobilized in response to clearly identifiable changes in baseline conditions. Risks need to be managed. Furthermore, they need to be managed in a context where historical conditions provide limited guidance regarding the future.

The importance of responding to major – but difficult to predict or quantify – changes is likely to exacerbate differing perspectives regarding response strategies. Populations and businesses located in vulnerable areas are likely to demand increased levels of protection, that is to say “climate proofing.” This is clearly evident in New Orleans where, following Hurricane Katrina, many have called for levies to be rebuilt to withstand category 5 storm conditions. Businesses, in particular, may not invest unless security can be assured. At the same time, the costs of constructing structures to meet extreme conditions are often unaffordable, particularly if financed by local communities. Furthermore, even with massive investment, it is impossible to guarantee that many vulnerable regions can be protected in the case of extreme events. As a result there are equal pressures for people and economic activity to move out of vulnerable areas and for the development of approaches that enable people to “live with” rather than “be protected from” such events.

In some cases this is already occurring in an unplanned manner as people move and change or diversify livelihood systems in response to both the impact of extreme events and perceived opportunities in less vulnerable regions. According to news reports, Hurricane Katrina caused the largest mass migration in US history in at least 150 years and many of those displaced have developed new livelihoods and will never return to New Orleans.[1] In contrast to a pre-Katrina population of over 400,000 (484,674 in the 2000 United States census), according to Logan (2006), the full-time population of the city was estimated at only 150,000 in January 2006. Logan further indicates that “if the future city were limited to the population previously living in zones undamaged by Katrina it would risk losing about 50% of its white residents but more than 80% of its black population” (Logan 2006, p.16). Reconstruction funding and activities are likely to be concentrated in areas where flooding was relatively shallow and technical protective solutions are more likely to be affordable. They are also concentrated in areas where residents have political power and the wealth to return and rebuild. One recent news report illustrates the dynamics in New Orleans. According to the report:

“Disparities in wealth and in the distance of evacuees from their ruined houses are dictating, in many cases, which neighborhoods will be part of the city’s future and which will be consigned to its history. For a city that was two-thirds black and nearly one-third poor before the storm, the uneven pilgrimage back to New Orleans has already changed voter turnout and seems certain to transform the culture and character of the city, making it substantially whiter, richer and less populous than before.” (Blaine Harden, Washington Post).[2]

Some of the areas being rebuilt are, from a technical perspective, equally vulnerable to flooding as those that are not. Vulnerability is as much about the economic and social status of residents as it is about specific climatic risk vectors. The poor are concentrated in high-risk areas and, when disasters occur, have less ability to rebuild. They often are forced to migrate, at least on a temporary basis. Temporary migration, however, often becomes permanent. Livelihoods change as people either take advantage of opportunities in other areas or are forced to rely on whatever source of work they can find elsewhere. This type of pattern is evident in many regions where droughts, floods or extreme storm events occur.

The Katrina example is one where migration and livelihood changes are forced as a consequence of a specific extreme event. In many cases, however, changes are undertaken in a more proactive manner in response to recurrent droughts, floods and storms. People are often unable to move from vulnerable regions and rely on diversification to reduce the impacts of variability. This is, for example, the case in parts of India where households rely on a combination of agriculture, local non-farm activities and remittances sent by migrants to develop stable livelihoods in drought and flood prone regions (Moench and Dixit 2004). Many developing economies rely heavily on remittances to supplement or buffer the variability and unreliability of traditional agricultural livelihoods. Such responses are not, however, confined to the developing world. Diversification is a core strategy many businesses use to mitigate the impacts of climate, weather and other risks. This is, in effect, a technique for spreading or pooling risk. In the private sector it is often facilitated through the use of formal insurance and other financial mechanisms for risk spreading or pooling. Similar effects are achieved at the household level through kinship networks and social risk spreading mechanisms.

More planned approaches to "living with" variability are also common. The "watershed program" in India, for example, involves an annual government investment of $500 million in small-scale water harvesting structures and land improvements that are designed to assist populations in arid areas to maintain local agricultural livelihood systems despite recurrent drought events (Gale, MacDonald et al. 2006). Flood management strategies that involve conceptually similar local interventions are also common. In Europe and North America this takes the form of, for example, attempts to reduce construction in flood plains and increase the amount of area devoted to parks and other open space uses that can also serve as flood spread/retention services. In other locations, such as Bangladesh, it involves activities such as the construction of cyclone shelters and housing above flood levels.

Overall, current responses to climatic variability fall into four general categories: (1) attempts to control hydrologic systems through large-scale structural interventions to deliver water or eliminate flooding; (2) attempts to reduce the impacts of variability through more distributed interventions; (3) shifts in livelihood systems, settlement locations and economic activities in ways that reduce exposure to climate impacts; and (4) diversification and financial mechanisms to pool and spread risk.

In this paper, we argue that effective strategies for managing the risks associated with climate change will require balancing the above approaches rather than treating them as alternatives. Balance can't, however, be achieved simply by implementing an "integrated" risk management program. Responses to climatic variability and change often are not driven by high-level policy or political decisions. They are, instead, driven by decision making within households, communities and companies in response to the risks and opportunities they perceive. Decision making at this level is a central part of the way human society manages risk. It can be influenced by policy-level interventions but responses are unlikely to be linear. Furthermore, different approaches to risk management tend to have a strong support from specific interest groups within society and many policy and implementation decisions are influenced by pressures stemming from the worldviews and political perspectives of these groups. The development of effective risk management programs will, as a result, require techniques to balance social and political perspectives as well as specific forms of intervention. Progress cannot be made unless the inherently political nature of decision-making is recognized and incorporated in response strategies. Both the diverse nature of the effective "decision makers" and their political perspectives are, as a result, essential to understand.

The importance of different perspectives is evident even within the professional communities dealing directly with issues related to climate change, water, disaster management, development and industry. The professional landscape can be seen as multiple circles where perspectives often overlap but only to a degree and the policy solutions that different groups advocate are often quite different. This is clearly illustrated by the contrasting cultures and policy emphasis of the climate, water, disaster response development and business communities to the challenge of climate change.

These perspectives can broadly be characterized as follows:

1. Climate Science
Climate change will have major impacts on the hydrological cycle, baseline environmental characteristics on which ecosystems are based and the severity of extreme events. Focused policy and societal responses to reduce GHGs and develop systematic processes for adaptation are essential. These can best be achieved through increased scientific understanding of climate impacts and integrated science-based policy interventions, some of which may require fundamental changes in basic livelihood and energy systems. While location specific impacts of climate change are currently difficult to predict, action is essential as a precaution to reduce the risk of major societal impacts.

2. Water sector
Most impacts associated with climate change will occur through effects on the water sector. Risks will increase due not only to changes in the hydrologic cycle but also to increased uncertainty in projecting hydrologic conditions. Response strategies need to build off existing experience with risk management in the water sector and will necessitate increased investment in infrastructure for water storage, delivery and control to mitigate the effects of increases in variability and the magnitude of extreme events.

3. Disaster Response
Increases in the intensity and possibly frequency of extreme weather events (floods, droughts and storms) are among the most likely outcomes of climate change. While the disaster response community has conventionally focused on relief and rehabilitation, the importance of advanced investments in risk reduction is increasingly recognized. The likely impacts of climate change further increase the importance of disaster risk reduction as a core response strategy. In addition, because risk reduction cannot eliminate disasters, tools for risk spreading and pooling – such as insurance – represent essential components of any response to climate change.

4. Development
Because marginalized communities often depend on agriculture and live in regions vulnerable to extreme weather events, changes in climate represent a fundamental threat to global attempts to reduce poverty and meet other millennium development goals. Effective responses to climate change depend on the ability of populations to move out of high-risk livelihood systems such as agriculture. They also depend on the ability to afford quality infrastructure (such as housing that is constructed to withstand extreme events), insurance and where possible to move out of vulnerable areas. All of these responses depend on economic growth and diversification. Economic development is, in essence, the single most important factor determining the adaptive capacity of populations and, therefore, the social and economic impacts of climate change.

5. Industry
A somewhat split response. Many businesses view climate change as something in the distant future that poses little risk for current operations and for which they do not really need to account. Others see climate change as an important emerging factor in their operational environment. This can involve investment decisions based on carbon emissions and the evolving carbon trading market. It also involves decision making related to production, supply chain and consumer vulnerability (sourcing of inputs, location of production facilities, product markets). Response strategies include risk pooling and spreading (through insurance, hedging and diversification) combined with operation specific analyses of vulnerability and decisions made to respond to specific perceived risk sources.

The diverse nature of the perspective characterized above clearly illustrates the broad array of responses that can be expected. These responses are likely to driven by the sets of interventions or changes specific groups see as effective in addressing the problems they face as a consequence of climate change. This paper focuses on water, climate, risk and adaptation. It is directed primarily at professionals in the water and climate sectors. Professionals in these sectors are likely to be most familiar with – and as a result promote – responses that are intended to directly affect climate water management. This limited perspective is insufficient. Climate and water specific interventions may have far less impact than decisions made outside of these sectors. Furthermore the political clout of other key actors is likely to overwhelm that of sector specific groups unless it is understood and channeled.
Risk is the unifying element in all of the above perspectives. As a result, rather than “water” or “climate” sector specific management, risk-focused perspectives can provide a unifying theme for understanding and identifying effective responses to climate change.

1.1 NATURE OF THE PAPER

This paper has been prepared as an initial working paper contributing to the publication of a compendium on Water Climate, Risk and Adaptation. The goal of the compendium will be to document and disseminate conceptual advances, tools and experiences. It will, as a result, contain a combination of conceptual, methodological and applied case chapters. This initial paper is intended to highlight some of the core issues that we believe have not been adequately highlighted in on-going debates over responses to climate change.

This paper is about water, climate, risk and adaptation. It is intended as a strategic input for those who formulate and make decisions on how to respond to emerging climate challenges, particularly in the water sector. The paper is intended to be useful for actors in national and local governments, financial and insurance institutions, multi-lateral organizations, non-government organizations and the wider private sector whose activities affect or are affected by the manner in which water resources are managed.

The paper approaches climate related water resource issues primarily through a risk management lens. This approach has been selected on both scientific and process considerations. From a scientific perspective, understanding and managing risks is essential to respond to the increased variability and uncertainty in local weather conditions that are among the most likely consequences of climatic change. From a process perspective, as argued in the introduction, risk represents a unifying theme that can be used to reach common understanding among diverse professional and policy communities and, by doing so, enable the identification of cross-sectoral responses that are socially as well as technically viable.

Our approach to risk focuses on the interaction between predictable and less predictable changes in the dynamics of water resource systems. It takes as a starting point the interaction between gradual and 'pulsed' changes in complex systems – the interaction between, for example, incremental changes in sea levels and sudden, less predictable, events such as hurricanes, droughts and floods. It also takes as a starting point the complementary nature of distributed and large infrastructure-based responses to climate impacts on the water sector. The dichotomy between attempts to "climate proof" regions by building protective infrastructure as opposed to "living with floods" is never absolute. Protection of key assets through flood control infrastructure, while essential, is often only possible if the size and impact of floods are reduced to smaller scale, more distributed interventions that "allow rivers their space." Furthermore, the economic (and in many cases the social and environmental) costs of protective infrastructure tend to rise exponentially with scale and the degree of protection they provide. The ability to afford such costs and the inherent tradeoffs they necessitate will vary greatly between regions, societies and specific local contexts. As a result, the relative weighting between large infrastructure-based and more distributed interventions will also vary greatly between contexts and a mix of strategies will be essential. Finally our approach recognizes the fact that many interventions affecting vulnerability to climate impacts are not made within the water sector and may, in fact, appear on first impression to have little to do with water per se. Policies regarding insurance can, for example, have as major implications as the nature of water infrastructure for the vulnerability of populations and economic activity to floods, droughts and storms. Insurance and other financial risk management tools are central to our focus and operate primarily through their distributed impact on behavior at an individual level. Similarly, trade and agricultural price support policies often have far more impact on local demand for irrigation water than the presence or absence of irrigation facilities. Virtual water flows – that is the water used as input to the production of key global commodities such as grain – will be fundamental to the ability of regions to cope with climate change induced droughts. While exploring these wider arenas in a comprehensive manner is beyond the scope of this paper, recognition of their importance is central to any effective strategy for responding to the risks associated with climatic change. As a result, they form a central theme running throughout the paper.

1.2 ROAD MAP

The paper is organized in the following manner. It starts with an extended synthesis designed to bring together theoretical and applied perspectives on adaptation to climate change and the specific issues facing the water sector.

This synthesis locates questions regarding adaptation to climate change in the water sector within three broad elements of context:

1. Emerging scientific consensus on the nature of climatic change and the risks society will need to adapt to at global and local levels. This focuses on known impacts on the hydrological cycle and their implications for water related risks.

2. Theoretical and conceptual perspectives on the nature of risk, change, and adaptation within complex interlinked social and environmental systems. This will pull together insights generated through decades of research on risk and systems dynamics and relate them to recent scientific insights on climate change and likely social responses to it.

3. The wide range of policy and implementation debates over responses to climate change that are currently emerging in the water sector. This focuses on two broad sets of response strategies: (a) those involving alternative approaches within the water sector (IWRM, living with water and climate proofing); and (b) the expanded arenas for response that are increasingly being recognized as having direct relevance for addressing climatic variability and change fall but outside conventional activities in the water sector. This section will bring together perspectives emerging from the recent Cooperative meetings of the Parties on climate change, the Hyogo framework and regional initiatives such as the European Framework Directive on Water. It also contains a section highlighting the tradeoffs and differential patterns of vulnerability associated with both the 'narrow' set of responses in the water sector and the expanded response sets.

Insights from these three broad elements of context set the stage for the second major section on strategic approaches to risk management. This section focuses on risk management as the strategic application of direct water management, planned disaster risk reduction, livelihood diversification and financial mechanisms. It then moves into an extended section that illustrates the relationship between major strategic approaches for supporting adaptation and how complementary courses of action within each of these arenas. These complementary courses of action could provide an effective basis for climate risk management. Insights from these sections are used to refine risk management concepts, particularly the difference between planned risk reduction strategies and emergent differences in risk profiles that result from wider decisions in relation to patterns of economic and infrastructure development. The final component of the paper highlights priorities for action in Climate-Water Risk Management.

02 SYNTHESIS OF KEY ISSUES AND PER-SPECTIVES

2.1 THE CLIMATE CHANGE CONTEXT

Scientific understanding regarding the impacts of climate change has evolved substantially since the release of the IPCC Third Assessment report in 2001. The most recent summary is that provided by the Stern Review on the Economics of Climate Change (Stern, 2006) and the summary reports of Working Groups 1 and 2 of the IPCC (2007). The full IPCC Fourth Assessment report will be released in its entirety by the end of 2007. The Summary Reviews for Policy Makers are available for the contributions of Working Groups 1 and 2 (IPCC 2007). The Stern review emphasizes the manner in which the costs associated of climate change increase as the average temperature increases. As figure 1 on page18 (adapted from Stern 2006) highlights, even a 1 ºC change will be sufficient to cause major impacts while changes of 2-3 ºC or more will cause massive disruption.

According to the review:
"The current stock of greenhouse gases in the atmosphere is equivalent to around 430 parts per million (ppm) CO_2, compared with 280ppm before the Industrial Revolution. These concentrations have already caused the world to warm by more than half a degree Celsius and will lead to at least a further half degree warming over the next few decades, because of inertia in the climate system"
(Stern 2006, p. iii). The report further points out that given the accelerating rate of emissions, the concentration could reach 550ppm "as early as 2035" virtually[3] committing the world to an average temperature rise exceeding 2 ºC. The average level of warming is, however, simply an indicator of the impacts, not the full story.

As the review states: "People will feel the impact of climate change most strongly through changes in the distribution of water around the world and its seasonal and annual variability" (Stern 2006, p. 62).

At an average global temperature increase of 2-3 ºC, the water related impacts of climate change highlighted in a figure prepared for the executive summary of the review (Stern 2006, p. v) include:

1. Disappearance of small mountain glaciers – and their contribution to base flow in streams – worldwide

2. Significant changes in water availability resulting in major regional scarcity problems, particularly in Africa. This includes a "greater than 30% decrease in runoff in the Mediterranean and Southern Africa"

3. Rising intensity of storms, forest fires, droughts, flooding and heat waves."

In addition to the specific impacts included in the diagram, the review notes that a 2-3 ºC rise would lead to *"many severe impacts, often mediated by water, including more frequent droughts and floods"* (Stern 2006, p. 56).

This level of warming could also *"induce sudden shifts in regional weather patters like the monsoons or the El Niño. Such changes would have severe consequences for water availability and flooding in tropical regions and threaten the livelihoods of billions"* (Stern 2006, p. 56).

[3] DEPENDING ON THE MODEL USED, THIS LEVEL HAS BETWEEN A 77% AND 99% CHANCE OF CAUSING AN AVERAGE RISE OF MORE THAN 2O ºC.

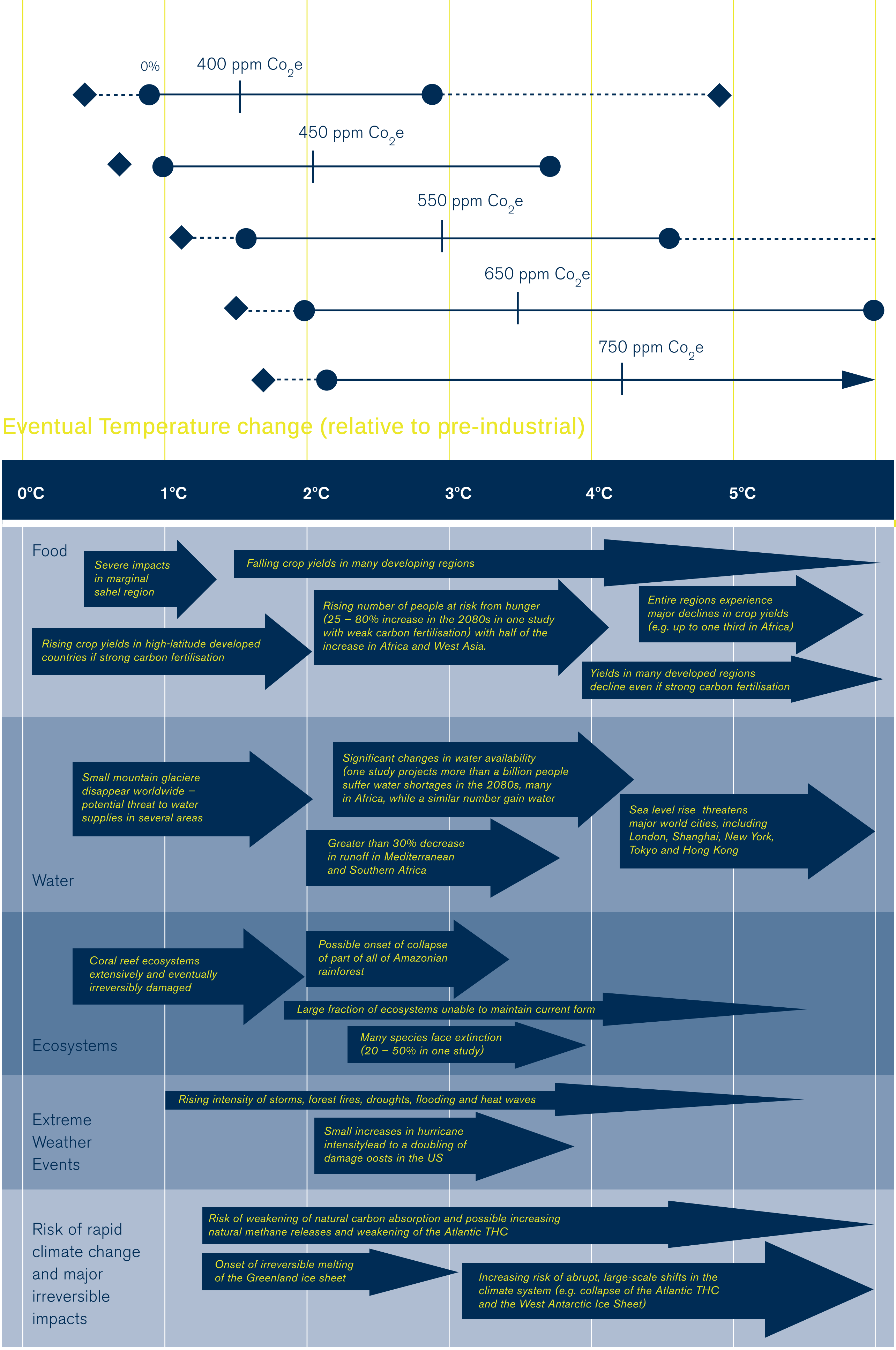


Figure 1 (adapted from Stern, 2006 p.V)

Stabilisation levels and probability ranges for temperature increases

The figure above illustrates the types of impacts that could be experienced as the world comes into equilibrium with more greenhouse gases. The top panel shows the range of temperatures projected at stabilization levels between 400_{ppm} and 750_{ppm} CO_2E at equilibrium. The solid horizontal lines indicate the 5-95% range based on climate sensitivity estimates from the IPCC 2001 and a recent Hadley Centre ensemble study. The vertical line indicates the mean of the 50^{th} percentile point. The dashed lines show the 5-95% range based on eleven recent studies. The bottom panel illustrates the range of impacts expected at different levels of warming. The relationship between global average temperature changes and regional climate changes is very uncertain, especially with regard to changes in precipitation. This figure shows potential changes based on current scientific literature.

The water related impacts of climate change are likely to vary greatly between regions. According to the Stern review, recent modeling results suggest that with a 2 ºC rise in average temperature, parts of Northern Europe and Russia will experience significant increases in runoff while other regions – notably the Mediterranean, Southern Africa and South America – will experience large decreases. Average runoff is, however, only a small part of the water story. If, as most projections suggest, the variability and intensity of weather events increase, even increases in average runoff may not increase the supply available to meet human and ecosystem requirements.
As the Stern review notes: *"an increase in annual river flows is not necessarily beneficial, particularly in highly seasonal climates, because: (1) there may not be sufficient storage to hold the extra water for use during the dry season, and (2) rivers may flood more frequently"* (Stern 2006, p. 62). In South Asia, for example, the Stern review specifically notes that *"much of the extra water will come during the wet season and will only be useful for alleviating shortages in the dry season if storage could be created (at a cost). The additional water could also give rise to more serious flooding during the wet season"* (Stern 2006, p. 63).

The impacts of any increase in climatic variability are likely to be compounded by preexisting patterns of environmental degradation. In India, for example, groundwater overdraft caused by intensive groundwater development for agriculture has been emerging as a major point of concern for policy makers since the early 1990s. Groundwater has served as the primary water resource input stabilizing Indian agriculture and enabling increases in production using green revolution technologies. Increases in average precipitation might increase groundwater recharge but this is not necessarily the case if the additional precipitation occurs during intense events. Recharge rates are limited by the infiltration capacity of soils. Instead of adding to recharge, intense storms, particularly if they occur during the wet season when the soil is already saturated, generate additional runoff but, due to fixed infiltration rates, little additional recharge. As a result, additional rainfall during the wet season may not contribute to additional water availability during the dry season. Where aquifers are already experiencing overdraft, dry-season scarcity could increase dramatically with increases in variability.

The impact of this type of dynamic could be further compounded by changes in snow and glacier melt patterns in melt-water fed river basins. Most projections of global warning have identified changes in precipitation and melt patterns as a likely impact of changes in average global temperatures. More precipitation is likely to fall as rain and snow melt is likely to occur earlier in the season. The IPCC (WG1 2007) notes that spring meltoff is occurring, on average, 10 days earlier than fifty years ago. Glaciers in the Himalayan region have been retreating rapidly for decades and, as the Stern review also notes, with higher levels of warming they could disappear entirely. At present, according to the Stern review, glacial melt provides 70% of the summer flow in the Ganges. Surface water scarcity during the dry season, a problem in parts of the Gangetic basin even now, is likely to increase. This trend is likely to continue and be exacerbated through all regions supplied by meltwater from mountainous areas. The IPCC (WG 2 2007, p. 7) states, *"In the course of the century, water supplies in glaciers and snow cover are projected to decline, reducing water availability in regions supplied by meltwater from major mountain ranges, where more than one-sixth of the world population currently lives."* At the same time with increases in overall precipitation – and more of that occurring as rain – flooding during the wet season is also likely to increase.

Dynamics such as the above will interact with existing environmental conditions and patterns of development in the basin. Dry season scarcity will increase incentives to pump groundwater and, unless recharge increases correspondingly, this will contribute to the already present rates of water level decline in key aquifers. This could further decrease dry-season base flows in streams (much of which comes from groundwater). In addition, recent publications indicate that, in order to maintain the same level of irrigation service (i.e. the same volume pumped) every meter decline in groundwater levels increases the GHG emissions in some Indian states by 4-6% due to the increased energy required for pumping. In sum, the impacts of increases in climatic variability are likely to be compounded by existing water problems such as groundwater overdraft and that these could, in turn, further contribute to emissions concerns.

Impacts summarized by the Stern review are corroborated by trends and predictions made by the IPCC. The IPCC Fourth Assessment report (2007) is the primary official assessment of scientific information on the impacts of climate change. Climate Change 2007: The Physical Science Summary for Policymakers (IPCC WG1 2007) and Climate Change Impacts, Adaptation and Vulnerability Summary for Policymakers (IPCC WG2 2007), reiterate the climatic changes to which the earth system is committed, even if C02 levels are maintained at those of the year 2000 and discusses possible futures under various greenhouse gas scenarios. Temperatures increases of about 0.2ºC per decade for the period of 1990-2005 have been observed. This warming trend is expected to continue for the next two decades, according to a range of greenhouse gas emissions. The report notes that numerous changes in precipitation, temperature and wind pattern trends have already been observed. Between 1900 and 2005, the eastern parts of North and South America, northern Europe and northern and central Asia have experienced significant increases in precipitation, while parts of Southern Asia, southern Africa, the Sahel and the Mediterranean have all seen drying. Drought frequency and intensity has increased since the 1970s, particularly in the tropics and subtropical regions. Warmer temperature extremes are more frequent, with the number of cold nights and days significantly decreased (IPCC WG1 2007, p. 8). The figure on the right, taken from the summary report (Figure 2 on page 21 adapted from IPCC 2007) examines the regional temperature trends that have been occurring since the early 1900s.

According to the IPCC; a mean sea level rise of 0.18 to 0.59m is predicted by 2090, relative to the 1980-1999 sea levels. The report makes the following statement, however: "Models used to date do not include uncertainties in climate-carbon cycle feedback nor do they include the full effects of changes in ice sheet flow, because a basis in published literature is lacking. The projections include a contribution due to increased ice flow from Greenland and Antarctica at the rates observed for 1993-2003, but these flow rates could increase or decrease in the future" (IPCC WG1 2007, p. 11). If the flow rates increase, mean sea level rise could be as much as 0.2m higher by 2090. Complete melt of the Greenland ice sheet and the West Antarctic ice sheet would raise sea levels by nearly 7m. Much is still not understood about ice flow dynamics and the ice flow from the Greenland ice sheets has accelerated faster than expected. The rate of ice flow could continue to increase.

The report (IPCC WG1 2007, p. 13) cautions that "continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century." In addition to mean sea level rises, it is "very likely that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent" (IPCC WG1 2007, p. 16). Model results also indicate that "it is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical SSTs" (IPCC WG1 2007, p. 16). The models are currently unable to predict with confidence whether the frequency of such tropical cyclones will increase and are inconclusive about the causes of the increase in high intensity storms since 1970. They found that "Sea-level rise is expected to exacerbate inundation, storm surge, erosion and other coastal hazards, thus threatening vital infrastructure, settlements and facilities that support the livelihood of island communities" (IPCC WG2 2007, p. 13). Scientific research subsequent to the IPCC third assessment has tended to substantiate many of the implications they projected with respect to both extreme events and water resources. Recent analyses of tropical cyclone intensity in the North Atlantic, for example, relate changes to increases in surface ocean temperature, part of which may be attributed to climatic change. The implications for extreme water related events are summarized below in in table 1 on page 22 (adapted from IPCC 2007).

figure 2 (adapted from IPCC 2007, SPM-4, p. 11)

Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906-2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901-1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5-95% range for 19 simulations from 5 climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5-95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings.

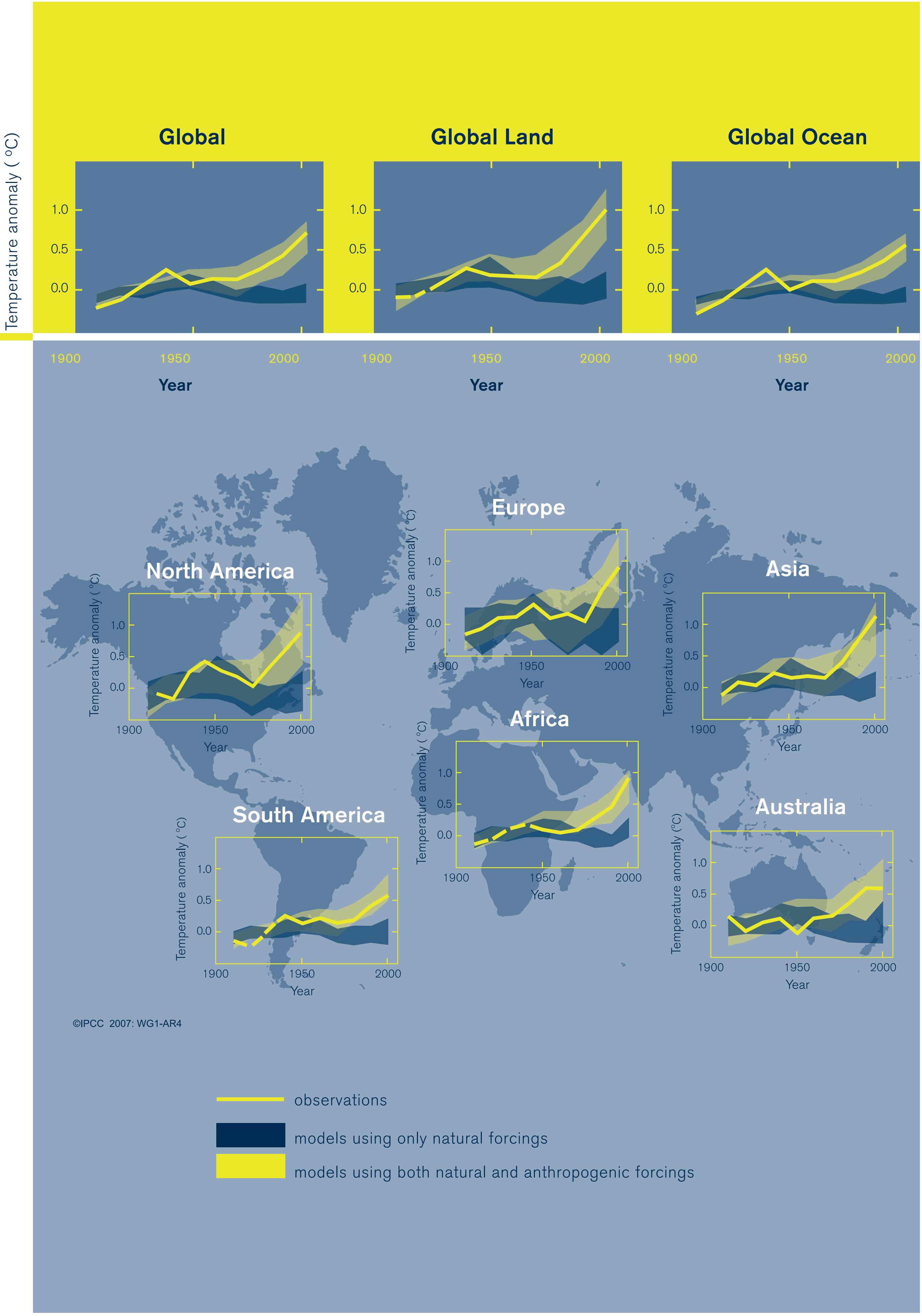


Table notes:

[a] See Table 3.7 for further details regarding definitions.
[b] See Table TS 4, Box TS 3.4 and Table 9.4
[c] Decreased frequency of cold days and nights (coldest 10%)
[d] Warming of the most extreme days and nights each year.
[e] Increased frequency of hot days and nights (hottest 10%)
[f] Magnitude of anthropogenic contributions not assessed.
Attribution for these phenomena based on expert judgment rather than formal attribution studies.
[g] Extreme high sea level depends on average sea level and on regional weather systems.
It is defined here as the highest 1% of hourly values of observed sea level at a station for a given reference period.
[h] Changes in observed extreme high sea level closely follow the changes in average sea level {5.5.2.6}.
It is very likely that anthropogenic activity contributed to a rise in average sea level. {9.5.2}
[i] In all scenarios, the projected global average sea level at 2100 is higher than in the reference period {10.6}.
The effect of changes in regional weather systems on sea level extremes has not been assessed.

Phenomenon[a] and direction of trend	Likelihood that trend occured in late 20th century (typically post 1960)	Likelihood of a human contribution to observed trend[b]	Likelihood of future trends based on projections for 21st century using SRES scenarios
Warmer and fewer cold days and nights over most land areas	*Very likely*[c]	*Likely*[d]	*Virtually certain*[d]
Warmer and more frequent hot days and nights over most land areas	*Very likely*[e]	*Likely (nights)*[d]	*Virtually certain*[d]
Warm spells / heat waves. Frequency increases over most areas	*Likely*	*More likely than not*[f]	*Very likely*
Heavy precipitation events. Frequency (or proportion of total rainfall from heavy falls) increases over most areas	*Likely*	*More likely than not*[f]	*Very likely*
Area affected by droughts increases	*Likely in many regions since 1970s*	*More likely than not*	*Likely*
Intense tropical cyclone activity increases	*Likely in some regions since 1970s*	*More likely than not*[f]	*Likely*
Increased incidence of extreme high sea level (excludes tsunamis)[g]	*Likely*	*More likely than not*[h]	*Likely*

Table 1 (adapted from IPCC 2007, SPM-2, p.8)

Recent trends, assessement of human influence on the trend, and projections for extreme weather events for which there is an observed late 20th century trend.

Temperature changes and alterations in precipitation patterns are expected under a wide range of greenhouse gas emission scenarios. Precipitation has been observed as increasing in the higher latitudes and decreasing around the tropics and subtropics and this trend is expected to increase. Figure 3 below and figure 4 on page 24 (adapted from IPCC 2007), display projections of temperature and precipitation changes for three different scenarios. Drought and heat wave events have increased in many areas around the globe and this trend is likely to continue into the future. Overall precipitation is expected to increase, as a warmer atmosphere allows for a higher moisture content, especially precipitation associated with heavy rainfall events. Warming is likely to be more drastic at the poles than at the tropics. Thermal expansion of the oceans will continue for several centuries, even if radiative forcing were to be stabilized.

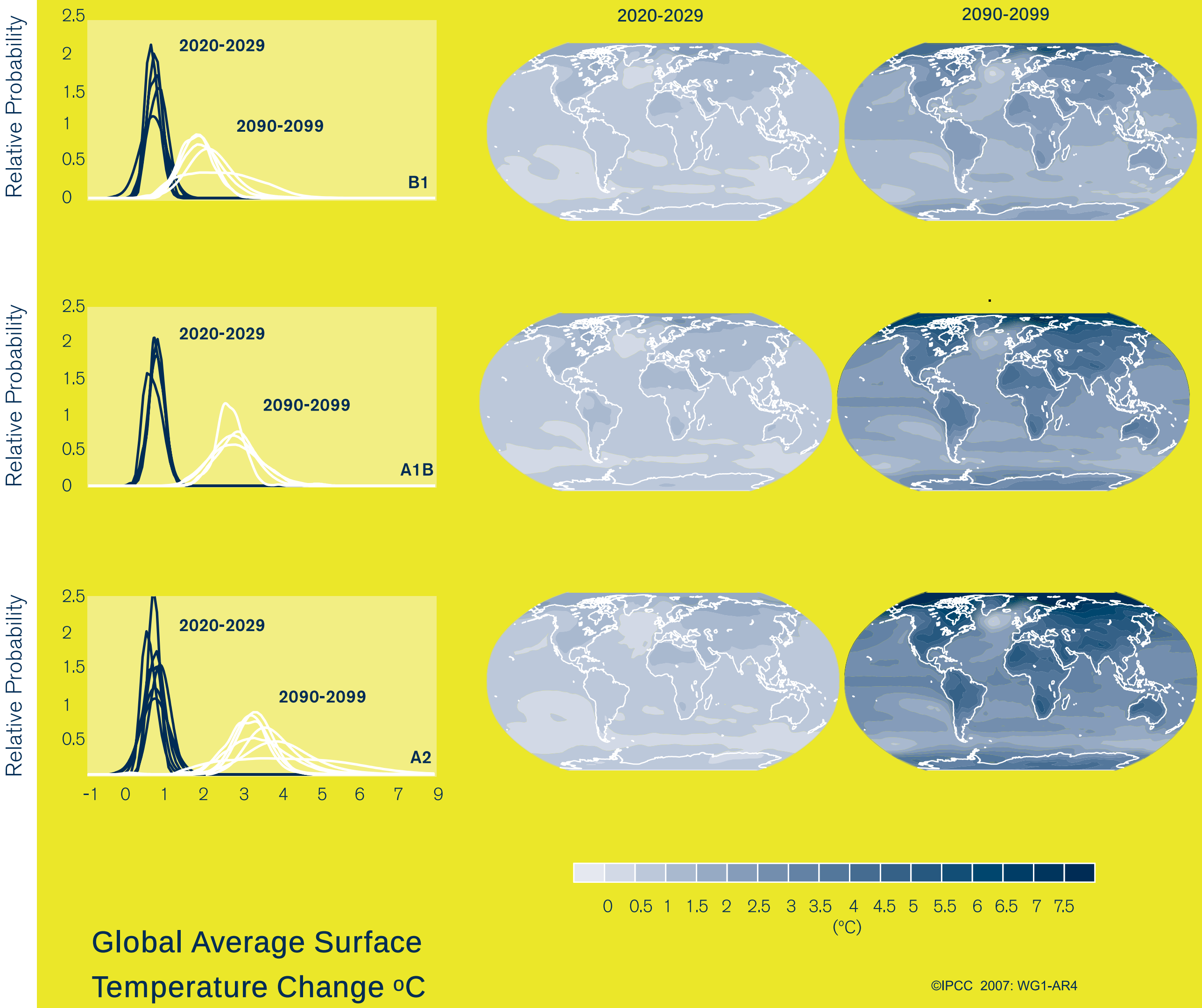
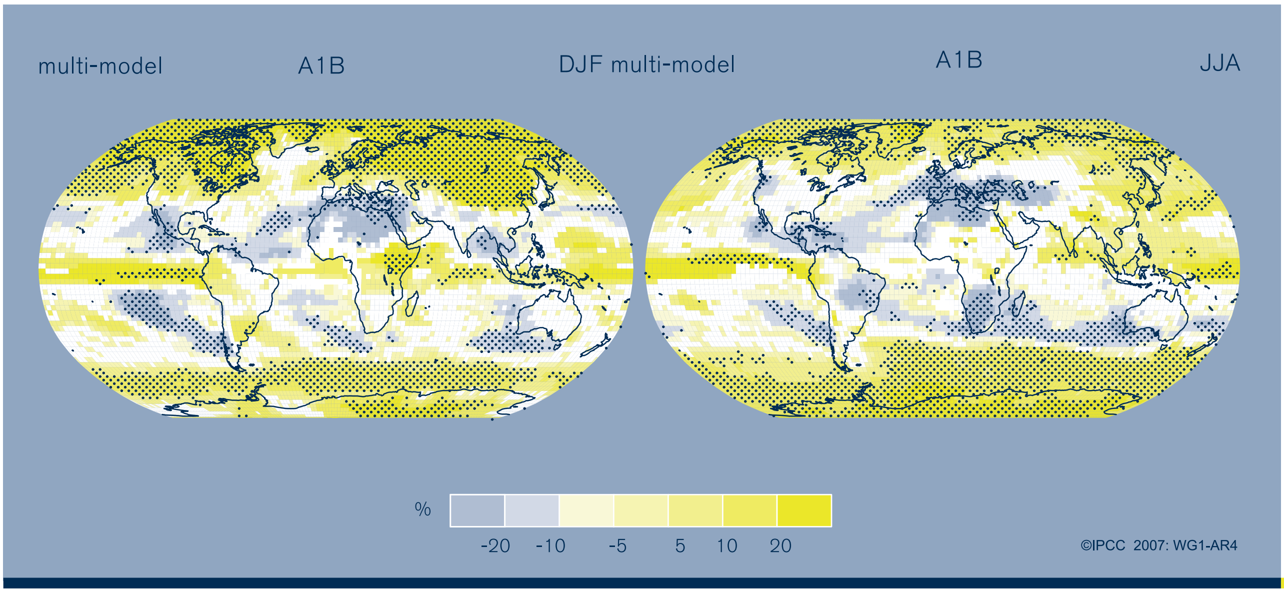


Figure 3 (adapted from IPCC 2007, SPM-6, p.15)

Projected surface temperature changes for the early and late 21st century relative to the period 1980-1999.

Figure 4 (adapted from IPCC 2007, SPM-7, p.16)
Relative changes in precipitation (in percent) for the period 2090-2999, relative to 1980-1999 for a single scenario.



Where water resources are concerned, a Fourth Assessment Report summary concludes that climate change will have a wide range of impacts on fresh water systems and the management of such systems. They state that: "By mid-century, annual average river runoff and water availability are projected to increase by 10-40% at high latitudes and in some wet tropical areas, and decrease by 10-30% over some dry regions at mid-latitudes and in the dry tropics, some of which are presently water stressed areas" (IPCC WG2 2007, p. 7). The distribution of projected changes in runoff is, however, dependent on the specific model used. As figure 5 (adapted from IPCC 2001) indicates (the full Fourth Assessment has not been released at the time of this writing), runoff calculations made using different versions of the Hadley Centre atmosphere-ocean general circulation model (AOGCM) produce markedly different results for some regions such as South Asia and North America and broadly similar results for other regions such as south-central Africa and the northern portions of South America. Recent attempts to downscale results from GCMs to regional contexts suggest climate change impacts may also vary greatly within broad regions. In India, for example, although many projections indicate broad increases in precipitation, some sub-regions (such as western Rajasthan) may experience substantial declines. In addition, models suggest a substantial increase in both 1-day and 5-day extreme events. The amount of runoff that occurs and the net increase or decrease in water availability will depend heavily on the intensity and distribution of the precipitation. Overall though, there is high confidence that the dry tropical areas, such as South Asia, will experience significantly decreased levels of runoff. "Freshwater availability in Central, South, East and Southeast Asia particularly in large river basins is projected to decrease due to climate change which, along with population growth and increasing demand arising from higher standards of living, could adversely affect more than a billion people by the 2050s" (IPCC WG2 2007, p. 10).

Overall, existing scientific information strongly suggests that climate change will result in increases in climatic variability and the intensity/frequency of both rapid and slow onset extreme events such as floods, tropical cyclones and droughts. While the vulnerability of some regions, such as small islands and low-lying coastal areas, to the extreme events anticipated as a consequence of climate change is relatively clear, the specific changes to which society will need to adapt in other regions is far less so. Many of the impacts of climate change will occur most directly, for example, to water resource systems. As climate changes, historical periods of record for water resources will be of limited use for projecting future conditions. Dry season flows in snow-fed rivers are likely to decrease as precipitation shifts toward rain, snowmelt occurs earlier in the season and glaciers continue to retreat. In particular, "glacier melt in the Himalayas is projected to increase flooding, rock avalanches from destabilized slopes, and affect water resources within the next two to three decades. This will be followed by decreased river flows as the glaciers recede" (IPCC WG2 2007, p. 10). Heavy precipitation events are very likely to increase over most areas, which will enhance flood risk. Secondary effects on, for example, erosion rates are also likely as a result of a generally more active hydrologic cycle. If storm intensity increases and a greater proportion of precipitation occurs as rainfall instead of snow, average erosion rates would logically increase as would the massive pulses of sediment movement that occur as base load.

The implications of changes in sediment load for water management are important to recognize. The Yellow River, for example, is known as carrying the heaviest sediment load of any river on the planet. This high sediment load has plagued attempts to manage floods and water in the river throughout China's history. Silt deposition between flood control embankments has caused the riverbed to rise by up to one meter per decade. Riverbed levels are, in some locations, now as much as 10 meters above the surrounding plain. Sediment load is closely correlated with precipitation intensity. Studies in the Yellow River show that "most of the sediment load is produced by a few major storms during the flood season, when the daily precipitation reaches 100-200 mm. In some areas, one storm event can contribute to more than 50 percent of the total annual sediment load. Very heavy storms can increase the annual sediment yield of small watersheds by a factor of two or more (Mou 1991). The Yellow River passes through the Loess Plateau, a region where soils are highly vulnerable to erosion. The pulsed nature of sediment fluxes isn't, however, limited to this type of situation. Studies on 20 of the largest streams entering the Pacific Ocean along the California coast between Monterey Bay and the Mexico border documented tremendous changes in sediment flux (Inman and Jenkins 1999). According to Inman, between 1948 and 1968 dry climatic conditions prevailed in the region. This abruptly transited in 1969 to a much wetter period that extended for an equal period of time. During three major flood years in the wet period, the sediment flux averaged 27 times the average annual flux in the dry period. In some rivers the amount of sediment moved in 1969, when the transition from wet to dry occurred, exceeded the entire amount of sediment moved during the preceding 25-year dry period.

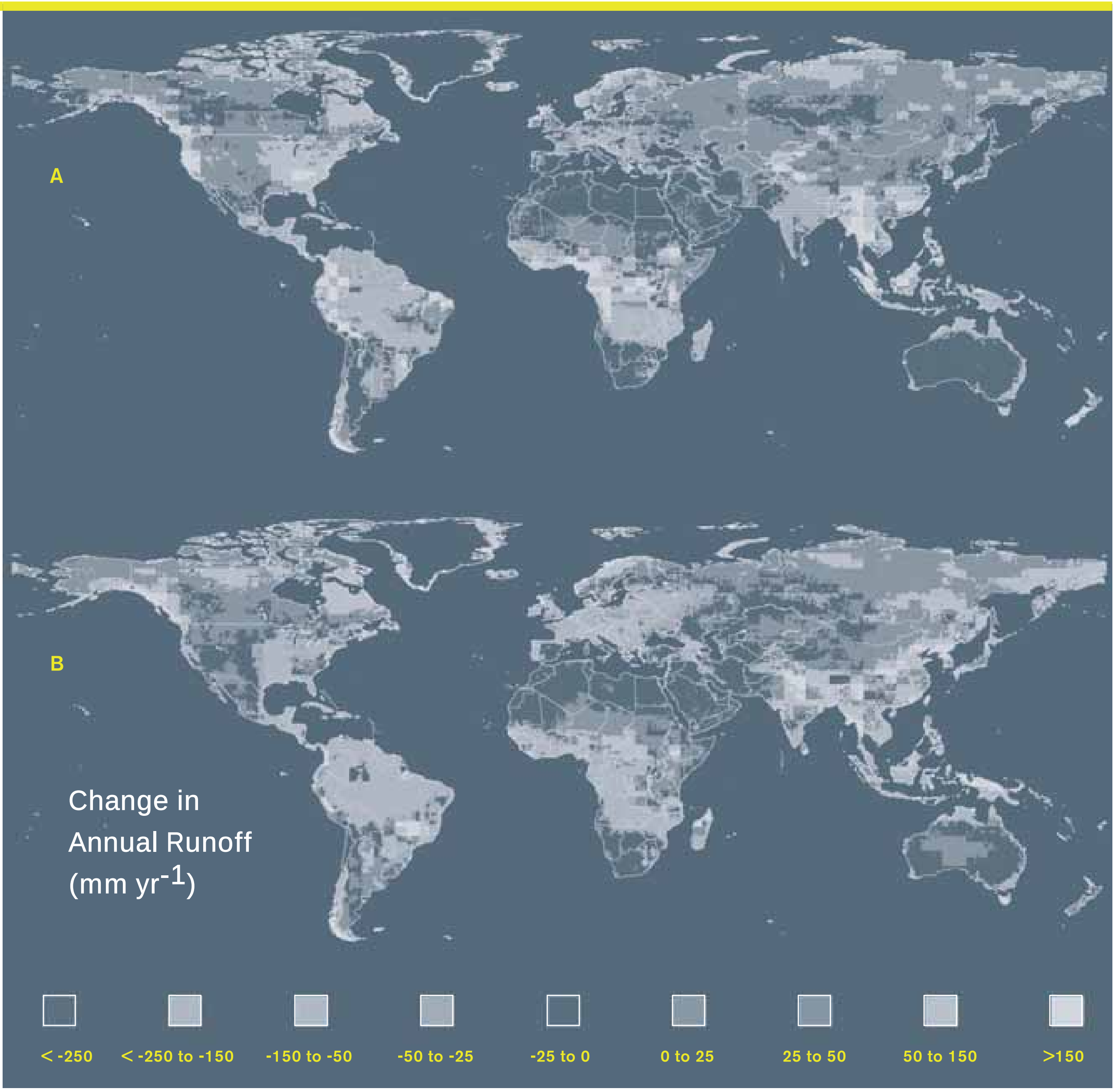


Figure 5 (adapted from IPCC 2001, SPM-4, p.11)

Comparison of observed continental- and global-scale changes in surface temperature with results simulated by climate models using natural and anthropogenic forcings. Decadal averages of observations are shown for the period 1906-2005 (black line) plotted against the centre of the decade and relative to the corresponding average for 1901-1950. Lines are dashed where spatial coverage is less than 50%. Blue shaded bands show the 5-95% range for 19 simulations from 5 climate models using only the natural forcings due to solar activity and volcanoes. Red shaded bands show the 5-95% range for 58 simulations from 14 climate models using both natural and anthropogenic forcings.

[4] SEE FOR EXAMPLE, WITH COASTLINE IN RUINS, CAJUNS FACE PROSPECT OF UPROOTED TOWNS, JERE LONGMAN, NEW YORK TIMES, DECEMBER 27, 2005. HTTP://NYTIMES.COM/2005/12/27/NATIONAL/NATIONALSPECIAL/27CAMERON.HTML?HP&EX=1135746000&EN=67534DAD13DA5FAE&EI=5094&PARTNER=HOMEPAGE

In the Yellow River, high sediment loads have a major impact on dam storage capacity, food production in the lowlands (due to excessive sedimentation) as well as increasing the potential for major floods and the breaching of levees. This is also common in other regions. Furthermore it is not a recent phenomenon associated with the large-scale water resources development activities of the last century. Studies of ancient irrigation systems in desert areas showed similar problems with larger systems having failed in large part due to siltation (Evenari, Shanan et al. 1971).

The core problem facing these historical irrigation systems was similar to those currently present in many large systems:

1. Attempts to control water flow in major river systems alter their hydraulic properties.

2. Changes in hydraulic properties through large structural interventions catalyze major changes in patterns of sediment deposition and scour.

3. These new patterns of deposition and scour ultimately cause many water control structures to fail.

Such problems are proportional to the scale of structural intervention because larger structures tend to have a larger and more concentrated impact on river hydraulic properties. Problems are also influenced by overall basin sediment loads (the more sediment being moved, the greater the impact of hydraulic changes) and by flow variability. Where flows are highly variable, sediment movement occurs in pulses that are particularly difficult to manage and water control structures are more likely to be subject to sudden failure.

What is the key lesson from experiences with sediment transport for climate change? The implications are fairly straightforward: anticipated increases in the variability and intensity of climatic events could logically exacerbate the types of sedimentation problems already present in many systems. If dry periods are followed by intense storms, the large pulses of sediment documented in the California watersheds are likely to be increasingly common. This may pose particular challenges for water management approaches that attempt to address water supply variability by increasing storage in reservoirs. It is also likely to pose particular problems for flood control strategies that rely on levies and other conventional flood control mechanisms.

The extent to which changes such as the sediment pulses discussed above, their regional distribution and the timing of change are uncertain. Some climate related changes, such as those related to average sea level, can be specified well in advance and are likely to occur in a gradual manner. Other changes, such as those associated with floods, droughts and extreme storm events, will occur in abrupt pulses.

The above broad patterns suggest that society will require strategies that are robust under different conditions for responding to both incremental changes and the abrupt pulsed impacts of extreme events. In many situations gradual and pulsed changes will occur in conjunction. The importance of small changes in sea level (an incremental change) for storm surges (a pulsed change) is widely recognized. A similar conjunction of impacts may occur when, for example, intense droughts occur in regions where precipitation or dry season flows have been declining incrementally over a long period or when intense storms occur in regions that are already saturated due to long-term increases in precipitation. Conceptually, as a result, the challenge is to develop strategies for adaptation that are capable of responding to both the incremental changes that can be anticipated and, probably more importantly, to changes that are either impossible to predict or where the changes will occur in a pulsed manner with the specific timing and magnitude subject to high levels of uncertainty. It may, for example, be possible to clearly project the timing and impact of gradual rises in sea level rises on coastal infrastructure (drainage outfalls, roads, houses, etc.) and resources (wetland areas, groundwater, etc.). Incremental changes in sea level can be projected decades in advance and coastal communities can utilize conventional investment and urban planning strategies to develop planned responses. The impact that increases in storm intensity will have on specific locations is, however, far more difficult to predict. Communities may know that preparation is required but when storms will hit, what their specific intensity will be and how frequently they will occur are all unknown. Investments in emergency planning and the strengthening of storm defenses can be made – but it will be difficult to project what levels of investment are justified and whether or not "adequate" protection against recurrent events can be achieved. In many situations it may be impossible to fully protect low-lying coastal areas using structural mechanisms. As a result, decisions may involve a trade-off between (expensive and difficult to maintain) long-term attempts at protection and (politically unpalatable) decisions to move populations and "abandon" land and infrastructure in vulnerable regions either in advance or when they are devastated by an extreme event. While it may seem unthinkable, this second scenario is precisely the one that is currently playing out in areas affected by Hurricane Katrina. Even for the major city of New Orleans, the costs of strengthening levies to withstand category 5 hurricanes are such that abandonment of many lower, more vulnerable and less wealthy areas is increasingly likely. Outside the city, protection is not a realistic option and officials are actively considering moving the entire population of some towns inland as much as twenty miles.[4]

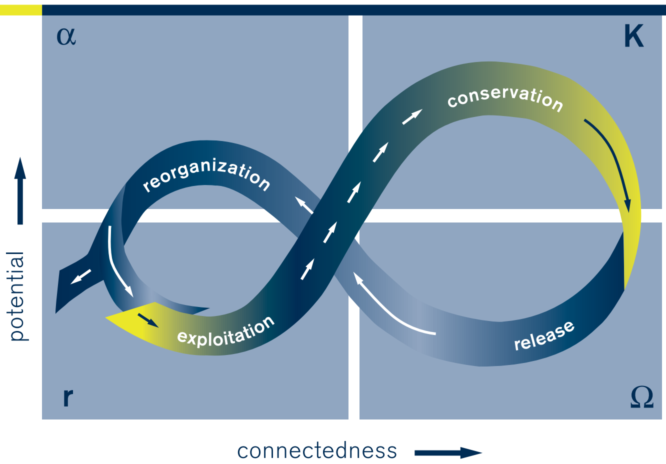
Within the water resource sector, projected changes in climate may have fundamental implications for management strategies. Increases in variability are, as many have noted, likely to increase the importance of carryover storage capacity. The viability of creating substantial reserves through conventional approaches to storage in large reservoir systems will, however, itself be affected by climate change. Problems such as sedimentation and conflicting operational rules (between, for example, flood control, power generation and water storage) are likely to be exacerbated by increased variability. If climate change increases the frequency or intensity of extreme weather events this is also likely to generate pulses of sediment that fill dams and create deposition behind flood control structures. Such problems are likely to be particularly important in basins that, like the Yellow River or the Gangetic Basin, have inherent geological, gradient or other features contributing to large sediment fluxes. Other strategies for water management that are less dependent on large structures (such as increased storage as groundwater through conjunctive management and aquifer storage and recovery systems) could, in some cases, serve as alternatives to surface storage and, in others, complement it. These could be implemented on a large scale in many parts of the world. As a result arid regions or those where precipitation is highly variable may face a choice between attempts to directly manage water resources to maintain agricultural and other water intensive activities or to rely on imports of food and other water intensive products. The shift of water intensive activities to regions where water is available coupled with greater reliance on low water intensity livelihoods and trade may, in fact, play a much larger role in responding to climate change than many more localized attempts to directly manage locally available water resources.

The societal implications of processes such as the above are, of course, huge. They will be compounded by differing patterns of vulnerability to extreme events such as those already illustrated in the case of Hurricane Katrina. Before going into detail regarding the societal issues inherent in adapting to extreme events generally or more specifically within the water sector, some of the core concepts related to change within complex systems and the factors that contribute to adaptive capacity are essential to understand. The next section focuses on some of these core concepts.


LINK-BELT

2.2 THEORETICAL AND CONCEPTUAL PERSPECTIVES ON RISK, CHANGE AND ADAPTATION WITHIN COMPLEX SOCIAL AND ENVIRONMENTAL SYSTEMS

Figure 6 (adapted from Gunderson and Holling, 2002)



Over the last two decades research on the dynamics of complex interlinked systems through groups such as the Resilience Alliance (www.resalliance.org) has highlighted fundamental similarities in ways that social and ecological system evolve. In most situations, as illustrated in figure 6 (adapted from Gunderson and Holling 2002), systems pass through a clearly recognizable cyclical sequence of increasingly structured growth and conservation followed by disruption and reorganization. During the 'r' growth phase entities (whether organizations, economies or organisms) exist in a resource rich environment and expand rapidly. Expansion eventually leads to increased competition as resources (energy, nutrients, commodities, money, etc…) become scarce or locked up by existing entities.

This leads in the 'K' conservation phase to organizational patterns that are increasingly efficient and specialized but generally less flexible. The system becomes more and more structured – and momentarily predictable – as entities specialize to capture any resources that remain available and to hold on to the resources they have already accumulated. Increasing efficiency and specialization reduce flexibility and the resilience of the system to external disruption declines. At some point, external disruptions exceed system resilience and, during the "Ω" release phase, fundamental change (which is often equivalent to destruction) occurs. Reorganization occurs in the "α" phase (Gunderson and Holling 2002).
In ecological systems, the r-K phase might represent the gradual transition over decades from pioneer species to a climax forest cover where most nutrients are locked in existing biomass. The K-Ω phase could represent a major fire or storm and the release of nutrients it enables while the Ω-α phase would involve the initial establishment of pioneer species that "prepare the ground" for a return to structured – and much more gradual – growth. In social systems, parallel processes can easily be identified at multiple levels from organizations to nation states. Processes of growth, conservation, release and reorganization are common and range from the relatively innocuous (a firm reorganizing in response to changing market conditions) to the transformative (the fall of the Roman Empire and the centuries it took following that for society to reorganize toward productive growth). This difference between the process of continuous small adjustments and transformative/disruptive change captured in this analogy is central to understanding the challenges climate change poses for human society.

Research on the dynamics of complex systems suggests that the more highly structured and rigid a system becomes during the K conservation phase, the more disruptive its eventual failure will be during the inevitable Ω phase of release and transformation. Change processes occur in pulses of disruption where the impact depends heavily on their relationship to the preceding, much more gradual, process of increasingly structured growth and conservation. Continuous exposure to small disruptions helps to maintain the flexibility and on-going processes of release and reorganization that form the basis of adaptation and overall system resilience. When systems are insulated from exposure to minor sources of disruption, they tend to become increasingly specialized, structured and rigid. If disruptions exceed their stability threshold, the resulting collapse and the probability of it resulting in fundamental restructuring of the systems involved is far higher.

To shift this into other terms, consider a standard engineering definition of risk as the probability of a given event multiplied by the consequences. If the probability of flooding is reduced through flood proofing measures, then society will generally make large, individually unprotected, investments within the protected areas. If floods are sufficiently large that they exceed the design capacity of the protective structures, the consequences in terms of life and livelihoods from a single event can, as Katrina demonstrated, be monumental. If, instead, areas remain exposed to flooding and investments in vulnerable areas occur in ways that minimize the impact regular flooding has upon them, then the consequences of any given event are much lower. Climate change complicates the design of protective structures because there is little basis for predicting the magnitude and frequency of extreme events. As a result, regions may not be able to do much to reduce the probability that floods will exceed the capacity of protective structures – at least not over the long-term.

Such issues are of direct relevance to many vulnerable regions. In the Netherlands, for example, extensive investment in dykes and other protective works has encouraged very high levels of investment and settlement in lands that lie below sea level. If these fail – and there is no mechanism for providing full surety that they won't as sea level rises and flood flows change – then the human and economic losses would be staggering. Advertising the limitations of structural control measures would limit the willingness of companies to invest in vulnerable areas and could have a very large economic and social impact on the Netherlands. At the same time, making the limitations of control strategies clear should also catalyze thinking and investment on how to live with or respond to the risks inherently associated with developing lands that lie below sea and river bed levels.

2.2.A Implications for Risk Management and Adaptive Capacity

The above discussion highlights the tradeoffs inherent in alternate approaches to risk management. Risk is a reflexive concept. Both the probability of an event and the consequences depend on the interaction of physical, social and behavioral factors over time. Flexibility, diversification, continuous adjustment, reorganization and learning in response to recurrent events enable adaptation to occur with less probability of disruption and fundamental transformation of complex systems. At the same time, maintaining flexibility and diversification are themselves not without cost. In Asia, groundwater development removed much of the risk farmers faced from water supply variability in rain fed systems. Now rapid declines in groundwater levels in many areas make intensive groundwater-based agriculture highly vulnerable to collapse, particularly during drought periods. The reduction in risk achieved by accessing assured irrigation from groundwater enabled intensification and directly contributed to economic development and poverty alleviation (Moench 2003). This has, however, created new forms of risk, rigidity and vulnerability within the agricultural system. At the same time, many farmers are using the assets accumulated through intensive groundwater based agriculture to educate children (which enables access to non-agricultural jobs), or take other steps to develop non-farm livelihoods. Those who are successful have reduced their exposure to agricultural risks. Such tradeoffs illustrate the multiple levels and timescales that contribute to risk and vulnerability. Risk management is, as a result, a process that requires a combination of strategies.

5 HTTP://WWW.RESALLIANCE.ORG/

Strategies to directly control some types of risks can be effective. Care must be taken, however, to evaluate whether or not, as the groundwater case above illustrates, such strategies create rigidity and increase vulnerability to catastrophic failures over the longer term. Alternative strategies that strengthen the ability of populations to "live with" and adapt to variability and the uncertainties inherent when complex systems interact are also central to risk management. The consequences of climatic events depend as much on the adaptive capacity of social and economic systems as they do on the ability to directly "control" such events.

What are some of the key attributes that contribute to adaptive capacity? Although much remains to be done to strengthen the conceptual and applied understanding of adaptation processes, existing research (Moench and Dixit 2004) indicates that adaptive capacity depends heavily upon:

A. Flexibility (within livelihood systems, economic systems, water management systems, institutional systems)
B. Diversification (multiple independent income flows to livehood systems)
C. The ability to learn from events (at both individual and institutional levels)
D. Education (the knowledge base required to develop new systems when existing ones are disrupted).
E. Mobility (an attribute of flexibility)
F. Risk pooling and spreading (institutional arrangements or other mechanisms for spreading and pooling the impacts of disruptions on the system as a whole);
G. Operational techniques for risk reduction before and following disruptions (techniques for directing the reorganization process so that growth and conservation phases do not increase rigidity and ultimate vulnerability).
H. Convertible assets (the ability to convert assets accum ulated during periods of growth into other forms when disruptions occur)

All of the above contribute to system resilience – that is the ability to adjust to shocks and variability without fundamental changes in overall system structure. Maintenance of adaptive capacity depends upon some degree of exposure to variability and uncertainty. Unless systems are continuously exposed to variability and risk, the immediate incentives for diversification, strategy shifting and learning are reduced and rigidity increases. If, for example, exposure to drought it eliminated, people have little incentive to plan for it by implementing efficient water technologies, purchasing insurance or diversifying crops. When such "adaptive capacity" declines, the drought "shock" to an agricultural economic system is likely to be far higher. Similarly, in the western U.S., decades of effort to reduce forest fires have led to high levels of fuel loading in the forests. Now, when fires occur, they tend to be far larger, far hotter and far more destructive than ever before. Such dynamics occur in relation to virtually all risks. Overall, reductions in exposure to risk reduce the incentive to maintain adaptive capacity. This, in turn, reduces overall system resilience when large shocks occur.

To return to the systems dynamics diagram developed by the Resilience Alliance,[5] this implies that attention needs to be paid toward risk evaluation and reduction in the long-term, incremental, process of development (the growth and conservation phase), that financial and other techniques need to be developed for mitigating the impact of disruptions and that much greater attention needs to be paid to the process of reorganization following extreme events as a key period shaping patterns of future growth.

Such processes are already partially in place in parts of the world for disaster risk reduction. Most of the work emerging from the disaster management community, however, emphasizes the reduction of vulnerability as occurring after reconstruction. Risk reduction is generally seen as separate from the period when society and infrastructure and disrupted following disasters – rather than recognizing that period as the critical phase when reorganization is occurring. In addition, disaster prevention activities tend to focus on the proximate causes of climate disasters (such as technical structures and land use) rather than the wider systemic sources of both vulnerability and resilience. As Tony Allan has emphasized in

much of his work on water in the Middle East, the solutions to water problems often lie outside the water arena (Allan 1997; Allan 1998). Drought, for example, is primarily a problem if food sources are local (rather than based on trade) and if people lack the resources to purchase their requirements because economies are dependent on local production.

The solution to water problems often depends as much on whether or not "virtual water" (that is the water used to produce imported food) can flow as it does on local "water management" activities. This is, as emphasized before in the discussion on the reflexive nature of risk, also the case with disasters. Whether or not a given event becomes a disaster depends as much on the wider context as it does on the specific nature of the event.

2.2.B Conceptual Implications for the Water Sector

What are some of the core implications of the above discussion on systems dynamics, risk and adaptive capacity for the water sector?

In many ways they suggest a need to reorient both the conceptual foundations and the practice of water management. This should not be interpreted as a call for a "new paradigm." Water management strategies have always dealt with risk. Most technologies for water control will not change. The need to base many management activities on hydrologic units while also maintaining a wider perspective that recognizes interactions between social, ecological, economic, institutional and other systems (the fundamental observation underlying Integrated Water Resource Management approaches) also remains valid.

All these factors suggest that reorientation is far more important than attempting to reinvent the wheel. Water management strategies do, however, need to change. The assumption of stationarity that underlies virtually all hydrologic analyses is not valid. As argued before, water managers can't assume that extreme events represent part of a well-defined statistical distribution with predictable return periods. As a result, some of the core tools that have been developed for water and land managers cannot be relied upon. The utility, for example, of flood frequency maps (a primary tool local planning departments and insurance companies use to assign insurance rates, codes, etc.) need to be reviewed. Similarly, the design of physical structures (dams, spillways, levies, etc.) is generally based on historical analyses of precipitation, stream flows and other climate parameters. Moving away from assumptions of stationarity will require new tools and greater recognition of uncertainty in projections regarding the behavior of water resource systems. This will require far greater attention to risk and the reorientation of management techniques in ways that reflect inherent uncertainty.

Conceptually, this implies that changes are likely to be required in at least six key areas. These are:

1. *Design principles for physical and institutional structures*
   Conceptually, the core requirement will be to develop physical and institutional structures that are robust and flexible under changing conditions. Where physical structures are concerned, this implies a much greater focus on structures that remain operational under highly varying assumptions regarding, for example, stream flows, sediment loads and water demand patterns. Physical structures that "work with" variability rather than attempting to control it are likely to be essential. Where institutional structures are concerned, it implies a premium on robustness, flexibility and reversibility. This could affect both daily operational mechanisms, such as reservoir operating rules, and deeper institutional arrangements such as rights systems. Rights systems that grant specific users or specific uses firm "rights" to given quantities of water are likely far more difficult to change and generally less flexible than systems that contain either social or market mechanisms for reallocation. Overall, design principles whether they relate to physical or institutional structures will need to shift away from concepts such as optimization and (in some cases) efficiency toward concepts such as resilience and flexibility.

2. *Analytical Tools*
As with design principles, analytical tools will need to shift in ways that respond to greater variability and uncertainty. Conventional modeling techniques for water resource analyses rely heavily on the existing hydrological record as a statistical basis for forecasting. New techniques will be required that rely on basic physical principles rather than historical relationships for their predictive capacity. The hydrological record will remain essential for historical calibration but not as a statistical basis for prediction. Scenario based approaches will also probably gain in importance as techniques to explore and unpack management issues. Beyond this greater attention will need to be paid to analytical tools for risk management. These tools will need to address both direct risks within the water system – such as structure failure probabilities – and much more difficult to evaluate or quantify risk patterns involving the interaction between society and specific water hazards.

3. *Management approaches*
Conceptually, increased uncertainty and change is likely to necessitate at least two broad shifts in approaches to water management. First, it will necessitate a shift toward more "adaptive" management systems – i.e. systems that contain explicit mechanisms for adjusting management objectives, tools and techniques as conditions change. Second, much more attention will need to be paid within management systems to "pulsed" change, the sudden intensive reshaping of infrastructure, needs and perspectives that accompany intense droughts, storms or floods.

4. *Management Objectives*
Most water management systems have had the delivery of security (secure water supplies to meet human, environmental or other needs; secure protection from floods or storms) as a core objective. While security objectives in management are unlikely to disappear, provision of "security" can undermine adaptive capacity. This is evident in the role groundwater development has played in agricultural intensification (secure water supplies encourage the development of agricultural systems that require that reliability) and flood management systems (levies encourage people to settle in vulnerable areas often with little understanding of the consequences should levies fail). Management objectives may, as a result, need to reduce the emphasis on security and shift instead toward approaches that encourage people to deal with inherent risks and adapt their lives and livelihood systems to such risks.

5. *Maintenance of Environmental Values*
Climate changeprocesses are almost certain to change conditions within hydrological systems in ways that have enormous impacts on aquatic ecosystems. The approaches humans take to meeting their water needs will have an equally large impact on the ability of these ecosystems to adapt. Take the case of flood control. If increased climatic variability leads to greater calls for river regulation, then the disruptions to aquatic ecosystems that are already known to accompany the construction of large reservoirs and control infrastructure are likely to compound the impacts of climate alone. If, instead, human approaches to flood management emphasize maintenance of buffering capacity within riparian zones and flood plains along with drainage rather than river regulation, then much more scope may exist for ecosystems to adapt to climate change. Similar issues are likely to emerge in a number of contexts. Overall, the importance of maintaining key environmental values appears, at a conceptual level, to have major implications for strategies for adapting to climate change within the water sector.

6. *Disciplinary boundaries*
Despite increased emphasis on interdisciplinary perspectives in recent years, water management debates have tended to focus heavily on strategic alternatives within the water sector. Debates focus, for example, on tradeoffs between large scale and local infrastructure for storage, between interventions designed to increase water supplies as opposed to strategies that increase water use efficiency and between the allocation of water to meet environmental versus other needs. Rarely do debates extend to explicit consideration of higher-level tradeoffs such as regional choices to shift economies out of agriculture and rely on food imports (virtual water) to meet the needs of local residents. Even within well-defined water use areas, such as municipalities, debates tend to focus on alternatives for improving existing utilities rather than alternate economic and institutio-

nal mechanisms such as water markets for meeting local needs. Because the water related risks associated with climate change depend heavily on factors outside the water sector, effective responses will increasingly require multi-disciplinary inputs. Decisions affecting the role of trade (virtual water) or reliance on urban water markets may have more fundamental implications for management needs as those taken within conventional water fields. In sum, at least conceptually, shifting to a risk management perspective will require far more attention to courses of action that lie outside the water sector than ever before.

The above bullets indicate some of the key areas where, at least on a conceptual level on-going change processes will necessitate reorientation within the water sector. The next sections explore in detail some of the debates that are actually occurring.

2.3 APPLIED DEBATES OVER CLIMATE, ADAPTATION AND WATER

Applied debates over the strategies required for adaptation to climate change in the water sector are concentrated in three large arenas. The first is very direct and consists of the National Adaptation Programmes of Action that many LDCs are preparing for the IPCC using funding from the Global Environment Facility. These are intended to provide a framework for countries and the international community to invest directly in activities that contribute to adaptation. The second is much more thematic. Debates over climate change are occurring within the water resource community in relation to the dominant paradigm of Integrated Water Resource Management (IWRM). Limitations in this paradigm have led to emergence of a related set of debates on courses of action that are related to climate and water but fall outside the traditional purview of the "water sector." All of these link back to questions of vulnerability – who is vulnerable and whether or not different courses of action would address the context and needs of different groups. The debate over adaptation, as a result, can be seen as a continuum from very tangible projects to broad concepts. We start below with the most tangible element, the NAPAs.

2.3.A Global Strategies: National Adaptation Programmes of Action (NAPA)

Globally, substantive attention to strategies for responding to climate and the implications such strategies might have for activities within specific sectors is relatively recent. Although "adaptation" is recognized as a significant issue in the Fourth Assessment Report, the summary for policy makers still heavily emphasizes the need for additional assessment and, in essence, contains no specific recommendations on the courses of action that would be required in key sectors, including water resources. Following publication of the Third Assessment Report, guidelines were established at the 7th Conference of the Parties (COP 7) for producing National Adaptation Programmes of Action (NAPAs) in LDCs. The NAPA process is, in essence, the primary process that is in place at a global level for developing applied responses to climate change. More localized initiatives are relatively common but they tend to be highly fragmented and site specific. As far as the authors are aware, outside the NAPAs systematic processes do not exist for adaptation evaluation and planning.

6 HTTP://PANA-NAPA.WEB.CERN.CH/PANA-NAPA/NAPA/

The NAPA process has proven complicated and many countries have encountered difficulties in completing them.[6] In 2003, four major country workshops were held with the goal of ensuring that NAPAs were country driven and country specific. At the time of writing (April 2007), the process in many countries is still underway. NAPAs have been completed for only six countries: Bangladesh, Bhutan, Mauritania, Malawi, Cambodia and Samoa.

Reviews of the first four of the above NAPA's highlight the central role of water and water related interventions among other issues identified as critical to address at the country level. All four link adaptation issues to disaster management; primarily flooding in the case of Bhutan and Bangladesh, flooding and drought in the case of Mauritania and drought in Malawi. All four also highlight the role of traditional coping strategies and, to the extent possible, of using those as an element in any larger attempts to promote adaptation. Statements on adaptation in the Malawi NAPA illustrate this last point. According to it: "In most parts of Malawi, rural communities have tried to devise ingenious ways to cope with and adapt to the adverse impacts of extreme weather events, including shifting homes to higher ground, storing grain in local granaries, hunting small animals, gathering and eating wild fruits and vegetables, sinking boreholes, and using traditional medicines to cure various ailments and diseases" (Republic of Malawi 2006). It goes on to state that "However, some of these are not very effective" (Republic of Malawi 2006, p. 6).

As intended under the NAPA process, the country documents identify and prioritize initial measures to support adaptation. They also identify specific projects and the funding required to implement them. Key elements of the Bangladesh, Malawi, Mauritania and Bhutan NAPAs are outlined below.

Bangladesh

The Bangladesh NAPA focuses heavily on water related issues, particularly those associated with flooding and storms (People's Republic of Bangladesh 2005).

In the Bangladesh case, priority areas for action are grouped into "interventions" and "facilitating" measures. The first four proposed intervention arenas focus on agriculture (to increase resilience to salinity and flooding) and fisheries (salinity again and diversification). Other interventions include construction of flood shelters, coastal afforestation, provision of drinking water in coastal areas and enhancing resilience of urban infrastructure to floods and cyclones. Facilitating measures focus on capacity building, insurance, information dissemination, drought, salinity and flood research and development of "eco-specific" knowledge on adaptation. Project concepts proposed under the Bangladesh (People's Republic of Bangladesh 2005, p. 39) that are directly related to water and extreme climate events include:

1. Providing drinking water to coastal communities to combat enhanced salinity due to sea level rise;
2. Capacity building for integrating climate change in planning, designing of infrastructure, conflict management and land-water zoning for water management institutions;
3. Climate change and adaptation information dissemination to vulnerable community for emergency preparedness measures and awareness raising on enhanced climate disasters
4. Construction of flood shelter, and information and assistance centre to cope with enhanced recurrent floods in major flood plains.
5. Mainstreaming adaptation to climate change into policies and programmes in different sectors (focusing on disaster management, water, agriculture, health and industry).
6. Promotion of research on drought, flood and saline tolerant varieties of crops to facilitate adaptation in future.
7. Promoting adaptation to coastal crop agriculture to combat increased salinity.
8. Adaptation to agricultural systems in areas prone to enhanced flash flooding in North East and Central Region.
9. Exploring options for insurance to cope with enhanced climate disasters.

Malawi

The Malawi NAPA (Republic of Malawi 2006) lists numerous areas where adaptation is needed. Of the 15 core points noted on p. 7 of the report, the following relate directly to water or disaster response:

1. Increasing resilience of food production systems to erratic rains by promoting sustainable dimba production of maize and vegetables in dambos, wetlands and along river valleys,
2. Developing food and water reserves for disaster preparedness and response,
3. Developing and implementing strategies for drought preparedness, flood zoning and mitigation measures,
4. Developing small dams, and other storage facilities, to mitigate flooding, to harvest water and to initiate community-based fish farming and breeding (Republic of Malawi 2006, p. 25).

Potential benefits for climate adaptation from sediment control through afforestation are also noted. Project activities designed to respond to adaptation needs include a wide variety of interventions from crop diversification to flood early warning. One project on "Improving Malawi's preparedness to cope with droughts and floods" for example, includes the following activities:

1. Conducting rapid assessment of drought and flood risks, resulting in flood delineation and zoning maps,
2. Establishing flood forecasting and warning systems,
3. Developing and implementing flood mitigation measures,
4. Establishing drought forecasting and warning systems, and
5. Developing and implementing drought mitigation measures.
6. Capacity building for rapid response to extreme climate change events.

Mauritania

The NAPA for Mauritania, naturally enough for a country in the Sahelian zone, focuses heavily on drought related issues. In the initial summary of climate vulnerabilities, the Mauritania NAPA notes three key issues. First, it points out that: "Though the rural areas are home to 45% of the country's total population and 56% of the active population, they are home to more than 75% of the poor and they generate only 26% of GDP" (Islamic Republic of Mauritania 2004, p. 16). Most of the country's GDP is generated in urban areas and recent decades have seen a massive shift in population toward urban areas. As the NAPA states: "At present, an estimated 55% of the total population is living in urban areas in comparison with less than 5% in the 1960s" (Islamic Republic of Mauritania 2004, p. 14). Second, the government is attempting to encourage mobility in the livestock sector. This is a distinct change from historical practices that were designed to discourage nomadic lifestyles. The government now recognizes that "mobility has been adopted [by rural populations] as a strategic response to variability of rainfall and scarcity of grazing pasture. It has made possible the development of grazing land, and of areas without water, and the seeding of pastures over a very wide radius." As a result, livestock mobility is now recognized as a key adaptation strategy that is essential to cope with the highly variable precipitation patterns typical of the Sahelian region. As a result, the NAPA explicitly calls for "the establishment and the implementation of a pastoral code promoting free access to resources and mobility" (Islamic Republic of Mauritania 2004, p. 25). Third, the NAPA notes agricultural intensification (including market gardening and the use of higher efficiency/value production techniques and crops) in areas where water is available as strategies people are adopting to adapt to climatic variability and the overall scarcity of water.

Where strategic recommendations regarding priority areas for investment to support adaptation in the water sector are concerned, the Mauritania NAPA states that: "appropriate solutions to adaptation to climate change should be sought in the effective implementation of the Integrated Water Resource Management approach" (Islamic Republic of Mauritania 2004, p. 26). This is described as consisting primarily of assessment, monitoring, communications, conflict resolution, regulation and capacity building. In addition to this it supports a number of specific priority interventions related to water. Of the twenty-eight priority interventions identified, the first five and a total of nine directly relate to water. They include:

1. Better knowledge of the regimes of surface waters for 20 ponds;
2. Construction of decelerating runoff waters obstacles (small dikes) in pluvial and oasis areas;
3. Promotion of water-saving techniques in oasis zones;
4. Introduction of electrical 50 MPs in the irrigated valley;
5. Dissemination of the water dropping technology in the valley and oasis zones;

6. Improvement of underground waters management in the Aftout zone;
7. Monitoring of the quality of water for three priority cities;
8. Experimental use of the drip technique in oasis zones;
9. Support for improved monitoring of the piezometric networks of the Aïoun sandstones in the Hodh; .

Bhutan

The Bhutan NAPA, as would be expected given the unique nature of the country, is significantly different from the others. It emphasizes some phenomena, such as glacial lake outburst floods (GLOFs) that occur as glaciers melt and retreat and are unique to such environments (Royal Government of Bhutan 2006). It also has a major emphasis on the implications of climate change for hydropower generation. Key water related sources of vulnerability identified in the NAPA include impacts on cropping systems (due to rainfall variability, erosion and flooding), infrastructure and energy systems (due to GLOFs and other floods, sedimentation and flow variability) and health (due to changes in water quality and again to floods). In response to the above, the NAPA proposes a wide variety of adaptation measures that are related to water. Among the numerous activities proposed the list below represent some of those most directly related to water. These are:

1. Increase number of / Protect existing water treatment plants to ensure safe drinking water
2. Monitor air and drinking water quality
3. Raise community awareness on sustainable use of water resources
4. Improve land use planning in degraded water catchment areas to promote afforestation; improve watershed management
5. Extend, improve and maintain water supply infrastructure
6. Provide technological and financial support to harness hydropower potential, including transmission and distribution
7. Improve efficiency in irrigation
8. Assessment of GLOF threat in hydropower projects
9. Performance of religious rituals (indigenous methods for bringing about timely rain, adequate water for irrigation, ward off pests and diseases and usher good harvests)
10. Safeguard generation of hydropower with improved upstream watershed management in critical and high risk areas
11. Installation of early warning systems; hazard mapping of key watershed areas; installation of hardware; real time monitoring (unmanned) with automatic data transmission
12. Artificial lowering of lake levels (esp. Thorthormay Tsho)
13. Reforestation of catchment areas and slope stabilization of landslide and flashflood prone areas
14. Build capacity in risk assessment from GLOF
15. Build technical capacity and expertise for integrated assessment of climate change adaptations; including technical capacity to monitor climate, plan and implement adaptation activities, improve forecasts and inform policy makers
16. Integrating climate change concepts into the planning cycles, sector policies and project level activities (Royal Government of Bhutan 2006, p. 15-16).

In addition to the above, proposed activities include those that go beyond direct agriculture and water interventions. Activities such as the creation of off-farm or "cash earning job opportunities (weaving, constructions, road labor, etc.) for farmers who are affected by crop loss due to climate change effects (early / late rains, pest damage, frosts, hail storms or droughts)" and building the capacity to respond to future disasters are noted as important parts of climate adaptation.

Synthesis

To a large extent the NAPA process focuses, as intended, on identifying activities that governments and organizations can implement in a planned manner and that match with existing development priorities. Where water and the direct impacts of climate are concerned, virtually all of the attention is project focused. This is, in some ways, a strength in that it leads toward practical interventions that can be implemented over the short term and will bring immediate as well as potentially longer-term benefits. At the same time, there is a notable lack of larger strategic analysis – linking climate, water and larger policy interventions — in the NAPA documents. The documents generally focus on interventions that, while may assist people, often do little to structurally change existing or future patterns of vulnerability. Furthermore they don't really address the social drivers of adaptation or, more narrowly, the key factors creating vulnerability within the water sector.

The Mauritania NAPA illustrates this dichotomy well. It notes the rapid growth of urban populations and urban activities in the national GDP. The rapid transition from a rural livestock/ agricultural to an increasingly urbanized population in Mauritania has probably been driven, as similar patterns have been across the globe, by increasing opportunities in urban areas as well as by livelihood constraints in rural areas. This type of transition is, as a result, evidence of the way populations are "voting with their feet" as they adapt to conditions where they reside. People are, in effect, switching strategies as they attempt to move out of low productivity livelihoods and into higher productivity ones. Water related activities related to this transition are absent in the Mauritania proposal. Although the need for good water supplies in urban and peri-urban areas is mentioned, it isn't noted as a key factor that would enable rural populations to shift out of climate vulnerable livelihoods. Instead the proposed activities focus largely on interventions that could help maintain agricultural and livestock based livelihoods – that is slow the erosion of livelihood systems that are already under threat and where anticipated climate changes are likely to speed their decline. While the most vulnerable people and the largest concentration of poverty are concentrated in rural areas that rely on agricultural and livestock based livelihoods, and the proposed interventions are clearly targeted at this community, the interventions are unlikely to result in any structural changes in the factors causing poverty and vulnerability. As a result, it is far from clear whether or not the interventions would really help populations "adapt" to climate change. Successful adaptation implies an ability to move away from the conditions that create poverty and vulnerability rather than merely coping.

Similar dichotomies are also present in the Bangladesh and Malawi NAPAs. Migration and remittances are a major mechanism the poor in both Malawi and Bangladesh use to buffer and, in many cases, substitute for agricultural livelihood activities (Department for International Development and Refugee and Migratory Movements Research Unit: University of Dhaka 2003; Chipeta and Kachaka 2004). Rural-urban linkages are also a major mechanism in both locations that provide access to diversified livelihood options and buffer out vulnerabilities in traditional resource based livelihoods. The role of livelihood strategy shifting and diversification in adaptation isn't, however, central in either of the NAPAs. Instead, the focus is largely on interventions that protect or maintain existing livelihood systems.

Where water is concerned, the Bangladesh NAPA does contain a number of elements that could contribute to structural shifts in vulnerability. The NAPA contains major elements focused on research to improve understanding of climate impacts, eco-specific adaptation strategies and some structural measures (such as insurance) that would contribute to risk management in the water sector. In addition, it contains elements to re-design infrastructure, improve early warning systems and manage disasters. Depending on how these are ultimately undertaken, they could contribute to structural changes in understanding of risk management in the water sector under conditions of increased uncertainty.

Overall, the NAPAs that have been prepared so far are relatively strong on the identification of specific water management and related activities that could mitigate some of the impacts associated with climate change. They don't, however, locate the activities in a larger framework that indicates why specific activities are of particular strategic importance in responding to the increased uncertainty, variability and change anticipated in the future. That is to say, they don't make much reference to core elements – such as mobility, diversification, education, information flow, asset convertibility, etc.– that build adaptive capacity and enable strategy shifting at a societal level. On a more narrow level in the water sector, they don't specifically address what we see as probably the most basic challenge associated with climate change: the reduction in assumed predictive capacity regarding hydrologic system dynamics. They frame adaptation in terms of improved management, protection and buffering capabilities in the water sector (both of which are needed) but largely don't take this an essential step further to say how could institutions, infrastructure and the structure of water science and data gathering be designed in ways that are both flexible and robust when it is impossible to predict future conditions? The call in the Mauritania NAPA for greater emphasis on Integrated Water Resource Management (IWRM) illustrates the distinction being made here.

The Mauritania NAPA calls for IWRM activities based on:

- Regular assessment of availability of water resources and requirements. In fact, good management of water resources requires a good knowledge of the resources, both as regards their development in quantity and quality as well as from the perspective of demand. It is therefore important to establish a functional evaluation network (quantity and quality) properly distributed throughout the country
- Establishment of a system of monitoring and mitigation of impacts related to the dynamics of sustainable socio-economic development which respecting the conservation of the environment.
- Establishment of a communications strategy to promote rapid dissemination and circulation of information among partners in an effort to organize periodic submission of results and to draft priority action plans.
- Establishment of a schedule for division of water and management regulations to prevent conflict of use. Knowledge of the resource must be taken into account at various levels so as to enable short, medium and long term projections and to share the resources equitably.
- Establishment of instruments of legal and economic regulation to promote improve use of water resources. Prior reinforcement of capacities to ensure the perfect implementation of Integrated Water Resource Management through the creation of viable institutions responsible for monitoring and evaluation of the status of water resources and the provision of reliable information to the various partners.".

Such activities, while themselves useful, are part of most conventional water management systems. They don't address anything that is unique to the climate change context or the particular challenges that will be posed for water management. They don't speak, for example, to the ways in which assessment approaches will need to change in response to the risks and uncertainties associated with climate change. They also don't really address the climate implications inherent in alternative strategies of water management – such as attempts to regulate flooding using hard infrastructure versus more "soft" adaptive approaches. Furthermore, the proposed IWRM process is one that focuses on gradual buildup of capacity and projection of future needs/demands on the resource base. The process doesn't address the fact that many changes in water use are likely to be catalyzed by "pulses" of change – droughts and other extreme events. There also is not much that responds to uncertainty and risk as core features of the environment water strategies. As a result, there isn't much in the call for IWRM that responds to climate change issues per se as opposed to courses of action that might contribute in a generic way to better water management.

The Mauritania case illustrates a generic issue in the NAPA processes and their links to global strategies for water management. As a result, it serves as a good lead into the next section — which focuses on global strategies, particularly those related to IWRM. As the NAPAs do, IWRM based strategies rely primarily on organized (governmental) mechanisms for promoting adaptation. This is a distinct contrast to the socially driven adaptive processes that rely on less planned dynamics and responses to risk such as migration and livelihood diversification. Structurally, the paper focuses first on planned responses and then moves on to these wider socially driven strategies.

2.3.B Planned Responses through IWRM, Climate Proofing and other actions in the Water Sector

Brief introduction

At a global level, recognition is increasing regarding the need to pay more attention in water sector planning to current and future climate related risks. Political awareness and support for the need to prepare for and protect societies better against water related risks is clearly reflected in recent documents such as the Hyogo Framework for Action (ISDR 2005) and those prepared for the IV World Water Forum (World Meteorological Organization, Co-operative Programme on Water and Climate et al. 2006).

The Hyogo Framework specifically notes climatic variability and climate change as key factors increasing the vulnerability of populations to natural disaster (p.3). It called for increased technical and scientific capacity to understand the vulnerabilities created by climate-related hazards. Among the key activities called for under the Hyogo Framework is to: "Promote the integration of risk reduction associated with existing climate variability and future climate change into strategies for the reduction of disaster risk and adaptation to climate change, which would include the clear identification of climate related disaster risks, the design of specific risk reduction measures and an improved and routine use of climate risk information by planners, engineers and other decision-makers" (p. 13). This was also specifically mentioned as a responsibility for states. The Hyogo Framework does not, however, emphasize the critical role of risk reduction in the water sector as essential for responding to the impacts of climatic variability and change.

The link between responding to climatic variability/change and risk was much more explicit in the structure of the IV World Water Forum. An entire day at the forum containing 36 technical sessions was devoted to Risk Management, virtually all of which were linked to topics of floods, droughts, extreme events and climate change. This said, very little attention was given to questions of risk in the other series of technical sessions that respectively address Integrated Water Resource Management, Water for Growth and Development, Water Supply and Sanitation, and Water Management for Food and the Environment. Of the 149 technical sessions held on days other than the one devoted to risk management, only three had key words in their title that indicate any topical link with climatic variability or extreme events. This dichotomy illustrates the gap between growing recognition of increasing risks and direct response to such risks within the water sector. Risks have, of course, always been a focus within the water sector – but this is generally at the operational level in, for example, the design of structures to withstand projected flow levels. Risk management has, in general, received far less attention at the strategic level.

As a result, despite growing political demands for more effective strategies for managing the risks associated with climatic variability and change, as evidenced by the discussion above regarding the IV Water Forum structure, this often does not translate into "core" water management and planning activities.

What might approaches for managing risk in the water sector look like? We argue that effective strategies would start with a basic philosophical shift in balance toward "living with" rather than "attempting to control" water systems. This shift, although it would never be a complete change in strategy, would have a wide variety of practical implications for the types of activities undertaken in the water sector. These are explored briefly below as preparation for examining their relationship to both the foundations of global water management strategies – that is the Integrated Water Management Paradigm – and global strategies for responding to disaster and risk.

Living with water, living with variability, change and risk

Throughout history, human strategies for responding to highly variable water and climatic systems have involved a mix of techniques designed to "control" water resource systems and, where that is not possible, to "live with" variability. Most large-scale interventions in the water sector are of the former type. They involve the construction of storage, diversion, supply and protective works designed to ensure that water is available at desired quality levels, in the amounts and at the time it is needed for economic activities (farming, industry, power generation, etc.). They also involve attempts to insulate human activities from inundation or the impact of extreme storms by keeping water confined and out of prime areas where people dwell or economic activities are occurring.

Strategies for "living with water" and "living with climate" are equally prevalent in society but have received somewhat less formal attention from engineers in the water sector. At a societal level, such strategies include those for risk pooling and risk avoidance (whether through insurance or, on a more basic level, diversification of livelihoods). Other institutions are also central to "living with" variability. Widespread debates over water markets and the role they can play in flexibility reallocating supplies to the highest value uses as conditions change are a prime example. Other examples include the development of physical infrastructure that is "adapted to" variable climate and water resource conditions. In some cases, strategies have been designed that actively use variability and the uncontrolled dynamics of water resource systems as the foundation for productive economic, environmental and other activities. This is, for example, the case in the Gangetic basin where regular flooding histori-

[7] SEE: HTTP://WATER.NATIONALACADEMIES.ORG/ADAPT.SHTML

cally provided the nutrients essential to maintain agricultural systems, in Kashmir (India) and Lake Xochimilko (Mexico) where lakes served as the foundation for floating agricultural systems and in modern day river management where pulsed flood flows are used to maintain environmental conditions. It is also central in current debates over approaches to reconstruction in New Orleans and the US gulf coast following hurricane Katrina (Seed, Abdelmalak et al. 2006). Recent reports, for example, highlight the importance of rebuilding wetlands and working with sediment discharge to create a buffer against storm surges.

Within the water sector, strategies for "living with" variability take a variety of forms. While a full discussion of this is beyond the scope of this paper, a few illustrations are provided below as a basis for the fundamental distinction we believe it is important to make between "control based" and more "adapted" management strategies in the water sector.

What are some of the core strategies within the water sector for living with variability? They include:

1. *Design criteria:* The range of flow, sediment load and other conditions water systems are designed to operate within, represent one of the fundamental starting points for "living with" variability in water sector infrastructure. In most structural design the focus is on projection of specific flow volumes (high and low) at given return periods and the capability of infrastructure (spillways, conveyance channels, etc.) to operate under anticipated extremes. More adapted designs are ones that function under a much wider array of conditions than other designs.

2. *Adapted management approaches:* The question of design goes beyond individual structures to overall philosophies at basin levels. Attempts to regulate rivers through a combination of storage (dams) and control (dikes/levies) infrastructure are philosophically different from approaches that focus on maintaining flood plains, limited physical infrastructure to deflect flows and protect specific critical assets. This later approach emphasizes the development of infrastructure and management systems that are "adapted to" rather than attempt to control water systems. Specific examples:
   a. Reservation of flood plains for open space or lower value (often agricultural) uses that don't obstruct high flows;
   b. *Flood resistant structure design.* Examples include houses on stilts, flood resistant lower floors (a common strategy along the Rhine), the construction of hydro-metropolis (Venice), reliance on narrow protected areas rather than regional flood control (raised villages rather than embankments in parts of India);
   c. *Drought adapted livelihood and infrastructure systems:* In agriculture this ranges from crop choice and the design of drought resistant varieties to the combination of traditional and modern (drip irrigation) irrigation techniques that are designed to use available water as efficiently as possible (Evenari, Shanan et al. 1971).
   d. *Storm and extreme event resilient dwelling, infrastructure and institutional design.* This includes building codes and the institutions for enforcing them, the development of early warning systems (from weather reports to requirements for reliable communication systems). It also includes institutions and systems for disaster management planning and risk reduction.
   e. *Adaptive Management Processes:* This includes explicit attempts by major government organizations in the U.S. and other countries to use adaptive management strategies (iterative planning, etc.) as a core paradigm for managing water dependent systems.[7]

3. *Application of precautionary principles:* Rather attempting to design the 'most efficient' mechanism for meeting water requirements the precautionary approach focuses on resilience and reliability. It may lead to the selection of specific water supply techniques (such as reliance on groundwater as opposed to surface storage) that are known to be able to function under more extreme conditions.

In many ways, the difference between strategies for "living with" variability as opposed to more control oriented management strategies, grows out of changes in the starting point and how needs are framed. Rather than starting with the questions such as: "how do we meet projected demands?" as most conventional water planning does, adapted management approaches reframe the challenge as one of coping with uncertainty and, where possible, taking advantage of natural variability. Variability and change are taken as given, rather than controllable, and techniques are adapted to that variability.

Although the literature surrounding strategies for "living with" rather than attempting to control water systems in response to variability and change are numerous, most water management practice remains control focused. Direct evidence for this is present at many levels in water management debates and activities including:

1. Continued reliance on the concept of "stationarity" and historical periods of record as a basis for most hydrological analyses. Water infrastructure and management systems are conventionally planned, designed and operated on the basis of historical data on precipitation probabilities along with demand forecasts (which are also often derived from historical patterns of use). This is problematic when changes in climate undermine the utility of using historical records as indicators of future conditions. Continued reliance on presumed probabilities encourages misconceptions regarding the likelihood of events exceeding operating or design criteria. This, in turn, encourages high-risk behavior as people build and invest on the presumption that flows "will be controlled," areas "will be protected" and water "will be available" when needed. In essence the assumption that future conditions "can be" known encourages a psychology that those conditions "can be controlled."

2. Closely related to the above, is the fact that "extreme events" are generally excluded in planning for water security (World Meteorological Organization, Co-operative Programme on Water and Climate et al. 2006). Most strategies for planning water security – from flood maps to drought frequency estimates – are based on return periods calculated on the basis of historical periods of records. "Extreme events," even those that have occurred in the past, are often excluded from calculations despite the fact that climatic change may be changing the incidence or characteristics of such events.

3. The absence of any significant mention of or practical avenues for addressing climatic variability and change in relation to global water development targets developed to meet the Millennium Development Goals (MGDS). The MDGs do not take into account trend changes in extreme events or changes in the hydrological cycle. (ref. IWRM handbook).

4. The limited attention to risk management and absence of any significant focus on climatic change in global water management forums, such as the GWP toolbox on IWRM.

Taken together, the above points illustrate the large gap in the water sector between emerging risk management needs related to climate change and variability and most approaches in water sector related issues. This gap, as discussed further below, is particularly acute in relation to the currently dominant IWRM paradigm.

IWRM and its limitations

Over the past two decades, most debates within the water sector have been conducted in relation to broad concepts of Integrated Water Resource Management (IWRM). The Global Water Partnership defines IWRM as: "a process which promotes 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". Under this definition, the core goal is to maximize welfare and the mechanisms to achieve that depend on coordinated management and development activities. Discussions by the GWP in its technical documents emphasize stakeholder and broad public participation in IWRM processes and subsidiarity (moving decisions to the lowest possible level) as basic principles. To be meaningful, it is widely recognized that IWRM processes must relate to the highly localized contexts in which virtually all water management ultimately occurs.

While IWRM definitions (and the paradigm itself) have been the focus of increasing questions (Biswas, Varis et al. 2005), our core point here is that the above definition and, as a result, its application in policy and implementation contexts do not address change, uncertainty and risk well including those aspects related to climatic variability and change.

Take for example the toolbox developed by the Global Water Partnership on IWRM. Based on a brief review of the main GWP website, the GWP-IWRM toolbox does have one theme (out of 15) on floods and droughts and, related to that, a section on "Risk assessment and Management" (tool C 2.5). This mentions the need for risk assessments in relation to "non-average

[8] HTTP://GWPFORUM.NETMASTERS05.NETMASTERS.NL/EN/LISTOFTHEMESFRAME_EN.HTML?1F9DFAE1-3452-11D7-8F33-0002A508D0B7

climatic events"[8] but makes no mention of changes in basic climatic parameters. There is no specific theme or set of tools to address climatic variability and change. There are also no specific case studies or other supporting tools that address extreme events, climatic variability or climate change.

The absence of much focus on risk management is compounded by the practical difficulties IWRM practitioners have encountered with stakeholder involvement and the subsidiarity principle. While professional documents often highlight the central role of these principles to the IWRM process, in practical terms governments and other actors in the water sector interpret IWRM in a highly centralizing manner. Integration tends to be "achieved" by bringing together key actors in high-level forums (such as central planning cells or committees) where departmental heads can agree on how activities are to be coordinated. No planning meeting is manageable if it involves large numbers of individuals. Furthermore, involvement is expensive. It requires time, travel costs and often preparation. Such costs are difficult to fund within program budgets. As a result, the natural tendency for bureaucracies to concentrate power in the hands of a few people is compounded by the practical difficulties of achieving broad-based "stakeholder" involvement in high-level coordination and planning settings. Local stakeholders are effectively "squeezed out" of the process by its very nature even if the intent to have high levels of stakeholder participation is strong. Furthermore, when IWRM is viewed, as it often is, as a set of governmental planning, coordination and implementation activities the practical difficulties are compounded by the lack of institutional incentives for supporting participation. On the part of bureaucracies, participation complicates planning processes and reduces the power departments and individual actors have within them. On the part of private sector and non-governmental actors, the intangible nature of such planning processes along with their frequent lack of real power within them makes it unclear what incentives such stakeholders might have for becoming involved.

It is important to contrast the way IWRM is often interpreted with the type of activity required for risk reduction. Risk depends on the integration of many factors but this integration is inherently localized. The nature of risk depends on the specific characteristics of areas, activities and systems at a local level. As a result, risk reduction cannot be achieved primarily through high level planning processes. This is why insurance industries and other actors with direct exposure to risk rely so heavily on tools such as flood zone maps and building codes to set rates – and then allow market-driven behavioral processes (i.e. the decisions of numerous individual actors) to accomplish the "integration." Participation occurs at a behavioral level and also, (because decisions on flood zones, insurance rates, building codes, etc. have a huge impact on what people can do with their own land and property) within political processes. In the U.S., review meetings for decisions on flood zone maps tend to draw extensive input from business and communities often draw substantial participation and comment because they directly affect the cost of insurance, the nature of activities or structures that can be built and the overall value of a piece of land. This is very different from the vision of integration and stakeholder participation within most IWRM processes. Lacking an emphasis on such tools, IWRM processes experience numerous practical gaps in achieving the levels of integration and participation such processes are supposed to catalyze.

In addition to the above practical gaps, the conceptual foundations of IWRM do not incorporate change processes and uncertainty particularly well. Two assumptions underlie the definition of IWRM presented by the GWP:

1. Stationarity; that hydrologic parameters, although stochastic in nature, fluctuate around long-term stationary means. This assumption is implicit in the goal of maximizing welfare – one can't optimize any system to provide maximum benefits when that system that is undergoing a continuous process of change.
2. That the coordinated management of complex systems is possible to achieve.

As discussed in the preceding section, climate and other change processes represent a fundamental challenge to the first assumption. The second assumption downplays the extremely complex nature of interactions within interlinked water and related resource systems. As a result, while IWRM represented a major advance over previous water management paradigms, it provides little guidance with respect to the strategies that are likely to be effective for the water sector in the context of climate and other change processes.

Shifting the focus of IWRM away from coordination and maximization and more toward risk could begin to address some of the practical issues highlighted earlier while also leading toward the identification of strategies that respond to climatic variability and change.

Risk has always been a central element in water resource development and management but, as discussed above, has received relatively little attention within IWRM. Given the rapidly growing importance of climate and other change processes, we believe the water sector needs to pay far more attention to risk and the resilience of management approaches under different conditions. Greater emphasis needs to be placed on uncertainty, flexibility and risk management rather than control over systems. In addition, the water sector needs to develop strategies that are responsive in the face of surprise. Given the huge array of factors influencing water resource conditions and management objectives within local areas and the complex dynamics generated by interacting systems, comprehensive coordination is unlikely to be possible. Surprise is inevitable. As a result, the ability to react and change course as conditions change and following the disruption caused by extreme events are equally essential. This doesn't undermine the importance of planning for activities such as IWRM, but in addition to coordination and improving welfare, it adds risk reduction and flexibility as essential objectives.

Increased emphasis on risk management could be used to address some of the limitations encountered in IWRM processes. First, where stakeholder involvement is concerned, it could be used to engage major private sector entities – the insurance and financial industries – whose core business activities focus on risk. These industries, in turn, interact on a daily basis with a much wider array of customers (direct "stakeholders") who are seeking loans or insurance. If water-planning processes focused heavily on risk, a strong incentive for involvement of these stakeholders could be created. How? Take for example, the intense public and private sector scrutiny of flood zone maps in the U.S. and Europe. This "stakeholder" involvement is present because flood maps determine insurance availability (and rates) and because lenders won't provide credit in some high-risk zones. The industries are 'involved' because they make or lose money based on the accuracy of risk projections. The public is "involved" because the maps have a major influence on what they can do with their land or within their own livelihood activities. Second, focusing on risk and creating incentives for stakeholder involvement of the type outlined above could counterbalance the tendencies for centralization and static planning within IWRM processes. Risk is all about "local conditions" – the specifics of flood maps, drought frequencies, etc., in specific areas. Risk is also about change, surprise and how these play out in specific areas over time. As a result, in a myriad of ways, focusing on risk could help to counterbalance the tendency to rely on high-level planning and coordination in the water sector by creating pressure for much more localized forms of engagement. This could result in greater reliance on adaptive management and planning processes and the development of chains of command that delegate authority to local areas. It could also help to focus the attention of all stakeholders (private sector, governmental and public) on the tradeoffs associated with attempts to insulate water systems from climate as opposed to "living with" water and variability.

Overall, in order to respond to climate and other change processes the focus within the water sector needs to shift from integration toward adaptive risk management. Whether or not the above arguments on the potential advantages associated with greater attention to risk in the water sector (and more specifically IWRM processes) play out, we believe this needs to balance approaches for "living with water, variability and risk" with attempts to control or manage water resource systems.

Climate proofing

In many ways, control-based strategies and those for living with variability come together in current applied debates in the water sector over climate proofing.

The term "climate proofing" is misleading, according to Dr. Michael Glantz (personal communication) because it implies an ability to insulate human activities from climatic impacts. In a recent exchange on the LCA email list, Dr. Ilan Kelman suggests "a reconsideration of the phrases "climate proofed" and "climate proofing." He goes on to state that he "might be misinterpreting, but… the connotation is that development would be completely protected from, or immune to, any climate (or

[9] LCA-DISCUSS. COMMENT BY ILAN KELMAN ON 2/14/06.

weather) influences. The reality is that it is challenging to completely proof against an environmental phenomenon." He concludes by stating that: "Toying with vocabulary is not just academic discourse. Simple, effective, meaningful phrases are needed tools for communicating and convincing." [9] If we promote the concept of climate proofing, in common language we run the danger of telling decision makers and the public that they don't have to think about risk. How we define the term internally in publications such as this one may have very little impact on the meaning it conveys in public discourse. We need to evolve terms that convey specific activities without the misleading connotations inherent in climate proofing.

Terminology aside, many of the applied activities that have occurred in the water sector around the concept of "climate proofing" involve a combination of techniques for both "living with" and "attempting to control" variability. Many specific examples of this are incorporated in the case studies that form the second part of this book. Typical examples include:

1. Flood-zone management as part of integrated strategies for controlling as well as 'living with' the natural dynamics of river systems: As previously mentioned, strategies are now emerging in many parts of the world to protect flood-zones and use them for environmental values, open space and economic activities, such as agriculture, that do not involve placing large physical assets at risk. These activities are often undertaken in conjunction with structural interventions (dams, embankments, etc..) designed to control water flow within basins;
2. The use of traditional water harvesting strategies for "drought proofing" in arid areas. Water harvesting strategies are present in many societies for coping with variability and water scarcity. This includes, for example, the water harvesting techniques found in locations such as India. See, for example, Dying Wisdom (Agrawal and Narin 1997) and The Negev: Challenge of a Desert (Evenari, Shanan et al. 1971). As previously noted, such strategies form the basis for major governmental programs to "drought proof" agriculture in arid portions of India.
3. Proposals for climate proofing in the Netherlands that would combine new structures for water control, moving people and economic activities out of vulnerable locations and development of urban systems above flooded lands (Kabat, Vierssen et al. 2005).
4. Strategies that combine supply and demand side measures such as those used to form the Active Management Districts for groundwater control in Arizona, that combine major structural interventions to increase supply (the Central Arizona Project) with restrictions on water use and mechanisms that will continuously increase water use efficiency. See for example Jacobs and Holway 2004.

Overall, although examples such as the above are common, approaches to "climate proofing" tend to be divided between large structural measures and more distributed approaches. Approaches that explicitly attempt to balance "control" measures with measures that improve the ability of people to "live with" variability are rare. There is a need for more action of this type at national and basin scales. Developing strategies for increasing the resilience of large investments and national/ basin sector plans to climate change and variability – that is 'climate proofing' in a wider sense of the terminology – represents a major challenge.

2.3.C Expanded Response Sets

As the above discussion illustrates, coping with the risks associated with climatic variability and change goes beyond the responsibility of water design engineers. Applied debates in the water sector, particularly those for "living with water" or "climate proofing" regions involve courses of action to influence factors as diverse as land-use in flood plains, the structure of urban areas, and demand for water. These activities within the water sector don't, however, reflect the fact that demand for water and vulnerability to water related disasters depend as much on factors outside the water sector as they do on the way water is managed. Water adaptation and climate responses can't, as a result, be considered in isolation from the broader socioeconomic context.

While numerous elements related to climate adaptation and risk are present at all levels within society, we believe three aspects have particular relevance for water managers.

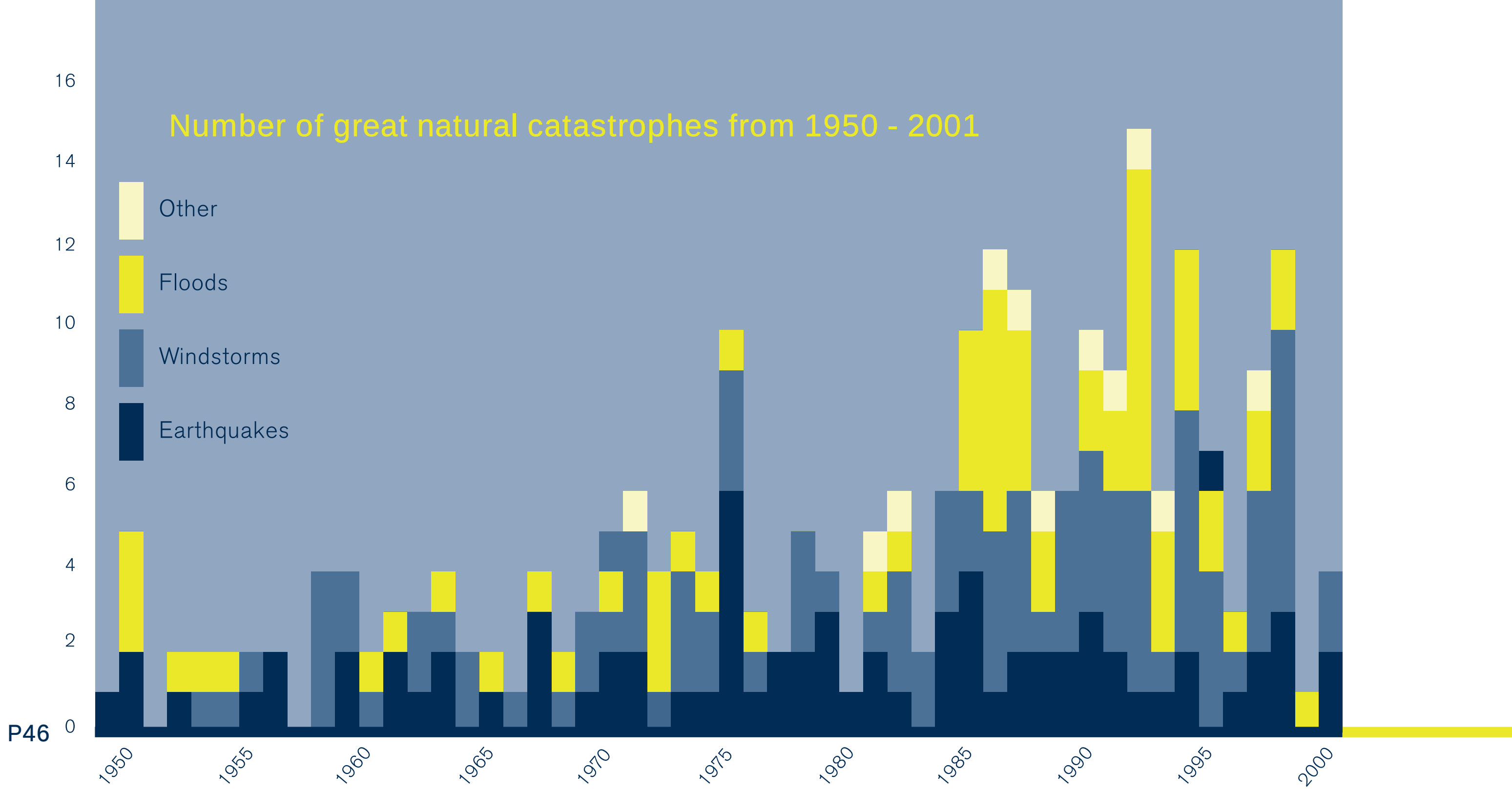


Figure 7 (adapted from Hoyois and Guha-Sapir 2004, p.44)
http://www.em-dat.net/documents/working_paper/30yearsoffloods3.pdf (cited with permission)

The first relates to the manner in which change occurs. It is difficult to pro-actively alter established land-use patterns, substantially reduce the demand for water or influence other aspects of behavior unless significant social demand exists for change. Social demand for change is likely to be particularly urgent in times of crisis or when crises appear imminent. As a result, the disaster context may represent a key window of opportunity for restructuring water systems and responding to change in a way that reduces risk. The importance of disasters as a window of opportunity for change is evident in situations such as those along the southern coast of the U.S. following hurricane Katrina. Debates over reconstruction in New Orleans focus heavily on future risks. Furthermore, the impact of the hurricanes last year has catalyzed widespread attention to risk reduction even in areas that were not directly affected. Pulsed change and the links with disaster risk reduction represent, as a result, a key area where strategies for responding to climate risk need to explore courses of action beyond the water sector.

A second key aspect has to do with livelihood diversification and trade. As Tony Allan and others have documented, imports of grain to the Middle East have far more impact on water requirements than more direct management activities (Allan 1997; Allan 1999). It requires approximately a thousand tons of water to produce a ton of grain. Grain imports are, as a result, equivalent to massive flows of "virtual water." At present 97% of Israel's GDP and 93% of Jordan's GDP are generated from activities that use only five percent of their respective water resources (Allan 1999). A century ago the percentages were probably reversed. Most of this transition has occurred not as a result of specific water demand management initiatives or other water-focused interventions but as a gradual, evolutionary process that has occurred in a context where limitations on water availability were clearly evident to most actors. The primary locations where this has not occurred is where national political considerations, such as the sensitivity of the Syrian elite to any external dependencies, have framed domestic food production as a national security issue. Similar dynamics also operate at a much more micro-level.

As some of ISET's prior research documents, households and communities in rural parts of South Asia respond to floods, droughts and water related events by diversifying livelihood systems into non-farm activities. They rely on earnings from these activities to "import" rather than produce food and other agricultural products. Overall, changes in trade and the reliance on local agriculture for food production and economic activity could, as a result, serve as a major mechanism for adjusting local water demands to conditions as they evolve in response to climate change.

The third and final aspect has to do with economic incentives and the financial mechanisms that exist or could be created to respond to climate and water related risks. Water managers tend to focus on techniques for controlling or mitigating the impacts of climate variability on water systems. They don't focus on the sources of water vulnerability or the non-water related mechanisms that could be used to reduce that vulnerability.

Overall, the above three components represent, we believe, areas where action outside the water sector is required to complement strategies for responding to the impacts of climate change that are present within the water sector. Expanded response sets that involve complementary courses of action to reduce vulnerability are, we believe, central to responding to the increases in water related risks that are likely to occur as a consequence of climatic change.

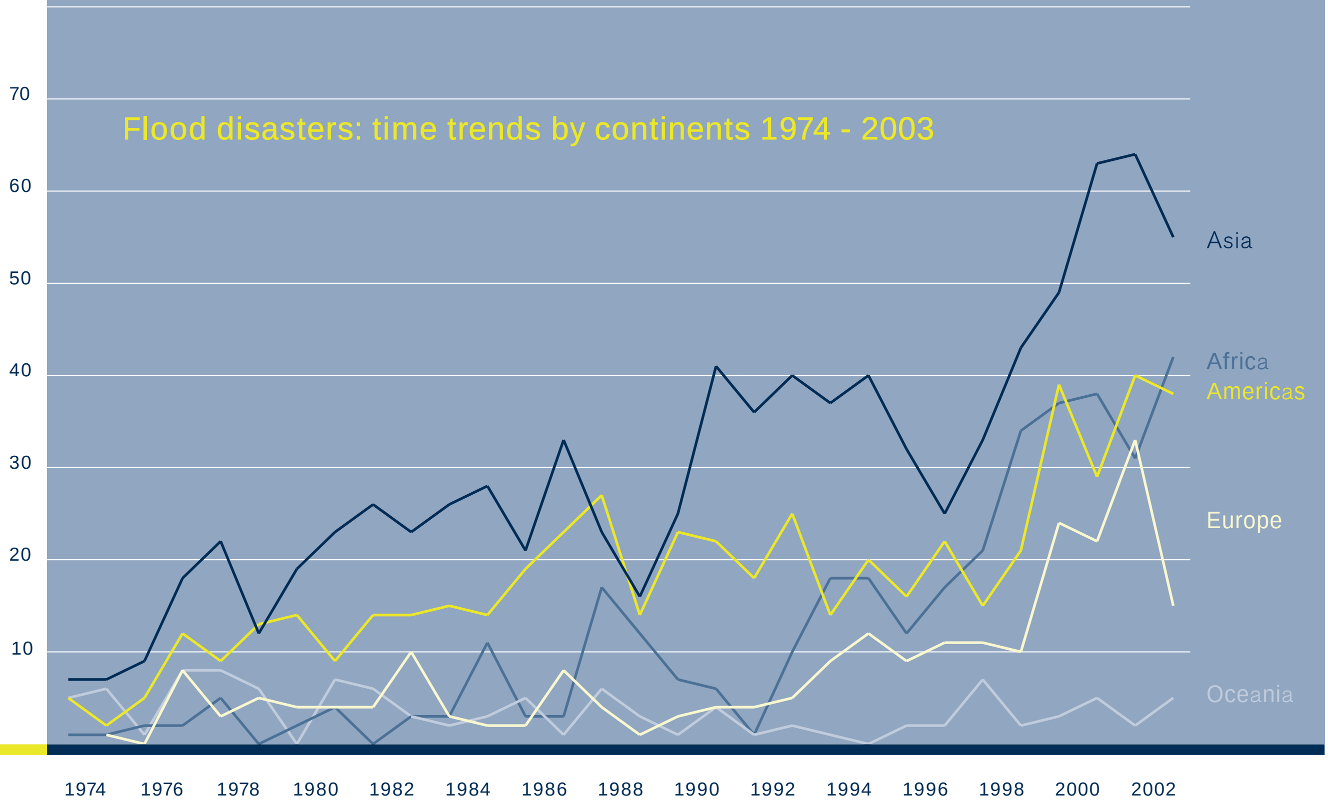


Figure 8 (adapted from Hoyois and Guha-Sapir 2004, p. 45)
http://www.em-dat.net/documents/working_paper/30yearsoffloods3.pdf (cited with permission)

The link with Disaster and Pulsed Change

There is increasing recognition at a global level that responses to climate change and disaster need to be linked. This is evident in creation of entities such as the United Nations Inter-Agency task force on Disaster and Climate Change and the Red Cross Climate Centre. A recent analysis of global disasters "supports the view that disaster risk management is a core issue of development" (Dilley, Chen et al. 2005). Data from EM-DAT cited earlier illustrate the fact that most disaster impacts are related to droughts, storms and floods – i.e. factors that are central concerns of water managers and likely to be influenced by climate change.

Water and Disaster

Between 1980 and 2000, over 80% of all disaster deaths were caused by water related events (droughts, storms, floods, extreme temperature and waves/surge) that could be directly affected by climate change. If one adds in landslides and wildfires – both of which could be affected, though less directly, by climate change and water management practices, the percentage of disaster deaths increases to nearly 85% (EM-DAT data cited in Dilley, Chen et al. 2005).

Major tropical storms both in the Atlantic and the Pacific region have increased since the 1970s in duration and intensity by about 50 percent, possibly due to global warming (Emanuel 2005). According to ISDR, "the number and impact of weather-related disasters have increased rapidly over the last few decades." (ISDR 2004, p. 46, diagram 2.7). Windstorms and floods have, as the diagram left (P.46) indicates, shown substantial increases between 1950 and 2002, P.44). The impact of drought has also been substantial. South Africa has, for example, faced "five recent major periods of drought, in 1980-1983, 1987-1988, 1991-1992, 1994-1995 and 1997-1998. Three of these events were regional in scale, with the 1991-1992 drought considered the worst in recent memory, placing more than 20 million people at risk" (ISDR 2004, p. 51).

Between 1974 and 2003, data collected in EM-DAT, the OFDA/CRED International Disaster Database, clearly show that flood disasters have been increasing in most regions in the world, see figure 8 (adapted from Hoyois and Guha-Sapir 2004)

This same database clearly indicates the disproportionate role water related disasters play in global disaster risk. In total, between 1974 and 2003, preliminary data from 6384 events show that windstorms, droughts, extreme temperatures, floods and wave-surges accounted for 75% of natural disasters, see figure 9 on page 48 (adapted from Hoyois and Guha-Sapir 2004). The nature of their impacts, however, varied greatly. While droughts only accounted for 9% of such disasters, they accounted for 44% of the total deaths. Similarly, while floods accounted for 34% of overall disasters, they only caused 10% of total deaths, see figure 10 on page 49 (adapted from Hoyois and Guha-Sapir 2004)

Overall, evidence is mounting regarding the large impact of climate related disasters and specifically increases in the number of incidents (hurricanes, typhoons) and increases in the human/economic and environmental costs associated with them. Political acceptance of risk may also be declining in many regions as populations come to expect effective government action to avoid disasters. All these are major factors contributing to political support for planned action to reduce risks to climatic variability and change in general and, more specifically, for action in the water sector.

Figure 9 (adapted from Hoyois and Guha-Sapir 2004, p. 2)
http://www.em-dat.net/documents/working_paper/30yearsoffloods3.pdf (cited with permission)

Distribution of natural disasters: World 1974-2003
World = 6,384

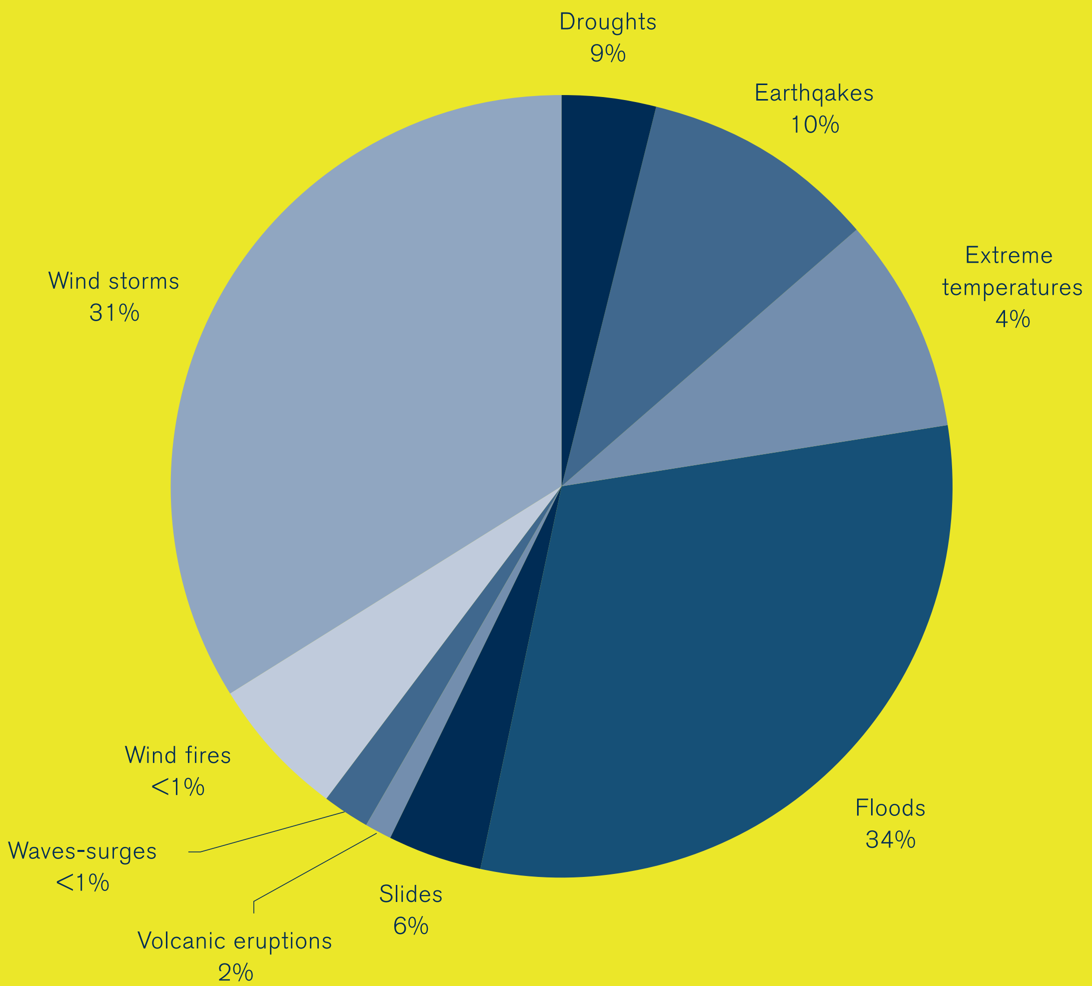
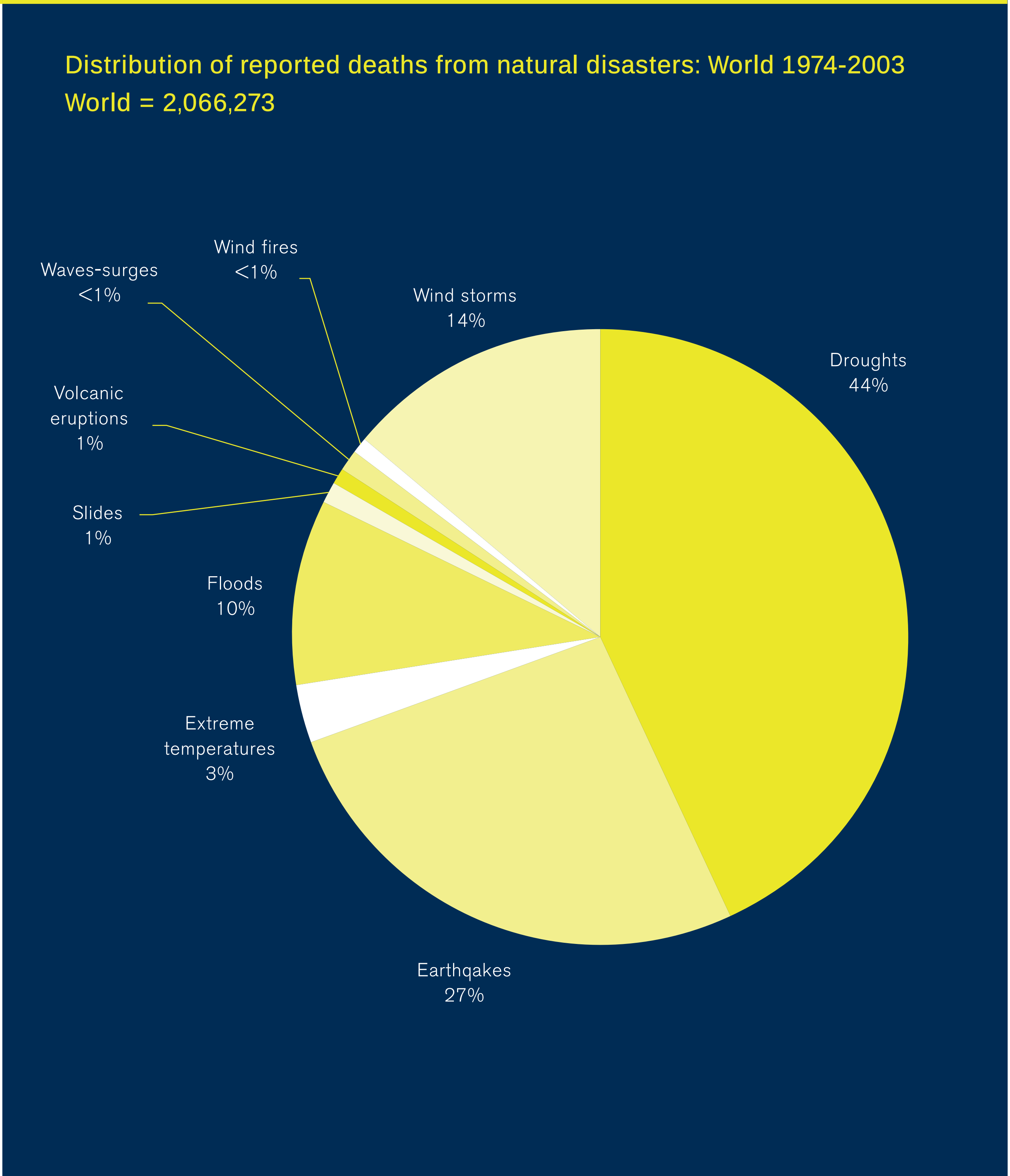


Figure 10 (adapted from Hoyois and Guha-Sapir 2004, p. 12)
http://www.em-dat.net/documents/working_paper/30yearsoffloods3.pdf (cited with permission)



[10] ADITI KAPOOR, OXFAM, PRESENTATION AT THE CONFERENCE ON ADAPTATION TO CLIMATIC VARIABILITY AND CHANGE, NEW DELHI, JANUARY 5-7, 2006.

The link between climate change response and disaster risk reduction goes, however, beyond immediate impacts. Most discussions of disaster and climate change focus on advance risk reduction. While the need for this is widely recognized and was discussed at recent COP meetings (COP 10 & 11) and at the WCDR, the post-disaster context has received far less attention.

The post disaster context

It is important to recognize that basic changes in infrastructure, institutions and livelihoods that affect long term patterns of vulnerability, are, paradoxically, often only possible to achieve when embedded patterns/structures have been disrupted. Specific examples of this include:

1. Passage of water use restrictions (and the establishment of permanent authority for this) during droughts in Colorado. As every water manager knows, droughts are among the best periods to bring out and obtain funding for long-term water management projects.

2. Extensive debates now occurring in New Orleans about the creation of large flood zones and potential abandonment of particularly vulnerable areas. The vulnerability of such areas and the infrastructure protecting them was well known in advance of the storm. It was, however, politically difficult to raise the funds required to protect them in advance of the disaster and only now are major changes being debated or, in some cases, simply "allowed to occur" as people vote with their feet;

3. Infrastructure system locations. Moving a sewer system, road or a rail line involves fundamental decisions regarding rights of way, property ownership, etc. In areas, such as those affected by recent hurricanes or the tsunami, such systems are being reconstructed and in some cases relocated to reduce their exposure to extreme events. Decisions to move such basic infrastructure are very difficult to justify under normal circumstances even when sources of vulnerability are immediately evident. Changes can, however, often be made when the existing infrastructure is damaged and needs to be replaced in any case;

4. Issuing of title for new housing to women as well as men in parts of Kerala and Tamil Nadu that were affected by the Asian tsunami. [10] The issuing of title to women represented a fundamental break with tradition that would not have occurred most situations. The change may, however, have very long-term impacts on the vulnerability of women to disaster because it influences their control over key assets and enables them as decision makers with resources and power of their own. This type of change could have major implications for the water sector if it focused on control over water related infrastructure assets.

5. Passage of building codes and the development of earthquake resilient construction methods following earthquakes in India and Pakistan (although code enforcement remains a problem). Although the earthquakes have nothing to do with the water sector, we often see design changes being advocated following floods or similar extreme events. As a result, the implications for the water sector of this "window of opportunity" for regulatory and design changes are important to recognize.

6. Shifts in livelihoods away from agriculture and into non-farm activities in drought and flood affected portions of India (Moench and Dixit 2004).

Changes in basic infrastructure and livelihood systems such as those above can alter patterns of exposure in ways that influence vulnerability across hundreds of years. Transportation systems and tenure influence patterns of settlement. Patterns of settlement, in turn, shape the manner in which people build, where they settle and what activities they undertake. In most cases, there is little logic in replacing vulnerable infrastructure until it is disrupted. In areas where hailstorms are common, for example, people often wait to replace roofs until they are damaged. Similarly, studies by the US EPA suggest that urban waste water systems in coastal regions will need to be replaced as sea level rises as a consequence of climate change. For many urban areas it may make little sense to make the huge investments required to do this proactively. Instead it makes strategic sense to get as much use out of the existing infrastructure as possible and only replace it when it is disrupted.

The above "logical" incentives to delay large investments are often compounded by political reality – the practical difficulties in building support for major changes to reduce risk. Even where there is a strong logic of investing to reduce risk prior to disaster, societies often won't. This is particularly true where options for risk reduction involve high political, economic or social costs. The Kathmandu urban area in Nepal, for example, sits on lakebed sediments in an area where massive earthquakes are inevitable. The population is poor and, even if it wished to, couldn't afford the cost of rebuilding housing and other infrastructure to fundamentally reduce earthquake hazards. At some point a massive disaster appears inevitable. Practical solutions that can be implemented within the political and economic context of Nepal to avoid this are, however, far from evident. This was, perhaps, also the case with Hurricane Katrina. The vulnerability of New Orleans was well known. Technical solutions were available. Reports claim that the disaster could have been avoided – and technically it could have been (Seed, Abdelmalak et al. 2006). The reports point to institutional and organizational failures as the root cause of the disaster and suggest solutions. These may well now be implemented and the possibility of future disasters may be reduced. This is different from saying that the disaster itself could have been avoided since it is a behavioral as well as a technical issue.

Humans and the institutions we create respond to stimulus. The highly sophisticated water management systems in the Netherlands owe their establishment to disastrous floods and levy failures that occurred in the 1950s. Katrina may catalyze similar changes in the U.S. Gulf coast. Behaviorally, disaster may be a prerequisite for stimulating responses within human institutional systems. Even if it isn't, disasters do provide a powerful incentive. Unpalatable though it may be, fundamental changes in systems to reduce risk may often only be possible following the disruption that accompanies disasters. The disruption, awareness and social consensus created by disaster may, in essence, be the critical ingredients enabling change.

Recent reports from Hurricane Katrina illustrate the behavioral issues in a particularly trenchant and scathing manner. Take the case of the U.S. Corps of Engineers, the organization responsible for most flood protection projects surrounding New Orleans. Authors of the most extensive analysis to date of the failures in the New Orleans flood protection system hypothesize that :

"it appears that while the President was trying to reduce Corps funding, Congress was trying to protect Corps funding. With the Lake Ponchartrain projects only about sixty percent complete as of 2005 (40 years after authorization) it may be that Congress, in its wisdom, decided to fund only what it thought needed to be completed….the Corps of Engineers is interdependent with the Office of the President of the United States and Congress. Congressional members bring pressure to bear on the Corps for new large projects. Faced with these pressures the Corps, then, defers maintenance. For over a decade Congress has funded the Corps at higher levels than recommended by the President. The Corps, then, has to devote time to currying favor with Congress. Currying favor with Congress is not supposed to be the main task of the Corps." (Seed, Abdelmalak et al. 2006 p. 13-8)

The institutional incentive problems noted above aren't confined to the Corps of Engineers. As another author quoted in the same reports states:

"Here is what we know. It is not just the tire, it's the car. And it's not just the car, it's the driver. Nothing in the system has made a numero uno priority either of protecting New Orleans from hurricanes or to restoring even hanging onto – the Louisiana coast. We have a flood control program, a navigation program, a permitting program, a coastal management program, a coastal restoration program – just for openers – and they do not talk to each other. They are riddled with conflicts, basically headless, basically goal-less, weakened by compromises are refuse outright to deal with first causes and first needs." (Houck 2006) quoted in (Seed, Abdelmalak et al. 2006, p. 13-7).

The above types of institutional problems are common in many regions. They reflect fundamental behavioral incentives that, in order to counter, require attention to the incentives created by different institutional frameworks and processes. To return briefly to the earlier discussion on IWRM, lack of attention to institutional incentives is, we believe, where attempts at integration generally fail. Pressures similar to those exerted on the Corps of Engineers are common in virtually all political systems. This is also true with the proliferation of "headless," "goal-less" and "conflict ridden" smaller organizations. Disasters, however briefly, can align interests at a political level and within institutions toward real change.

On a more positive note, it is important to recognize that disaster contexts often result in huge influxes of resources to affected areas. The total amount of funds committed to areas affected by the Asian tsunami, Hurricane Katrina and the earthquake in Kashmir far exceeded the amounts those areas could have raised for development in the normal course of events. As a result, in some ways disaster represents a critical window of opportunity for obtaining the resources necessary to reduce future vulnerability. From a cynical perspective (the one many local residents may take), this influx of funds has other advantages: Why pay to replace functioning infrastructure when others will pay for that to occur if it is disrupted by a disaster?

The importance of disaster risk reduction and working with the opportunities in post-disaster contexts as part of any strategy for responding to climatic variability and change is a generic observation. It is, however, particularly important in relation to water management and water related risks. Much of the infrastructure that is most vulnerable to disruption by climate change is water related. Levy and embankment systems, dams, water treatment facilities, irrigation systems – all of these are directly affected by both extreme events and gradual changes in the hydrologic characteristics of river systems. It isn't, however, just physical infrastructure that is influenced by changing conditions. The institutional infrastructure for management can also be directly affected. In Colorado, for example, recent droughts have highlighted major flaws in both water rights systems and interstate water compacts. As a result, major legal battles are occurring that may reshape the institutional foundations on which management occurs. Contradictions generally "come to a head" when systems are under stress. The link between institutional change in water management and extreme conditions is, therefore, an inherent "natural" feature of human behavior.

All of the above said, many challenges must be addressed in order to take advantage of the "silver lining" — the opportunity to make basic changes and reduce longer-term vulnerability – in post disaster contexts. Disasters are inherently chaotic. Relief needs are urgent. Longer-term considerations must often be placed aside to meet urgent survival needs. As the urgent needs for immediate relief transition to reconstruction and rehabilitation, however, abundant opportunities often exist for restructuring systems in ways that reduce vulnerability. Advance planning and dialogue in areas that are known to be vulnerable – such as coastal regions – could reduce the complications inherent in working in post-disaster contexts. Even if, due to cost, institutional or political reasons, vulnerability can't be reduced in advance of disaster, knowing what changes would be important to make is a huge advantage.

What does all this mean for the water sector?

Overall, we believe that the development of strategic approaches for disaster risk reduction and post-disaster recovery could be a major avenue for catalyzing changes in the water sector that respond to the risks associated with climate change. More attention needs to be given in the water sector to questions such as:

1. What can pro-actively be done in specific situations to reduce climate related risk in advance of disasters?

2. What would we do differently (in terms of infrastructure, institutions, etc.) to reduce climate risks if we had the opportunity to rebuild existing infrastructure?

3. How can we ensure that "plans for change" are available and that support exists for their implementation when windows of opportunity for change, such as those that existing during post-disaster recovery periods, open?

The second and third of the above questions suggest that advance planning will be essential in order to implement basic changes – even when those changes are likely to occur in a post-disaster recovery context. This is a common strategy in the private sector – any major consulting and construction company knows that it is essential to have key projects "on the back burner" ready to be sold when the opportunity is available. It isn't, however, a common strategy in the public sector. What might implementing it imply in practice? In practice, it would require the water sector to review vulnerable areas, institutions and infrastructure and then work with counterparts in disaster management agencies, local governments and civil society to identify critical interventions that can be made pro-actively to reduce disaster risk and also to plan for those changes that are desirable when existing systems are disrupted.

Livelihood Based Responses: Economic Diversification and Water Management

Research in South Asia, Africa and other parts of the world highlights the fact that vulnerability to the impacts of climatic variability and change as well as other risks depends heavily on a wide variety of factors in regional social and economic systems. Major differences in vulnerability and strategies for responding to disaster are present in relation to gender, economic status and other social differences (Enarson and Morrow 1998; ISDR 2004; Wisner, Blaikie et al. 2004). In general, however, core strategies for responding to climate variability and change within households involve diversification of livelihood and asset systems (Moench and Dixit 2004). Secondary strategies that support diversification include mobility (through migration or market transport of goods), education, communications and developing financial institutions that enable access to the resources required to support new activities. These strategies have major implications for water dependent livelihoods and, as a result, need to be recognized by water sector professionals.

Climatic change and variability have particularly direct impacts on the stability of agricultural livelihoods. People respond by developing non-farm sources of income to replace or balance the risks associated with farming. Establishing a business, locating a family member in a job or migration are all part of the core diversification strategy. People also respond by diversifying the mix of crops and livestock within farming systems. Finally, they diversify by obtaining key inputs to livelihood systems through markets that allow them to obtain water, food, fodder and other inputs from sources that aren't affected by the local impacts of climate variability. This was, for example, the case in Gujarat and Rajasthan during the droughts of 1999-2002. In that case, fodder imported from distant areas was used by local farmers to increase milk production when crops failed. In addition, they diversified into wage labor and local non-farm economic activities (such as diamond polishing) to replace at least part of the income lost from agriculture (Moench and Dixit 2004).

Similarly, in the case of floods, shifting attention in the water sector from the goal of protecting large areas to identifying mechanisms that reduce the impact of flooding could result in the identification of major new avenues for risk reduction. This might result in more attention to traditional techniques for living with floods – such as recessional agriculture. It might also direct attention toward concepts such as the Hydrometropol proposed by Paval Kabat and others for responding to the threat of sea level rise in the Netherlands (Kabat, Vierssen et al. 2005). While such water-specific techniques

for responding to floods are likely to be important in many regions, wider processes of economic diversification are, as in the case of drought, likely to be as well. Research in South Asia indicates that, as in the drought case, households respond to the impacts of recurrent flooding by diversification within livelihood strategies. This diversification reduces risks from asset losses, provides the returns necessary to invest in risk reduction and serves as a reserve source of income and capital to rebuild following disasters.

In many cases, diversification strategies are occurring in response to wider economic or social changes and not just in response to the localized impacts of climatic variability and change. Take the case of India. According to a presentation by Sudhir Katiyar from Aajeevika Bureau, Udaipur, Rajasthan, at the recent conference on Adaptation to Climatic Variability and Change (New Delhi, January 5-7, Institute for Social and Environmental Transit 2006) estimates indicate that there are over 80 million seasonal migrants in India. In a study of 68 villages in 10 blocks of Rajasthan, 72 % households reported that members were involved in migration. In this area migration now "generates 41% of household income as compared to 18% from agriculture." The balance of household income is from livestock and non-farm activities. Migration in these areas is "a regular strategy, not just a response to shocks, like drought."

The growth of migration and diversification into non-farm activities reflects wider diversification of the Indian economy. Similar processes are occurring in other areas as well. This is, as the reference already made to the work by Tony Allen on "virtual" water, also true at national and regional levels.

Processes of socioeconomic diversification are relevant for strategies for responding to the impacts of climatic variability and change including those directly related to water. Diversification influences the risks regions as a whole and different gender, socio-economic and other groups within them face in relation to climatic variability and change. In relation to water, the socioeconomic basis of livelihoods within regions is a major factor influencing how much water will be required and for what purposes. It is also a significant factor determining the incentives people have for investing time, money and other resources in water management or risk reduction. Where people aspire to non-farm occupations in the "modern" sector, they often have little incentive to spend time on water management. This has been a major factor undermining the willingness of communities to invest time and energy in local water initiatives (British Geological Survey, Institute for Social and Environmental Transition et al. 2004).

What might the above imply for strategies to respond to climatic variability and change in the water sector?

Most planning considers water demand as a fixed factor that is largely determined by economic growth and demographic projections. Efficiency improvements tend to be the primary (and often limited) strategies proposed for demand side management. As a result, risks are conceptualized as the relationship between supply reliability and projected demand. Similar approaches are also common in relation to other water related risks. Risks are framed as the probability of flooding in settled areas or the probably of storms damaging projected infrastructure and economic activity in an area. The analytical equation is rarely reversed.

To effectively address risks, courses of action that address the sources of vulnerability and respond to social trends are required. The analytical equation commonly used for water planning needs, in effect, to be reversed. Rather than only asking: *"how much water needs to be supplied to meet the projected requirements in agriculture, industry and domestic sectors;" it may be possible to identify new strategies by framing the question as: "what patterns of development and socioeconomic activity will be sustainable and will reduce the water related risks associated with climatic change and variability?"*

Reframing basic approaches in the above manner would lead to the identification of major new avenues for risk reduction that could, in many cases, build off existing trends within society. It would also necessitate tactical shifts in management strategies that give far more importance to the incentives that drive livelihood and other choices within households and communities. In locations such as India where economic diversification is already a growing trend in rural areas, for example, interventions to support the growth of non-farm livelihoods

could greatly reduce demand for water in the agricultural sector. Since agriculture is by far the largest user of water, this could free substantial supplies to meet the much smaller requirements for domestic uses. It could also fundamentally reduce vulnerability to droughts. Economic diversification often occurs in response to a combination of opportunities and perceived risks. Creating the conditions that enable and encourage diversification into forms of activity that reduce reliance on secure water supplies or reduce vulnerability to extreme events could become important "tools" for management in the water sector. How could this be achieved? Water sector professionals have generally relied on infrastructure and water management institutions (laws, regulations and organizations) as their primary tools for achieving management goals. Encouraging diversification and vulnerability reduction, however, requires a fundamentally different tools such as the financial mechanisms discussed below that are designed to shape the behavior of large groups of individuals.

Insurance and other Financial Mechanisms

The role, discussed above, that diversification plays within livelihood systems relates both to risk pooling and strategy shifting. Diversification provides alternative income streams when, due to climatic or other factors one source of income is temporarily disrupted. It also creates the assets and networks required to fundamentally shift strategies when existing livelihood systems become unsustainable. These two roles are also important in relation to insurance and other financial mechanisms.

In most parts of the world, water management activities and insurance work in tandem – linked through operational mechanisms such as flood hazard and other risk maps – but rarely applied as integrated strategies for managing water risks. In the flood case, insurers generally take the presence or absence of water control structures as "givens" and develop risk profiles based on probabilities that combine event recurrence (flood, drought, storm frequency-intensity) with protective structure design criteria. Similarly, water managers generally design structures to meet whatever set of event criteria (ability to withstand the 100 yr flood, etc.) decision makers have selected with little direct reference to the implications that may have for insurance availability and rates. Once structures are in place, computer models with outputs such hazard maps are created that, at least in principle, "capture" the vulnerability of specific locations to floods or other extreme events. These are used by insurance companies, to estimate risks and, through this, for the companies to make decisions regarding whether or not to offer insurance and, if so, at what rate.

Where risks are high or the ability of people in hazard prone areas to pay is thought to be low, governments will often serve as an insurer using public funds. This latter element is, of course, a slippery slope because it opens the door for political or other considerations (i.e. factors that are unrelated to the actual risks or the social value of economic activities in hazard prone areas) to influence insurance availability and rates.

While insurance and similar risk pooling or spreading mechanisms are common in the industrialized world, they have generally been unavailable to meet the needs of the poor in developing countries. Insurance mechanisms for risk pooling and spreading work particularly well when transaction costs are low (i.e. asset values, losses, etc. are easily quantified and monitored and the assets themselves are large enough that administrative costs represent a small part of premiums) and where risks are not covariant (Linnerooth-Bayer, Lofstedt et al. 2001). Insurance works well when relatively small losses are randomly distributed across large populations. This allows for risks to be pooled without exposing insurers to the potential need for sudden large payouts. When risks are covariant – as in the case of major regional catastrophes – then insurers must maintain large capital reserves and the risks themselves must be spread across very large populations. All this tends to work against the ability of the poor in developing countries to use insurance as a mechanism for reducing their losses in the case of climate or water related events. Crop insurance, for example, although widely available and used in locations such as the US to address drought risks, is relatively rare for small farmers in the developing world.

Insurance and other risk pooling mechanisms are, however, now emerging as mechanisms to address the impacts of climate, water and other risks in developing as well as developed countries. India, for example, began considering the development of crop insurance programs soon after independence

11 HTTP://AICOFINDIA.NIC.IN/8.HTML
12 HTTP://INDIABUDGET.NIC.IN/ES2002-03/CHAPT2003/CHAP811.PDF
13 JENNIFER IFFT, "THE GOVERNMENT VERSUS THE WEATHER" SUMMER INTERNSHIP PAPER, 2001. HTTP://WWW.CCSINDIA.ORG/POLICY/LIVE/STUDIES/WP0010.PDF
14 ONE LAKH = 100.000
15 HTTP://INDIABUDGET.NIC.IN/ES2002-03/CHAPT2003/CHAP811.PDF

in 1947 and began small-scale experiments with it in 1972-1973.[11] Major programs for crop insurance have been in place since the so-called "Comprehensive Crop Insurance Scheme" was established in1985.[12] This program has now been replaced by the "National Agricultural Insurance Scheme." Both schemes have had mixed success both in terms of coverage and financial viability. According to a Ministry of Agriculture Publication, Background Note on Crop Insurance, cited in a study by the Center for Civil Society,[13] (CCIS):

"The scheme had a positive and stabilizing influence on agricultural production and productivity in respect of crops insured and is a popular program particularly in those areas of certain States where the risk factor in agriculture is relatively higher. This "positive" and "stabilizing" influence came at a large cost. The claims percentage (percentage of claims to premiums) was 572%. The loss between premiums paid and insurance claims amounted to 184,446 lakhs[14] exclusive of administrative costs (five to seven percent typically). Only four of the 22 participating states had insurance charges greater than claims."

Losses have continued under the new NAIS. Documents prepared for India's 2002-2003 budget indicate that paid claims exceeded premiums by a factor of almost three over the period from the 1999-2000 winter (Rabi) and 2001-2002 winter (Rabi) crops.[15]

The above problems illustrate the major challenges inherent in delivering effective insurance for small farmers in developing countries. To be affordable, premiums must be kept low. As a result, payouts are often far higher than the amounts collected – even when the schemes don't address the needs of large portions of the population.

In response to problems, such as the above, new models for insurance and risk pooling are being developed. A recent article in Science reviews (Linnerooth-Bayer, Mechler et al. 2005) some of the recent initiatives. In Ethiopia, for example, proposals exist for offering farmers the ability to purchase weather derivatives that would provide some insurance against crop losses during droughts. Programs involving catastrophe bonds are also being tested in Turkey and Mexico to provide insurance for major infrastructure in the case of earthquakes. Because of the covariant nature of disaster losses, these initiatives may only be sustainable with international backing. This presents an opportunity for donor institutions to supplement post-disaster with pre-disaster assistance.

There are also emerging initiatives in India and Bangladesh for combining microfinance and credit with insurance against earthquakes, floods and droughts. Post-Gujarat experience shows that extending micro-credit may be a valuable alternative to direct aid; in other words, donor institutions could make contractual arrangements with micro-finance institutions to assure additional funding after a disaster. Ultimately, programs such as the above could play a role in addressing the impacts of climate change. As the article cited above comments:

"As developed countries recognize that their greenhouse gas emissions can lead to increased intensity and frequency of weather extremes in the developing world (21), climate negotiators are seeking options for helping affected countries adapt. Specifically, the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol call upon developed countries to consider actions, including insurance, to meet the specific needs and concerns of developing countries with respect to adverse climate impacts. Providing assistance to public-private risk-transfer programs such as those in Turkey, Mexico, and Ethiopia, is an innovative option to consider." (Linnerooth-Bayer, Mechler et al. 2005, p. 1046).

Aside from serving as a mechanism for pooling risk and providing the finances necessary to reconstruct livelihoods following water or climate related disasters, insurance mechanisms could be developed into proactive tools for water management that encourage strategy shifting. In some areas this is already occurring. Companies in the U.S. and Europe, for example, already often require clients to implement risk reduction measures (increasing storm resilience, construction of flood resistant lower floors and, in a few cases, rebuilding in less vulnerable areas) in order to qualify for insurance. Conceptually this could be moved several steps further to support fundamental changes in the strategies that create vulnerability. If water managers engage actively with the insurance industry, insurance rates and access to coverage could be used as proactive tools to discourage investment in vulnerable regions or to encourage shifts from vulnerable activities to activities that are less affected by climatic change. More broadly, insurance and other risk pooling measures could serve as one set of tools in integrated approaches to climate and water related risk management that bring together physical interventions with those that change risk "creating" behavior.

2.3.D Differential Dimensions of Vulnerability

None of the above strategies for water and risk management, whether they involve conventional "structural" approaches, living with water or risk pooling through insurance, specifically address the needs of the poor or vulnerable communities. This issue is of fundamental importance if the world is to achieve basic poverty reduction and development goals as articulated in the MDGs.

Globally, the poor and other marginalized are often, though not always, the most vulnerable to climate and water related disasters. In regions, such as India, where most of the population resides in rural areas and is involved in agriculture as the primary livelihood activity, secure water sources are of fundamental importance to poverty alleviation. This is well documented in India where the growth of groundwater irrigation played a critical role in moving large populations out of poverty (Moench 2003). Assured irrigation water was the lead input that allowed farmers to invest in fertilizer, improved crop varieties, labor and other agricultural inputs with far less risk of loss. This both increased yields and stabilized production, allowing farmers not only to increase income but also to accumulate assets between seasons. The key advantage of groundwater over surface sources is reliability – farmers can access groundwater as needed and in the amounts required. Furthermore, groundwater availability is, at least over the short-term, generally unaffected by fluctuations in climate and weather. This is fundamentally different from irrigation systems that depend on surface sources. The value of "reliability" doesn't just apply in developing country situations. Economic evaluations of in the Central Valley of California and the Negev Desert ascribe much of the economic value of groundwater to stabilization and the insurance it provides against fluctuations in water availability (Tsur 1990; Tsur 1993). Groundwater access in essence provides insurance that other water-dependent investments will not be lost and thus reduces vulnerability. When high levels of groundwater extraction lead to long-term declines in water levels, however, vulnerability can be dramatically increased. This occurred in Gujarat and Rajasthan (India) during the 1999-2002 drought. That drought affected regions where intensive agricultural systems had been developed that required reliable water supplies, but groundwater levels had been declining for several decades. When the drought occurred, wells failed – not primarily as an immediate consequence of declines in rainfall – but due to the cumulative impact of long-term over exploitation. In this situation many of the larger farmers, those with the most invested in intensive agricultural activities, were the worst affected. Many of the poor, in contrast, already had extensive familiarity with regional labor markets and were, as a result, able to maintain livelihoods (Moench and Dixit 2004).

Similar situations exist in the wealthy U.S. context.
The impacts of Hurricane Katrina on the much less well off African American community in New Orleans were broadcast worldwide. According to a recent report by Dr. Logan at Brown University:

"In brief an analysis of FEMA storm damage data shows that the storm's impact was disproportionately borne by the region's African American community, by people who rented their homes, and by the poor and unemployed....In the region as a whole, the disparities in storm damage are shown in the following comparisons (arranged in order of the degree of disparity):

- *By race. Damaged areas were 45.8% black, compared to 26.4% in undamaged areas.*
- *By housing tenure. 45.7% of homes in damaged areas were occupied by renters, compared to 30.9% in undamaged communities.*
- *By poverty and employment status. 20.9% of households had incomes below the poverty line in damaged areas, compared to 15.3% in undamaged areas. 7.6% of persons in the labor force were unemployed in damaged areas (before the storm), compared to 6.0% in undamaged areas."*

It goes on to state that:
"if the post-Katrina city were limited to the population previously living in areas that were undamaged by the storm – that is, if nobody were able to return to damaged neighborhoods – New Orleans is at risk of losing more than 80% of its black population. This means that policy choices affecting who can return, to which neighborhoods, and with what forms of public and private assistance, will greatly affect the future character of the city."

Rebuilding will, in all probability, result in a city that is smaller, whiter and more affluent. Paradoxically, if global warming increases the vulnerability of coastal areas, these more affluent groups may ultimately face greater risks than the currently poor groups that have been forced to migrate to other distant areas.

The above examples illustrate the complex nature of differential vulnerability. As a group, the poor often lack assets, education and other resources that contribute to adaptive capacity. This is also true with respect to other marginalized groups. Women, for example, often have less control over assets (land, livestock, businesses, etc.), may not have access to education and may face restrictions on their mobility or ability to work outside the home. These factors constrain their ability to adapt when "socially sanctioned" livelihoods are disrupted. Similar constraints apply in the case of many other groups. This said, however, generalizations regarding vulnerability often do not "play out" along projected lines in the complex reality of local situations. Numerous examples of this can be cited from recent disasters. In Afghanistan, for example, relatively wealthy shopkeepers were one of the groups affected (in terms of income and food security) by the drought of 1999-2002 (Lautze, Stites et al. 2002). Shopkeepers, the traditional lenders, were unable to recoup their investments and, unlike farmers, were not included as beneficiaries in drought assistance programs. As a result, many of their families experienced high levels of malnutrition.

The core point here, however, is not just the complex nature of the factors influencing vulnerability but that these factors depend heavily on location and context specific factors within household and community livelihood systems. This contrasts fundamentally with the fact that most strategies for managing water and climate risk are designed and structured at a macro-level. As recent experience with IWRM indicates, whatever the rhetoric, fundamental practical, institutional, political and other issues frequently undermine attempts to encourage broad-based participation by relevant stakeholders. In practice, the voices of the poor and other marginalized groups are often excluded from water management decisions. This is, unfortunately, also often the case with insurance and other formal financial mechanisms for risk pooling and spreading. Some of the issues are clear. If a family faces the choice between buying food and paying insurance, food will be the priority. Other issues are a bit more subtle – those who lack formal education generally don't have the familiarity with the bureaucratic procedures necessary to access insurance or credit from formal systems. Furthermore, the covariant nature of risk exposure at local levels undermines the viability of unsubsidized micro-insurance schemes while the economics and overhead costs of serving the poor often undermine the ability of large insurance companies to deliver services to such communities (Linnerooth-Bayer, Mechler et al. 2005). Even strategies for "living with" water may contain inherent biases against the poor. Strategies that support, for example, the construction of "flood resilient" housing imply costs (such as raised construction) that may be unaffordable for many communities. They also suggest the reservation of high-risk areas as climate buffer zones. This would, for example, include reservation of low-lying lands as flood zones or regions vulnerable to drought as forest and environmental reserves. Since such lands also tend to be low value, they also tend to be where the poor congregate.

Overall, no magic bullet exists to "solve" problems of differential vulnerability. The inherent factors that create differential vulnerability can only be addressed by strategies that respond to the location and context specific factors underlying it. This requires a combination of location specific and higher-level responses. Where location specific responses are concerned, this requires understanding of the specific manner in which water or climate related hazards affect vulnerable populations in specific locations and the identification of specific interventions that address their needs. Where generic responses are concerned, economic development strategies that allow populations to build the wealth and social capital necessary to move out of vulnerable areas or occupations and afford "higher-level" risk management support (such as insurance) are essential.

2.4 THE INTERSECTION BETWEEN STRATEGIES

The approaches that are currently applied to manage water and the risks associated with climatic variability, whatever they are termed, involve a combination of strategies to control the dynamics of hydrological systems, live with or adapt to the dynamics of those systems and spread the risks where the combination of attempts to control and live with water system is insufficient to mitigate all impacts. Conventional management techniques within the water sector have focused on the first "control-based" set of strategies. Global attention to IWRM has expanded this somewhat to include water-focused courses of action (such as attempts to improve water use efficiency and manage riparian zones as flood corridors). Most applied management debates have, however, stopped short of exploring the much wider way diversification and changes in economic and production systems could alter water management needs by, for example, enabling virtual flows of water. They have also stopped short of explicit attempts to link with the insurance and risk management world. Finally, they tend to ignore the behavioral considerations facing institutions, governments and households that drive decision-making and the actual courses of action ultimately taken.

Responding to the increases in variability, extreme events and other, often difficult to predict, consequences of climate change on hydrologic systems will require new approaches that build on the above already existing strategies but apply them in a manner that is much more strategic and reflects basic behavioral incentives.

Physical infrastructure that enables human society to influence the dynamics of hydrologic systems and supply water where, when, in the amounts and at the quality levels required will be essential. We cannot delude ourselves, however, that attempts to control the dynamics of complex, highly dynamic and variable, hydrological systems can be completely successful. Robust "muscular" attempts to control the impacts of climate change that focus primarily on the building of more storage, higher sea walls, and larger conveyance channels will, however, ultimately create higher levels of vulnerability. By protecting society from the impacts of small variations in climate, they will encourage patterns of behavior that will ultimately result in far larger disasters. Relying on control strategies would, in effect, be creating the conditions for future impacts similar to those that just occurred in New Orleans when Hurricane Katrina made landfall. This is a fundamental lesson emerging from analysis of complex systems. As a result, far greater emphasis than has occurred historically must now be placed on strategies for living with water and managing the inherent increases in risk that will accompany increasing variability and extremes. Effective approaches for responding to climatic variability in the water sector will, in essence, require the strategic application of a combination of adaptive, control and risk mitigation techniques.

The best terms to effectively describe the above combination of strategies are difficult to identify. Risk management, a central point of emphasis here, suggests the challenge is "all about" reducing the impact of variability and change. It isn't. As the section above on differential vulnerability suggests, strategies that pro-actively seek to meet the water needs of the poor are essential. Some have proposed that a basic minimum daily level of water supply should qualify as a fundamental human right. This cannot be achieved solely through risk management. Integrated Water Resource Management terminology carries, as discussed above, an equally misleading set of implications. Other terms, such as Climate Proofing, are now gaining currency. In a recent article in Nature, Kabat et al. (2005) define climate proofing by stating:

"We think the international science and policy communities should develop plans for achieving future sustainability in these vital areas of our planet, using a 'climate proofing' approach. Climate proofing does not mean reducing climate-based risks to zero – an unrealistic goal for any country. The idea is to use hard infrastructure to reduce risks to a quantified level, accepted by the society or economy. This risk can be further combated by 'softer' measures, such as insurance schemes or, as a last resort, evacuation plans. Such climate proofing should be driven by opportunities for technological, institutional and societal innovations, rather than purely by fear of the negative effects of climate change."

This definition either implicitly and, in some ways, explicitly includes the mix of societal and other measures needed to manage risks – but the emphasis is clearly on a hard infrastructure led approach. It does not emphasize the strategic selection of approaches in response to the constraints, opportunities and needs inherent in specific situations. It also relies on a partial definition of risk that implicitly emphasizes the quantifiable "probability" that structures will fail while downplaying the mobility of consequences. If you build hard protective structures, people and economic activity will grow in the protected area. With the probability of failure constant but the consequences increasing rapidly, risk will continuously increase from the day such structures are completed. This behavioral dimension is essential to recognize and incorporate in climate risk management.

The tradeoff between approaches to flood and storm risk management is eloquently outlined by Oliver Houck (Houck 2006), quoted in (Seed, Abdelmalak et al. 2006) relation to debates over reconstruction along the Gulf Coast following Hurricane Katrina:

"What we have had in the city of New Orleans and along the entire gulf coast is planning by default (local attorney Bill Borah calls it 'planning by surprise'. Planning takes place. It's just that we haven't taken part in it. Where water resources are concerned, it starts with real estate developers, port authorities, levee board and other outside-the-ballot-box enterprises, their projects facilitated and funded by the Army Corps of Engineers. In their minds, the only question is a technical one: what kind of engineering do we need to get our project done? The system has produced the expected results: more rip-rap here, more drainage there, and levees to the horizon. The goal is – although it is never stated anywhere – to develop as much of the coast as possible. When you add the projects up, they determine the destiny of the city and South Louisiana.

What is apparent is that these levees, designed by engineers and approved by Congress, are the basic planning documents for the future of South Louisiana. What is north of these levees will be developed. What is south of them will be anyone's guess, although not for long; the map on global warming shows these coastal marshes gone within a century. De facto, we end up with a wall. Not all that adequate a wall, by the way. Only Category three, if that. Can you imaging the costs of maintaining even a Category three levee system winding back and forth to the Gulf from New Orleans to Texas? Can we imagine what will happen when development piles in behind it, and then gets flooded? Do we already know from Lakeview and New Orleans East, what happens to land elevations behind levees once they are drained and paved?

Our choice it to start this process from the other end. If we do, another range of options open. There are a dozen major towns across the southern tier with thousands of home and residents, and they deserve protection. But the way to provide it may be with the same kind of ring levee systems that protects (or should) New Orleans and its surrounding parishes, supplemented by flood gates at the mouths of the main canals. Or, it may mean peninsular levee systems down the historic ridges of the bayous, protecting what has always been the high ground….Problem is, we have lacked the process – we have lacked even the language — for such a discussion.
In addition to scientists and engineers, we may need some social workers. In saying this I am most serious." (Houck 2006) quoted in (Seed, Abdelmalak et al. 2006, p. 14-4 and 14-5).

Overall, while recognition is increasing that a broad array of strategies will need to be carefully applied in order to address the impacts of climatic variability and change, the balance between strategies and the terminology required to discuss them remain points of debate. The section below attempts to clarify this debate by exploring in more detail, the mix of strategies available for managing climate risks while meeting water needs and discussing the relative balance between strategies that may ultimately be required.

2.5 STRATEGIC APPROACHES TO MEETING WATER NEEDS THROUGH CLIMATE RISK MANAGEMENT

Strategic approaches to meeting water needs through climate risk management will require courses of action that address the specific water related consequences of climate change across a range of scales. They will also need to address the differing impacts of gradual as opposed to the sudden "pulsed" changes that accompany extreme events. Finally they will need to address the tradeoffs inherent in decisions regarding the relative balance between approaches used. Decisions are likely, for example, to be influenced by:

1. Tensions between "precautionary principles" (that is planning and investing in response to contingencies) and the economic, social, environmental and other costs associated with providing a given service or level of protection. This tension is also inherent in the balance between preparedness and response (disaster relief/reconstruction) when systems fail.

2. Differing social perspectives regarding what is "doable" and "desirable." This is likely to be evident in the already mentioned differences in perspective implicit in definitions of climate proofing (e.g. hard infrastructure led responses) as opposed to more distributed and "adapted" interventions that help people live with climate variability and water system dynamics.

3. Differing emphasis on formal "planned" mechanisms for risk pooling/spreading (i.e. insurance) versus informal mechanisms (such as economic and livelihood diversification) that serve a similar purpose but grow out of behavioral incentives that influence the decisions actors (businesses, individuals, households) take in response to risk within livelihood systems and markets.

Effective responses to climatic variability and change will ultimately depend both on strategies that incorporate planned (focused water management, disaster risk reduction and the "safety chain" of disaster preparation) courses of action while building the inherent flexibility and resilience of societies and the economic and infrastructure systems on which they depend. How decisions regarding the strategic balance approaches are made will ultimately play a large role in determining outcomes.

This institutional and social process issue will be addressed later in this paper. Before doing that, however, identification of the specific strategic tradeoffs within core decision-making arenas and how those influence the ability to meet water needs while addressing climate risk is essential. This is done below in relation to water management, disaster risk management, economic diversification and financial tools for risk management.

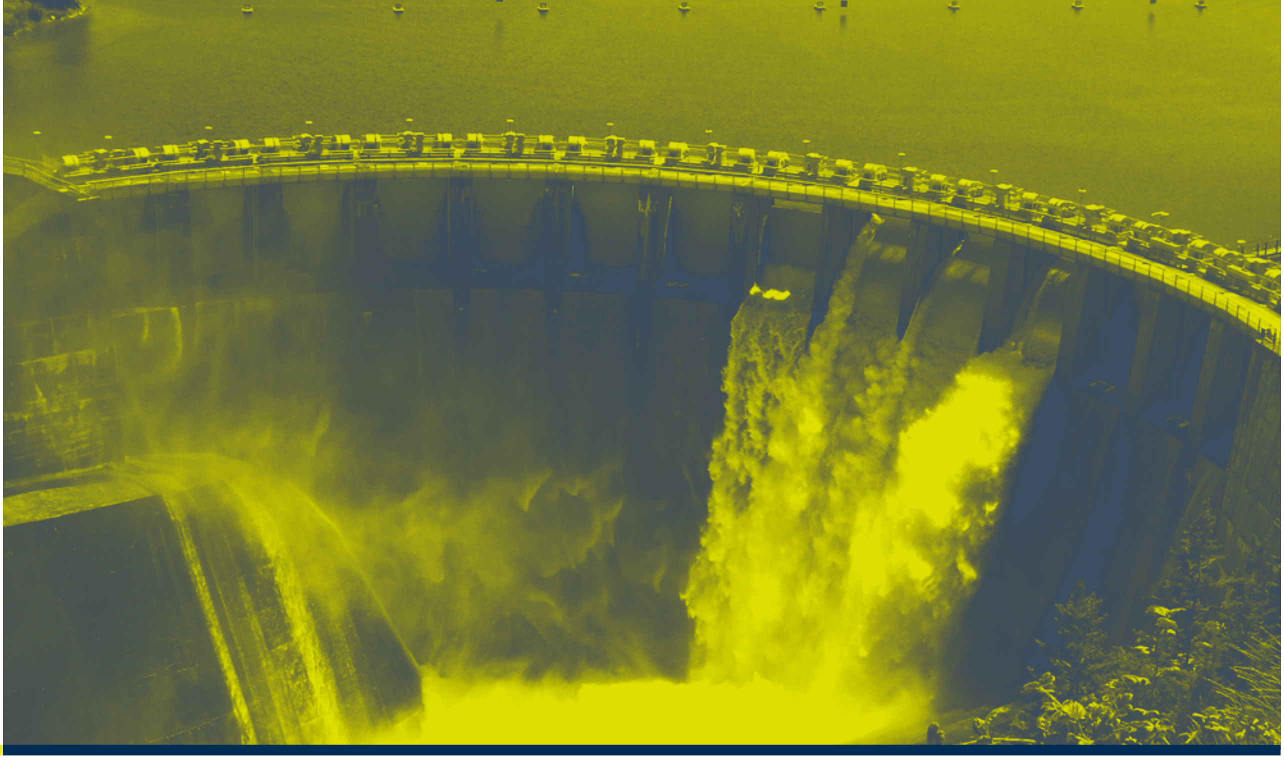
2.5.A Strategic Water and Risk Management

Developing an effective and balanced mix of strategies for responding to the impacts of climatic variability and change on the water sector will, as many of the issues raised earlier in this book document, be a highly complex process. Focusing first on the balance of techniques (large-scale hard infrastructure versus other more distributed "softer" techniques) is likely to lead to deadlock. As a result, we focus here first on the functions that approaches need to deliver – and only later on the balance of techniques for serving those functional purposes.

What are the services that will be particularly important in meeting water needs as climatic variability and the frequency of extreme events increase? To us, key services required will include: (1) storage – the ability to buffer fluctuations in water availability; (2) delivery – the ability to supply water to all users when needed, in the amounts needed and at the quality needed with the definition of "need" incorporating efficiency and use considerations; and (3) protection – the ability to avoid damage to livelihoods, infrastructure, the environment, etc., as hydrologic systems fluctuate.

Storage

Hydrologic systems are highly variable and this variability is anticipated to increase as climatic change proceeds. Throughout human history, techniques for storing water have been a cornerstone of strategies for coping with this variability. The need for and importance of storage is undisputed. The question is, however, how should storage be achieved? Here the answer becomes much more complicated. Options include storage in aquifers and surface storage across a spectrum of scales from local to regional systems.



Groundwater Storage

Globally, most freshwater outside the frozen icecaps of polar regions is stored underground as groundwater. In India, groundwater supplies over 50% of the irrigated area and is used to meet perhaps 90% of drinking water needs. As much as 80% of India's agricultural production may be groundwater dependent (World Bank and Ministry of Water Resources-Government of India 1998). This has occurred despite the low groundwater potential in the Indian subcontinent. Two thirds of India is underlain by hard rock with very low storage capacity – yet groundwater has played and continues to play a central role in India's water supply equation. Although India is an extreme case, similar patterns are common in many parts of the world. Where it is available, groundwater represents a uniquely reliable source of supply. Farmers and other users can, by simply turning on their pumps, access it at the precise time and in the precise volumes required to meet their needs. This ability does not depend on the functioning of large water supply bureaucracies and makes groundwater access much less subject to the political "clout" of users than is often the case in surface systems. As a result of this reliability, as noted earlier in this publication, the economic value of water from groundwater sources often greatly exceeds the value of water from surface sources.

The unique role of groundwater has not been reflected in most global debates concerning mechanisms for water storage. While discussions of conjunctive management of surface and groundwater are relatively common in the literature, far less has been done on the ground. As with opportunities for the construction of surface impoundments, options for groundwater storage vary greatly between regions. In theory, however, using aquifers as primary storage locations is both possible and has unique advantages over surface sources. These include: (a) substantial reductions in evaporative losses; (b) greatly reduced levels of dependence for users on large-scale delivery systems; and (c) very substantial reductions in pathogens and suspended materials (reducing health impacts and increasing the ability to use efficient technologies such as drip irrigation). This last advantage is, in some locations, offset by increases in exposure to elements such as arsenic, fluoride and boron that have negative health or other impacts.

Global expertise on aquifer storage and recovery techniques is growing and increased management of aquifers could be a key strategic option for meeting water storage needs in many areas.

Large-Scale Surface Storage

The role of large-scale surface storage systems in water management has a long and controversial history. This history has resulted in extensive polarization between the proponents and opponents of dam projects. More importantly, however, it has resulted in a degree of negotiated consensus, as reflected in the report of the World Commission on Dams, that large surface structures are, in some cases, essential – but that the broad costs and benefits associated with them require careful evaluation on a case by case basis (World Commission on Dams 2000). The role of large-scale infrastructure, such as dams, needs to be evaluated on a location specific basis with equal consideration given to other approaches for meeting basic water requirements. Large-scale "hard" infrastructure should, as a result, be viewed as one element in strategic approaches to water risk management rather than located in a "lead" position that dominates consideration of other approaches.

The above balance aside, as with groundwater, the technical viability of large-scale storage varies greatly between locations. Surface storage systems also often have key drawbacks including: (a) high levels of evaporative losses, (b) sedimentation problems, (c) highly differential equity impacts, and (d) major impacts on river ecology. They also often have unique advantages including the capacity to serve as reliable facilities for electricity generation.

Distributed Surface Storage

The viability of smaller-scale, distributed systems for surface water storage involves as many equally important trade-offs as large-scale ones. Sedimentation and evaporation concerns are no less severe (and in many cases are more severe) than in large storage systems. For very small systems (such as the tanks and millions of small water harvesting structures that have been built across India), maintenance is a perennial problem. They also, however, have unique advantages. Perhaps the most important of these is the role they can play as distributed points for groundwater recharge. They are also able to play a key role as sources for local water supply, particularly for large rural populations that are not possible to serve through major distribution systems.

Other forms of storage

It is important to recognize that, in addition to groundwater and the spectrum of small to large options for storing water in dams, other forms of water storage exist. In agricultural areas, land-use practices such as leveling and field bunding can contribute very substantially to water storage in the soil profile and also to groundwater recharge. This technique is central to agriculture in arid areas, such as the Negev (Evenari, Shanan et al. 1971). The impact of land management on water storage in the soil profile and through groundwater recharge may also heavily dominate, for example through the numerous small surface structures that have been constructed in locations such as India (Gale, MacDonald et al. 2006).

Other forms of storage are also present in relation to domestic water supply. Cisterns and tanks are a ubiquitous feature in villages and urban areas across much of the world. Household level storage systems such as these are essential infrastructure for the operation of water markets – the core institution that supplies water to many millions of people.

As a final note on storage, it is important to emphasize that the volumes "required" depend heavily on livelihood activities and water use efficiency. As a result, storage requirements can only be evaluated in conjunction with changes that influence the nature of water demand.

Delivery

The core objective of water delivery systems is to ensure that people and other users have access to the water required to meet basic needs. When water managers think of "delivery" systems, they tend to think of the large-scale canal and piped conveyance systems that accompany other large-scale infrastructure. While such infrastructure does play an important role in water delivery, it is important to recognize that other delivery systems often dominate.

In many village and urban areas, particularly in the third world, water delivery often isn't through piped systems. Instead, delivery occurs through the operation of tanker-based water markets and local supply points. In some cases, piped delivery systems have not been constructed. In other cases, supply levels and high losses undermine delivery capabilities. This last point is important to emphasize. Many urban and rural piped supply systems have very, very high loss levels. This is also the case with major canal systems for agricultural water supply. Maintenance is a perennial problem – and one that can't easily be solved. Furthermore, large sections of the population, particularly the poor and those living outside urban areas, are not served by centralized distribution systems. Local delivery systems, such as wells, tankers and storage in the root zone are as a result an essential part of the delivery equation.

Overall, the issues inherent in delivering water to meet basic needs will, as with storage options, need to be carefully evaluated on a location specific basis. Innovation will be required. Attempting to simply increase supply will not be sustainable if loss rates remain high. Solutions that reduce loss rates, such as the above ground piped systems found in some areas, may be an important part of the delivery equation. Local supply systems using tankers and local wells also have far lower loss rates than many piped systems. As a result, strategic approaches to water delivery will need to involve a wide array of techniques that include, but expand beyond, conventional piped and canal systems.

As with storage, it is important to emphasize that delivery requirements depend heavily on livelihood activities and water use efficiency. As a result, delivery systems can only be evaluated in conjunction with changes that influence the nature of water demand.

Protection

The final major service required out of water systems is protection against extreme impacts and the consequences of variability in hydrological systems. Protection can be achieved through two basic strategies: control and avoidance.

In most situations, control strategies utilize hard infrastructure to keep “water out” and regulate the flows generated by extreme events. This type of strategy can be highly successful in areas where the dynamics of hydrological systems remain bounded within predictable ranges. It involves higher levels of risk where the extremes likely to be encountered are greater or less predictable. The reasons for this are related to fundamental principles of physics. Take the case of flooding:

– First, as the water-spread in flood areas decreases, the height of hard infrastructure will need to increase exponentially simply to hold the same volume. When floods of a govern volume enter an area, cutting the water spread area by 50% doubles the required height of levies or embankments, reducing the spread area by 75% quadruples the required height. Confining structures need to be eight times as high when the water-spread is reduced by 87.5%

– Second, as water is confined, the force pushing against structures increases exponentially as well. Force = mass * acceleration. Increasing the water column at any point greatly increases the mass per unit length pressing against the confining structure. This greatly increases the chance of structural failures of the type that breached levies in New Orleans.

– Third, as water is confined, potential energy increases. Potential energy of any mass in relation to gravity is defined as PEgrav = mass * acceleration due to gravity * height. When water is confined between control structures, the mass concentrated at any given point increases as does the height of the water column. As a result, when structures fail and this energy is released, the resulting flows are far more destructive than for similar amounts of water that have not been confined behind control structures.

Protection is complete when events remain within design criteria. When hard infrastructure for water control fails, however, the results tend to be catastrophic. As a result, the viability of control based approaches needs to be evaluated very carefully in relation to the likelihood of events exceeding design criteria. Where uncertainties are great, avoidance strategies often carry lower levels of risk.

Avoidance strategies for protecting key assets emphasize techniques that reduce the need to confine and directly control large volumes of water. Techniques for this in the case of floods include courses of action such as:

1. Maintenance of flood zones as protected areas where uses are not damaged by flooding (essentially a strategy for increasing the water spread) and moving high value activities out of vulnerable areas;
2. Creation of small protected zones such as “islands” or raised structures. This type of technique is common for traditional housing in flood prone areas and, in a modern context, would include the hydro-metropol proposed by Kabat and others (2005). This strategy, in essence, focuses on avoiding the need to reduce water spreads.
3. Development of forms of economic activity (such as floating agriculture) that actively utilize flooding as part of their operation.

Such avoidance approaches are gaining practical currency in countries such as the Netherlands. According to the Netherlands Water Partnership (2005)

“The Netherlands is changing its approach to water. This change involves the idea that the Netherlands will have to make more frequent concessions. We will have to relinquish open space to water, and not take back existing open spaces, in order to curb the growing risk of disaster due to flooding, we will also need to limit water-related problems and be able to store water for expected periods of drought. By this we do not mean space in terms of the height of ever taller levees or depth through continued channel dredging, but space in the sense of flood plains. This approach will require more area, but in return we will increase our safety and limit water related problems. Safety is an aspect that must plan a different role in spatial planning. Only by relinquishing our space can we set things right; if this is not done in a timely manner, water will sooner or later reclaim the space on its own, perhaps [in a] dramatic manner.” (Netherlands Water Partnership 2006) also quoted in (Seed, Abdelmalak et al. 2006, p. 14-6).

Although the above example focuses on flooding, it is important to recognize that the same alternatives apply in the drought case. Protection from droughts can either be achieved by "supplying" water – or by developing forms of economic activity that do not depend on reliable water supplies. Providing more "space" for variability within livelihood systems for water and climate variability is the strategic alternative to control.

Key Messages

The above discussion on strategies for water storage, delivery and protection can be summarized as two key messages:

First, the techniques that can provide water storage, delivery and protection services will vary greatly between hydrologic and development contexts. Factors such as the availability of potential storage locations in groundwater aquifers, the nature of river basins, the nature of urban water systems, etc… may all play a significant role in determining the mix of techniques that may work well in any context. Second, demand for the above services will also vary greatly depending on an equally wide variety of factors. As a result, the balance between approaches must be driven by opportunities and constraints within local contexts.

In addition to the context dependent nature of demand for key water services, as argued before in the section on expanded response sets, opportunities for change are time dependent. They often occur following major water related disasters when political and social conditions support fundamental change. As a result, our focus in this paper now returns to strategic issues related to disaster, livelihood diversification and financial mechanisms for risk management.

2.5.B Disaster risk reduction and proactive planning for change strategies

As with the issues discussed above in relation to the delivery of key water services, approaches to disaster risk reduction will involve inherent strategic tradeoffs.

Recent assessments of disaster risk vulnerability highlight broad regions in the world that are vulnerable to climate and other hazards. Such assessments are, however, very general. They specify broad vulnerability to specific hazards but can tell very little about when events may or may not strike. The vulnerability of specific regions to cyclones and other climate related hazards, for example, is well known. Whether or not events of a given magnitude will actually occur within any given period is, however, often highly uncertain. Preparedness is essential to reduce disaster risks. Since, however, the probability of an event occurring in any given time period is uncertain, pressures will always exist to defer the costs of preparedness to fund other unrelated "immediate" priorities. This is, we believe, a fundamental social and political reality. Risk reduction is most likely to be given a high social priority immediately following disasters when other priorities are subsumed by the immediacy of a large event.

What does this reality imply?

It implies that those working on disaster risk reduction must focus on the opportunities for change following disaster as well as advanced risk reduction. It also implies that disaster risk reduction approaches must be structured in a strategic manner. Prior to disasters, attention needs to focus on high priority areas where available risk reduction investments can have the largest impact. Planning is also essential in order to identify — and create social awareness — regarding the types of changes that could substantially reduce future risk if implemented during the recovery phase following disaster.

The balance between the above approaches is, as already mentioned in this book, clearly evident in the Gulf Coast region where Hurricane Katrina recently caused so much devastation. Advance risk reduction is essential to ensure that protective structures are designed to reduce risk as far as possible. Since protective structures can, at best, only serve part of the coast, advance activities are also essential to prepare for early warning and evacuation should another event occur. Finally, as the current debates over recovery in New Orleans illustrate, advance planning could assist governments and communities to identify those areas where fundamental changes in land-use or infrastructure may be required following disasters. This is, for example, the case of the ninth ward in New Orleans where rebuilding in an area that is now well below sea level, may not make social or economic sense.

Advance risk reduction requires extensive efforts to assess risks and involve the broad array of government and other stakeholders in vulnerable regions in risk reduction activities with the goal of developing what is known as the 'safety chain' of preparedness. Preparedness before an extreme event strikes is rather uncommon in many countries, and in particular developing countries, where resources are meager. To address this support, such as the recent decision by DFID to allocate 10% of resources for disaster response to risk reduction, represent an important step forward. In addition, far greater attention needs to be devoted to practical mechanisms for incorporating risk reduction in post-disaster recovery activities. These activities can, as previously noted, bring far more resources into areas than is possible during more normal periods. They also represent periods of time when systems are disrupted and it may be possible to embed new risk reduction measures within development processes.

As a final point on this aspect, it is important to emphasize that, as with water management measures, the mix of risk reduction activities that can be undertaken will depend heavily on location specific conditions. The resources available, whether or not risks can physically be reduced through structural measures, the types of technologies (and social acceptability) of strategies for living with water – all these and a host of other factors will influence the balance that could be achieved between strategies. Approaches that enable specific activities to be targeted in response to the opportunities and constraints inherent in local contexts are, as a result, essential.

2.5.C Livelihood diversification and economic development strategies

The ability of society to withstand both the extreme climate events likely to cause disaster and the mix of basic water problems that are likely to emerge as a consequence of climate change depends as heavily on the nature and flexibility of economic and livelihood systems as it may on specific interventions within the water sector or for disaster risk reduction. Evaluating the role that economic and social flexibility can play in the development of strategic approaches to meeting water needs through climate risk management requires skills that are not generally found in the water management and disaster response communities. In addition, economic development and diversification are driven by actors (private companies, individuals, market institutions) that fall outside the operational areas of governmental line agencies similar to those involved in water or disaster response. As a result, while the role of economic transitions and diversification as a key strategic element in responding to climate change cannot be denied, evaluating such options and identification of points of leverage for change may represent one of the largest challenges in the development of strategic approaches.

The above said, the nature and flexibility of livelihood systems are among the largest factors influencing water management and disaster risk reduction requirements. This was, in fact, the perspective expressed by the India's Secretary for Environment and Forests at a recent conference on Adaptation to Climatic Change and Variability. According to his and the Indian government's point of view, economic development and increasing economic diversification are the fundamental strategies India is pursuing to adapt to climate change. National policies in developing countries such as India increasingly focus on poverty alleviation through employment generation outside subsistence agriculture and income diversification aided by education and other programs. Priorities and policies within the water sector, while they often lag behind national policies, are likely to gradually shift in ways that support national directions.

Virtual water flows – trade in grain, fodder, people and jobs – have a fundamental impact on water demand and the vulnerability of economic activity to climate related disruptions. As a result, however difficult, approaches must address the opportunities and constraints for responding to climatic variability and water management needs through indirect socio-economic and livelihood changes. Furthermore, as with other points for strategic action, specific opportunities and constraints will depend heavily on location specific characteristics.

2.5.D Financial Strategies Mechanisms for Risk Spreading and Pooling

Financial mechanisms are the final major element addressed here in any strategic approach to meeting water needs through climate risk management. As emphasized earlier in this book, the core questions herein developing approaches that strategically reduce risks are:

1. Whether or not financial mechanisms can be developed that encourage changes in 'risk making' behavior – i.e. provide incentives and mechanisms for reducing risk exposure rather than simply spreading existing risks; and

2. Whether or not financial mechanisms can be designed that meet the needs of the most vulnerable communities.

As with economic diversification, those involved in insurance and financial risk management have rarely interacted with the engineers and response specialists who comprise the communities most involved in water management and disaster response. Many of the best experts on this are located in private sector financial institutions. Major institutional and sectoral gaps will, as a result, have to be bridged in order to develop strategic responses.

2.6 INSTITUTIONAL MECHANISMS FOR ACHIEVING STRATEGIC BALANCE

The above sections highlight the behavioral dependency and location specific nature of many of the interventions required to reduce climate risks while also meeting water needs. They also highlight the major perceptual and sectoral gaps that need to be bridged.

Where behavior is concerned, processes, techniques and institutional frameworks are required that focus on the incentives from which risk-producing behavior emerges. Institutional mechanisms such as insurance that provide economic or other signals to households, businesses and other actors regarding the nature of risks and rely for their sustainability on self-sustaining business models are essential. Similarly, mechanisms that rely on basic processes of economic diversification and encourage strategy shifting are central at a societal level. Such mechanisms should contribute to the maintenance of adaptive capacity and encourage a continuous process of adjustment to take place as conditions change.

Where planning processes and the perceptions that drive them are concerned, the development of effective strategies will require bridging divisions between advocates of large-scale "hard" infrastructure and those advocating more distributed "softer" combinations of interventions. In addition, at least four distinct professional communities – water managers, disaster managers, economists and financial managers – from the public, private and NGO sectors have key insights to contribute.

The history of attempts to "integrate" perspectives across similar divides is not encouraging. IWRM strategies have been criticized on the basis of their often bureaucratic and highly centralizing tendencies. Although high levels of "stakeholder" involvement are part of the IWRM rhetoric, in practice this has been difficult to achieve. It should be recognized that this is not a criticism of IWRM alone. In the 1970s and 1980s, approaches to "integrated rural development" were criticized on a very similar basis. Furthermore, as anyone who has worked on communications theory knows, it is difficult to separate the "signal" from the "noise" in large-scale processes involving large amounts of randomly selected data. This is also the case in "broad-based" stakeholder driven processes. In many such processes, dialogue does not boil down to core strategies but remains divergent and provides no clear broadly acceptable course of action. Consensus is, at best, elusive.

Recent advances in social frameworks using approaches from complex systems and cultural theory may provide guidance. Studies on water management in the Netherlands and other regions using these frameworks highlight the mix of strategies that commonly emerge from different social groupings (market actors, government bureaucracies and social/religious activists) (Deursen and Middelkoop 2004). Such social groupings have inherently different driving rationalities that underpin the strategies they advocate. Mapping these strategies through focus groups can, in effect, be used to bound alternatives in a way that enables negotiation and reduces the number of stakeholders that need to be involved. Indeed, some recent work using these frameworks "have explicitly rejected the "more the merrier" approach to discursive democracy in favor of the "law of requisite variety," which specifies the minimum level of heterogeneity (Rayner 2003a, Rayner 2003b).

Institutionally, this suggests that planning approaches involving key representative stakeholders could, rather than consensus, catalyze convergence on action despite inherently different motives and perspectives. Mechanisms for attempting this may represent the first steps toward the development of strategic approaches to meeting water needs through climate risk management. What might such mechanisms consist of? In many ways they would require recognition of the highly political nature of planning processes. Planning for risk reduction, while it would entail technical inputs, is not primarily a technical process. Instead it is a political process that involves complex trade-offs between the perceptions and incentives driving different groups within society. Recognition of this suggests that mechanisms central to any political governance context are essential to develop for resolving issues related to water and climate. This suggests that it will be essential to develop systems within water and climate related clusters of organizations for:

1. Stakeholder representation (elections);
2. Balancing and separating powers – i.e. separation of planning (legislative) and implementation (executing) functions; and
3. Dispute resolution (judicial).

Establishing such mechanisms could enable identification of the diverse types of action in multiple sectors that are required to develop strategic responses to climatic variability and change.

03 PRIORITIES FOR ACTION IN CLIMATE-WATER RISK MANAGEMENT

3.1 CONCEPTUAL PRIORITIES FOR CLIMATE-WATER RISK MANAGEMENT

What are the immediate priorities for action to develop strategic approaches for climate-water risk management that emerge from the above analysis? From our perspective, priorities for action need to reflect the strong cross-cutting relationships between activities within the water sector per se and those that operate at much wider societal levels. Risk management in the water sector cannot be effective if it focuses solely on water infrastructure, water institutions and water related activities. It needs to address the wide array of factors that create vulnerability to water related risks and also the wide array of non-water related interventions that can complement or substitute for interventions within the water sector. Water risks and water infrastructure requirements are fundamentally different if a country decides to rely on "virtual" water flows, non-farm income sources and larger-scale agriculture than if it decides to rely on small-holder, rural-based, agriculturally dominated livelihood systems. The tradeoffs between such approaches are not primarily technical. Instead they reflect conceptual and strategic choices (the foundation for operational interventions) that will ultimately need to be made in political contexts where numerous stakeholders with inherently different perspectives and motives will demand that their voices be heard. Clarifying the conceptual, strategic and operational issues that need to be understood is, as a result, probably the most important step societies can make in order to inform the inherently political processes that will determine what courses of action emerge at a societal level. Core conceptual, strategic and operational priorities are identified in the next paragraph.

This working paper has discussed many of the conceptual factors underlying the importance of responding to the impacts of climate change on the water sector using a risk management approach. Risk management concepts and tools now need to be utilized for analyzing the impacts of climate change across a wide variety of very practical water management contexts. As emphasized at many points in this document the techniques evaluated for managing water related risks should not be limited to water related supply or demand elements alone but should also include the wide array of economic, land-use and other factors that influence vulnerability to water conditions. The application of risk management concepts to a wide variety of "real" situations is essential in order to inform populations, governments and other actors regarding the strategic choices they face. In addition, the process of training a new generation of climate-water risk management specialists needs to be started. This new generation is essential in order to translate emerging global insights into practical courses of action in the huge number of local contexts where such skills will be required. Overall, as a result, at the conceptual level two steps are key:

1. Applying climate-water risk management concepts to specific locations and contexts;

2. Beginning the process of educating and training a new generation of climate-water risk management specialists who are familiar with the concepts and tools required.

3.2 STRATEGIC PRIORITIES FOR CLIMATE-WATER RISK MANAGEMENT

Concepts and experience are the foundations for strategic decision making. Existing experience and the emerging, much wider, body of insights on climate-water risk management need to be brought together in ways that illustrate the strategic alternatives regions face. In the Netherlands, for example, the ability to continue relying on protective structures is increasingly questioned and proposals for approaches that would allow the region to "live with water" are emerging. These approaches are fundamentally different on a strategic level and, while elements of each could complement the other, in some locations and contexts they represent true strategic alternatives. The construction of sea walls and river dykes, for example, may be fundamentally incompatible with maintaining the ability of coastal marshes and wetlands to absorb floods. There could, as a result, be fundamental strategic decisions required regarding which type of approach to rely on for buffering coastal storms. Systematic analyses that outline potential courses of action and the resulting risks facing the Netherlands under different strategic approaches are essential as a basis for informed dialogue within both the technical management community and, more importantly, at a societal decision making level.

The above type of strategic analysis is also essential in many other vulnerable parts of the world. Again, it is important to recognize that the strategic alternative may have little directly to do with the water sector. In the Middle East and North Africa, for example, the Stern review highlights the increasing probability of extreme water scarcity. In this region, strategic choices will probably have to be made at an economy or even global level. Relying on agriculture to support a significant part of the population may not be possible. Countries will, as a result, face strategic decisions regarding their willingness to rely on global trading systems to meet food – and by implication virtual water – requirements. Their ability to make such decisions may also depend on their willingness to trust the global trading system and the mix of political actors that have influence over it. Strategic analysis of climate risk management needs will, as a result, be influenced by the courses of action global actors take and the degree to which trading systems are perceived as reliably independent from political considerations.

Overall, translating concepts into practical courses of action that illustrate and ground the types of strategic choices that will have to be made is an essential next step.

3.3 GAINING OPERATIONAL EXPERIENCE IN CLIMATE WATER RISK MANAGEMENT

The final, and possibly highest, priority for action is to gain operational experience in climate water risk management using techniques and approaches that extend beyond the infrastructure toolbox that has historically dominated within the water sector.

Pilots are required in key settings to demonstrate practical approaches to meeting water needs through climate risk management. These pilots need to substantially expand in order to demonstrate a wide array of hard infrastructure, distributed, financial, early warning and risk management approaches in key contexts. Specific contexts where demonstration activities are essential include:

1. Post-disaster recovery: Activities to demonstrate how longer-term climate risks can be substantially reduced in the post-disaster recovery process. This could include analysis of the opportunities and constraints facing attempts to change water management approaches in high vulnerability areas. Harvesting lessons and testing alternative strategies following events such as the recent Katrina Hurricane are high priority.

2. Coastal area risk reduction: Can ideas such as the hydrometropol be demonstrated in key areas? What are the technologies that will work – and how may they influence the choice and design of conventional coastal protection structures?

3. Flood prone area risk reduction: Can balanced approaches involving new "adapted" designs for hard infrastructure in conjunction with "softer" approaches for living with water reduce risk in specific areas?

4. Drought prone area risk reduction: Can approaches to economic diversification be effectively combined with local and larger scale water interventions in ways that substantially reduce drought risk, particularly for the most vulnerable communities.

5. Urban and rural water supply risk reduction: What can be achieved in terms of supply reliability and delivery of key water services, particularly to the poor, by innovative approaches to water service delivery including water markets and new infrastructure designs?

In addition to contexts, the role of specific techniques in climate-water risk management needs to be tested and documented. In specific, techniques that need further demonstration include:

1. Spatial planning to reduce vulnerability to a wide variety of climate risks, including drought (as opposed to floods where this has a long history);

2. Financial, particularly insurance, mechanisms for reducing as well as spreading climate risks. While insurance has a long history as a mechanism for risk spreading little has been done to link insurance to risk reduction. Practical avenues for using financial mechanisms to reduce risk exposure are essential.

3. Economic diversification, including the use of virtual water and strategy shifting. Practical examples of how regions can shift from climate-water vulnerable livelihood systems to more resilient systems are essential to identify.

4. Living with water. Identification and testing of packages of technologies and strategies that substantially improve the ability of large populations to "live with water" are essential. Pilot implementation projects in vulnerable regions (such as the Gangetic Basin) are required to generate operational experience.

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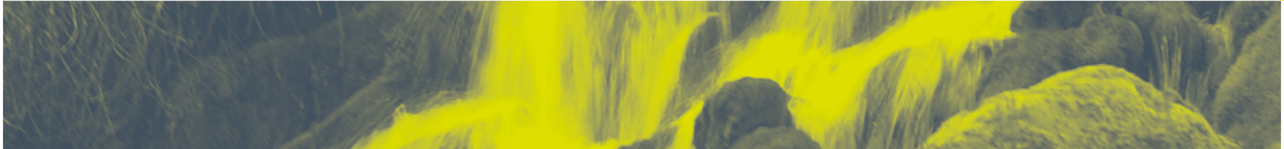

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