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Adaptation Challenges in Complex River Basins: Lessons Learned and Unlearned from the Colorado

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Climate variations affect the function and operation of existing water infrastructure—including hydropower, structural flood defenses, drainage and irrigation systems—as well as water management practices in support of efficiency and environmental needs. As is well documented climate change challenges the traditional assumption that past hydrological experience provides a reasonable guide to future conditions. Selected basins around the world, including the Colorado, show agreements in model projections of increasing aridity. Adverse effects of climate change on freshwater systems aggravate the impacts of other stresses, such as population growth, changing economic activity, land-use change and urbanization and most importantly upstream-downstream winners and losers. Thus current water management practices may not be robust enough to cope with the impacts of climate change on water supply reliability. In many locations, water management does not even satisfactorily cope with current climate variability, so that large flood and drought-related environmental and economic damages occur on seasonal to decadal timescales.

The recently released IPCC Technical Paper outlines the impacts and adaptations in the water resources sector identified in several countries. It notes that adaptation procedures and risk management practices that incorporate projected hydrological changes with related uncertainties are being developed in some countries and regions.

Since the release of the IPCC report several of the authors (including the presenter) have held meetings on comparative assessments of adaptation and its challenges in interstate and international river basins. As a first step, improved incorporation of information about current climate variability into water-related management could assist adaptation to longer-term climate change impacts. Future adaptations include technical changes that improve water use efficiency, demand management (e.g. through metering and pricing), and institutional changes that improve the tradability of water rights.

The co-evolution of climate history and adaptation did not start with the release of IPCC scenarios. The development of the Colorado River Basin was itself influenced by water resources planners from around the world (including the Middle East) in the late 1800s. As such lessons identified, but not always learned, abound. These lessons include, an expanded use of incentives for improving water-use efficiency, including metering and pricing, to encourage water conservation and development of water markets and implementation of virtual water trade, These hold considerable promise for water savings and the reallocation of water to highly valued uses. Supply-side strategies generally involve increases in storage capacity, abstraction from watercourses, and water transfers. Integrated water resources management provides an important governance framework to achieve adaptation measures across socio-economic, environmental and administrative systems. However, several paradoxes in water management and governance mitigate against the effectiveness of scientific information for meeting short term needs in the context of reducing longer-term vulnerabilities and for providing water to meet environmental needs. Consequently a complete analysis of the effects of climate change on human water uses would consider cross-sector interactions, including the impacts of changes in water use efficiency and intentional transfers of the use of water from one sector to another.

In this presentation we will review the challenges and lessons provided in drought and water resources management and optimization in the context of climate variability and projected change in the Western U.S.,

the European Union (including the Iberian Peninsula), the Murray-Darling Basin, and elsewhere.

Climate change poses a major conceptual challenge to resource managers, in addition to the challenges caused by population and land use change. For example it is no longer appropriate to assume that past hydrological conditions will continue into the future (the traditional assumption). Due to the uncertainty associated with climate change, managers cannot place confidence in single projections of the future. It will be difficult to detect a clear climate change effect within the next couple of decades, even with an underlying trend. The vast majority of published impact assessments have used only a small number of scenarios of the future. These have demonstrated that impacts vary among scenarios, although temperature-based impacts, such as changing in the timing of streamflows, tend to be more robust. The use of a scenarios-based approach to water management in the face of climate change is recommended, but poses two problems. First, the large range for different climate model-based temperature scenarios suggests that adaptive planning should not be based on only a few scenarios: there is no guarantee that the range simulated by the models represents the full range of temperatures that could be experienced. Second, it is difficult to evaluate the credibility of individual scenarios, and uncertainty injects additional complications. Based on the studies done so far, it is difficult to reliably predict the water-related consequences of climate policies and emission pathways. Adaptation procedures that do not rely on precise projections of changes in river discharge, groundwater, and other variables need to be developed. Consequently, research on methods of adaptation in the face of these uncertainties is needed. Whereas it is difficult to make concrete projections, it is known that hydrological characteristics will change in the future. Early warnings of changes in the physical system and of thresholds or critical points that affect management priorities become important. Water managers in some countries are already considering explicitly how to incorporate the potential effects of climate change into specific designs and multi-stakeholder settings. Integrated water resources and coastal zone management, are based around the concepts of flexibility and adaptability, using measures which can be easily altered or are robust to changing conditions. For example, in California adaptive management measures (including water conservation, reclamation, conjunctive use of surface and groundwater and desalination of brackish water) have been advocated as means of proactively responding to climate change threats on water supply. Similarly, resilient strategies for flood management and environmental restoration, such as allowing rivers to temporarily flood and reducing exposure to flood damage, might be preferable to or combined with traditional "resistance" (protection) strategies, such as in the Confederation Bridge case discussed above.

Adaptation procedures and decision support tools are important both in the context of present day climatic risks and for increasing societal resilience into the future. To develop the necessary procedures and tools requires continued scientific, technical and operational efforts. The focus of such efforts is on developing research and management partnerships that provide decision makers and communities with credible, relevant information and the capacity to use such information effectively for climate risk management. Experience has shown that such knowledge and capacity is most effectively produced through:

- Enhancement of networks of systematic observations of key elements of physical, biological, managed and human systems affected by climate change particularly in regions where such networks have been identified as insufficient;
- Research into understanding and managing physical, biological and human systems where there is a risk of irreversible change due to climate and other stresses;
- Increased understanding of the potential costs and benefits of impacts due to various amounts of climate change, of damages avoided by different levels of emissions reduction, and of options for adapting to these impacts and managing the risks;
- Studies to explore how adapting to climate change and the pursuit of sustainable development can be complementary; and
- Learning-by-doing approaches, where the base of knowledge is enhanced through accumulation of practical experience.