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REVIEW ESSAY

Embracing Uncertainty to Improve Water Management, with Examples from Seven River Basins

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The Adaptive Water Resource Management Handbook
Jaroslav Mysiak, Hans Jørgen Henrikson, Caroline Sullivan, John Bromley & Claudia Pahl-Wostl (Eds) *London, Earthscan, 2010*

Integrated and Adaptive Water Resource Management

The notions of integrated water resources management (IWRM) and adaptive water management (AWM) have been discussed in the literature and promoted in the halls of water ministries and donor organizations for more than 20 years. Many scholars and practitioners of water management have developed their impressions of what these notions involve (Medema *et al.*, 2008). Many also have suggested that thoughtful perspectives incorporating IWRM and AWM can be helpful in crafting better policies and designing more effective resource management interventions (Johnson, 1999; Pahl-Wostl, 2007). Promoters suggest that such programmes will be more successful in achieving a broader set of policy objectives than programmes reflecting a more limited view of key issues and stakeholders. Others have suggested that implementation issues will constrain the applied usefulness of IWRM and AWM approaches (Biswas, 2004; Jeffrey & Geary, 2006; Gregory *et al.*, 2006).

The Global Water Partnership (GWP) defines IWRM as a "process that promotes the coordinated development and management of water, land and related resources to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (www.gwptoolbox.org). The GWP suggests that IWRM is not an end in itself but a means of achieving three strategic objectives:

1. efficiency—making the most of limited water resources,

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2. equity—allocating water fairly across social and economic groups; and
3. environmental sustainability—protecting water and associated ecosystems.

The GWP definition is intuitively appealing and the strategic objectives are nicely comprehensive. Who could disagree with a process that seeks efficient, equitable and environmentally sustainable outcomes? A clear path to follow in achieving these goals with respect to land, water and associated ecosystems would quickly become the chosen course of travel for most public officials and development practitioners. Yet finding such a path is quite challenging in practice, perhaps because the goals can rarely be achieved simultaneously, or with degrees of success that appeal to all stakeholders.

One can think of many water resource issues in which the goals of efficiency and equity are at odds, or in which stakeholders promoting efficiency clash with groups demanding environmental sustainability. The challenge in gaining the benefits of an IWRM approach lies in the difficulty of bringing all stakeholders to the table—and keeping them there—while designing policies and programmes that reflect IWRM principles and achieve levels of efficiency, equity and sustainability that truly appeal to all stakeholders.

It is easy also to consider the importance of uncertainty when planning water resource projects or designing policies to promote wiser use of limited resources. Rainfall, river flows, groundwater levels and seepage from water delivery canals are just a few of the variables that are stochastic, rather than deterministic. Farm-level water demands, irrigation applications, crop yields and market prices also are influenced by variables unobserved by public officials and canal system operators. Water managers in provinces or countries downstream of others along transboundary canals or rivers generally cannot predict with certainty how much water will flow into their territory. Uncertainty pervades water management decisions at national, regional and farm levels. Hence the notion of adaptive management, which addresses the issue of uncertainty head on, is perfectly suited for application within the water sector.

AWM Adds Value to IWRM

As described very nicely by the authors of *The Adaptive Water Resource Management Handbook* (Mysiak *et al.*, 2010), AWM adds value to the IWRM approach by directly embracing uncertainty. In essence, if we know the system we are managing is stochastic, and we know some of the sources of uncertainty, then we should design management strategies with built-in learning components that intentionally seek to gain information that will reduce uncertainty or enhance our ability to accommodate it. Such a pro-active approach toward learning about uncertain resource systems is certainly appropriate, whether or not the approach is placed within the context of IWRM.

One might suggest, however, that AWM belongs within the construct of IWRM, given the latter's broad scope and ambitious objectives. It seems implausible to speak about achieving efficiency, equity and sustainability without considering the role of uncertainty in resource management strategies and decisions. A strategy based only on what is known will likely fall short of a strategy that acknowledges uncertainty and includes a learning component that will inform resource managers over time and enable them to adapt their programmes accordingly. In an ideal world, resource managers would collect and analyze empirical information continuously, while meeting with stakeholders on a regular basis to review the information and consider appropriate adjustments in programme components.

A fully integrated and adaptive programme would require substantial time, effort and coordination, but the quality of resource management strategies would improve as new knowledge is developed and shared.

The NeWater Initiative

The authors of the AWRM Handbook describe seven case studies in which they have implemented programmes that match this description to some degree. The case studies were conducted as part of the NeWater initiative (New Approaches to Adaptive Water Management Under Uncertainty), a four-year programme supported by the European Commission (http://www.newater.info/). In each of seven major river basins (Figure 1), the authors engaged a variety of stakeholders in discussions of key challenges and potential strategies that might be implemented to improve efficiency, equity, or environmental quality.

Specific research methods vary across the seven case studies with differences in resource endowments, key challenges and programme goals. Yet all of the case studies reflect a commitment towards participatory research and decision making. Stakeholders were encouraged to speak freely and think creatively about the role of uncertainty and the design of adaptive management strategies. Perhaps the most notable differences in the implications

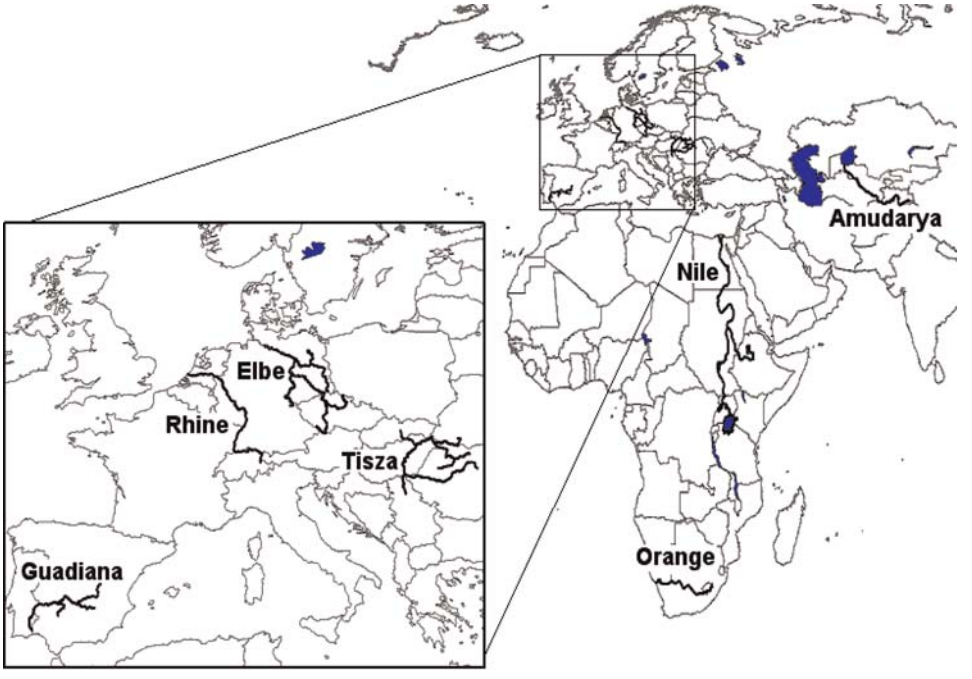

Figure 1. Seven river basins were selected as case study areas in the NeWater study of Adaptive water management under uncertainty: Amudarya, Elbe, Guadiana, Nile, Orange, Rhine, and Tisza. *Source*: This figure is borrowed from "Adapted Integrated Water Resources Management (AWM): Explicitly Addressing Today's Challenges". Results from NeWater: An integrated project in the sixth EU Framework Program, 2005–2009 (http://www.newater.info/).

of uncertainty for policy design across the seven case studies pertain to issues that often distinguish river basins in industrialized regions from those in developing countries.

Key issues in the Elbe, Guadiana, Rhine and Tisza River Basins include flooding, droughts and water pollution from nonpoint sources. Enhancing understanding of the role of uncertainty in these basins will improve the efficiency of resource management programmes, while reducing potential economic losses from floods, droughts and declining water quality. It should also be possible to implement *active* adaptive management strategies in which the systems are pulsed intentionally to gain information about how resources respond to shocks that move them away from equilibrium (Lawler *et al.*, 2010).

In the Nile, Orange and Amudarya River Basins, key issues include water allocations within and between countries, salinity and waterlogging in agricultural areas, and the implications of hydropower development on countries located downstream. The sources of uncertainty in these areas include climate, weather, hydrology, and also the responses of poor households to changes in their access to land and water resources.

Although not discussed widely in the book, water resource managers in developing countries must learn more about the roles of uncertainty and the impacts of water allocation and development programmes on poor households in both urban and rural settings. Perhaps quite unlike the situation in industrialized countries, in developing countries the livelihoods of millions of poor residents hang in the balance of our ability to implement resource management programmes and interventions that reflect due consideration of uncertainty, while including effective strategies for reducing uncertainty over time.

Adaptive Water Management in Seven River Basins

The Elbe River Basin

Floods, drought and pollution of groundwater and surface water are among the leading issues that public officials and residents of the Elbe River Basin must address as they consider implementing adaptive management strategies. Floods can damage infrastructure and arable lands in the highly developed basin, which includes the cities of Berlin, Hamburg and Prague. The region is also subject to water stress in dry periods when the sum of competing demands from agriculture and other uses exceeds the available supply.

The authors describe their efforts to engage stakeholders in addressing two research issues: (1) how to incorporate adaptation to climate change into water management (with an emphasis on floods); and (2) how to integrate water quality and water volume issues in water management, while seeking also to understand the impacts of changes in land use and climate on water quality. Stakeholders were asked to participate in surveys and workshops designed to elicit their preferences regarding the relative importance of water management issues and to gain their perspectives regarding potential management alternatives and research needs (Hesse *et al*., 2007). The workshops also provided a platform for informing stakeholders of current research efforts regarding climate change, flood protection and water quality improvements.

Workshop participants discussed methods of coping with uncertainties in flood management and water quality protection, and the role of research in enhancing their understanding of complex management issues. They agreed that a combination of adaptive and preventive measures was needed to reduce vulnerability to flood damage in the region. While flood protection currently involves largely structural measures, participants considered

implementing non-structural approaches, such as extending flood plains, slowing the flow of water to enhance infiltration, improving flood forecasting and warning systems, and providing timely evacuation of residents in flood-prone areas. Some of these options can be examined further using biophysical and institutional models already constructed for the Elbe River Basin (Berlekamp *et al.*, 2007; Nunneri & Hofmann, 2005; Matthies *et al.*, 2006).

The authors note that considering the challenges and describing potential adaptive management strategies is somewhat straight forward. The more challenging aspect of this effort for residents of the region will be to implement helpful measures and maintain the degree of communication and cooperation displayed in the participatory planning exercises. While additional analysis using economic and hydrologic models is conducted to further evaluate policy alternatives, public officials should continue to communicate clearly with stakeholders and all residents regarding the importance of adapting management strategies to accommodate uncertainty, particularly with respect to climate change.

The Guadiana River Basin

The transboundary Guadiana River flows from Spain through Portugal. Key issues in the river basin include sharing limited water supplies between competing uses, restoring degraded wetlands, and stabilizing aquifers that are pumped heavily for agricultural needs during dry years. The increasing frequency and intensity of droughts in recent years have complicated efforts to meet all water demands in the Upper Guadiana basin, which is one of Spain's driest areas. Many farmers have installed unregulated wells to supplement their surface water supplies, thus further complicating efforts to understand and manage aggregate water demands and supplies in the region. Additional issues include wetland degradation and nitrate pollution of groundwater.

The authors conducted meetings and field trips designed to inform farmers and educators of the hydrology of the Guadiana River Basin, with emphasis on linkages involving surface water, groundwater and wetlands. They also convened stakeholders from pertinent organizations and asked them to provide their views regarding key problems in the region, uncertainties, and potential management options. The goal of this participatory process was to develop site-specific scenarios involving adaptive water management tools. The stakeholders requested an economic-hydrological model for analyzing alternative policy scenarios, and such a model was developed. Model results suggest that controlling illegal water mining and implementing water quotas, water pricing, and systems of water rights would be helpful in achieving stakeholder objectives. However, those who lose access to water, or must pay higher prices, will oppose some policy choices.

Regarding transboundary issues along the Guadiana River, new agencies or initiatives might be helpful in addressing uncertainty due to climate change (Cots *et al.*, 2009). One or more new agencies could adopt the participatory process and analytical models developed within Spain as part of the NeWater programme, and extend them as appropriate to examine cross-border issues. Such an extension of the authors' work might build nicely upon participatory modelling work conducted elsewhere in the Guadiana River Basin (Videira *et al.*, 2009).

The Rhine River Basin

Nine countries share the Rhine River Basin which is home to an estimated 60 million persons, with Germany accounting for 55% of the area, and Switzerland and France

combining to account for 31% of the basin. International cooperation along the Rhine River began in the 19th century, in conjunction with industrial development in the region. Both cooperation and development continued throughout the 20th century resulting in a highly developed basin with notable water quality and flooding issues. While most of the point source pollution in the basin is regulated and taxed, non-point source pollution remains a challenging water quality problem. Providing adequate flood protection, particularly along downstream portions of the basin, is also a current policy issue. The prospect of climate change in the region adds substantial uncertainty regarding the frequency and severity of floods and droughts, and changes in water quality (Hooijer *et al.*, 2004; Middelkoop *et al.*, 2004; Zwolsman & van Bokhoven, 2007).

Working within the context of the NeWater programme, the authors conducted case studies in three sub-basins: (1) the Lower Rhine, (2) the Kromme Rijn, and (3) the Wupper. Transboundary flood management is the key issue in the Lower Rhine, which flows through Germany and the upper portion of the Netherlands. The authors conducted several workshops with stakeholders in which they applied participatory scenario analysis to identify alternatives for improving flood management in the basin. Participants focused on political and social priorities, the distribution of public and private responsibilities, political and economic power relations, and the spatial and structural orientation of decision making. The authors report that the viewpoints of most participants changed during the process, but success in reaching consensus was not enhanced.

Stakeholders in the Kromme Rijn sub-basin are interested primarily in developing an adaptive water management plan for allocating water supplies between competing uses. Dairy farmers, fruit farmers and representatives of nature organizations were among the participants in the NeWater sponsored planning workshops and activities. The authors report successful engagement with stakeholders, although tensions remain between some of the farmers and other participants, regarding water management strategies.

Participatory water management planning was also the focus of NeWater efforts in the Wupper sub-basin, which includes a densely populated portion of Germany. Many drinking water reservoirs have been constructed along this segment of the Rhine River. The primary challenge facing stakeholders in the sub-basin is implementation of the European Water Framework Directive, which includes stringent water quality guidelines. Consistent with the spirit of adaptive water management, stakeholders jointly examined the potential implications on water quality of alternative operations of the Dhünn dam, a key feature of water supply infrastructure in the sub-basin. Together, the group produced a report describing possible measures to improve water management.

The Tisza River Basin

Water quality and flooding are the primary problems facing policy makers in the transboundary Tisza River Basin, which includes portions of six European countries and is home to a population of 14.4 million. Annual precipitation ranges from 1700 mm in the high mountains to 500 mm in the plains. Most of the discharge in the Tisza River is generated by rainfall, while some is generated by snowmelt and groundwater. Severe floods and droughts have characterized the history of this river basin, perhaps for centuries (Sendzimir *et al.*, 2008).

As in many river basins, much of the current flooding risk is due to anthropogenic developments that have occurred over time, resulting in unsafe situations for a proportion

of the current population. Residents of low-income regions are more vulnerable to damage from floods because they have fewer resources to invest in flood prevention and protection. The flooding issue seems ideally suited for analysis in an adaptive management framework, particularly given the interesting set of geo-political issues the riparian countries have been addressing since 1990.

The authors describe their work in bringing experts and stakeholders together from Hungary and Ukraine to discuss common goals and strategies. They describe the use of conceptual and cognitive modelling, in conjunction with group model building, to investigate systems of understanding pertaining to flood risk and uncertainties regarding the generation of floods. They describe also a knowledge elicitation game they use to examine uncertainties regarding flood risk prevention.

The participatory process encouraged experts and stakeholders to contribute their opinions and explore ideas together in an open and helpfully positive atmosphere. The sense of ownership in the intermediate and final products of the process was helpful in reaching consensus regarding meaningful adaptive strategies. The authors conclude by noting that adaptation planning is neglected largely due to a lack of institutional and financial capacity to undertake planning activities, rather than a lack of knowledge of adaptation strategies. This would seem to be encouraging news for practitioners of participatory policy analysis, particularly if donor support for such activities is available.

The Amudarya River Basin

The Amudarya and Syrdarya River Basins have gained notable international attention in recent decades, due largely to the drying up of the Aral Sea and the institutional changes that have occurred in Central Asia since the dissolution of the Soviet Union. During Soviet times, Central Asia was viewed by planners in Moscow largely as a prime source of cotton and wheat. Many large government farms were constructed throughout the region and large-scale irrigation schemes were developed, using water diverted from the Amudarya and Syrdarya Rivers.

The partial list of major problems in the Amudarya Basin today (p. 143) reflects the legacy of large-scale mismanagement of land and water resources for many years (Spoor, 1998; O'Hara, 2000). Water shortages occur in some regions, in part because large volumes of water are diverted upstream with little coordination or concern for downstream water demands. Soil salinity and waterlogging have occurred, in part because farmers have applied excessive amounts of irrigation water, often with little knowledge of crop irrigation requirements (Qadir *et al.*, 2009). Wetland degradation also has resulted from large-scale water diversions and from land conversion to support required increases in cotton and wheat production.

In a sense, the list of major problems might be viewed more appropriately as a list of symptoms that persist due to several underlying problems that remain in the region, even twenty years after the Soviet republics became independent countries. For example, the lack of private property rights to land and water during Soviet times left farmers with little incentive to manage soil and water resources carefully to ensure long-term productivity. The heavy reliance on irrigation norms and production quotas sent down from central planners gave farmers little incentive to understand agronomy or to study the implications of excessive irrigation. Many of the new farmers in Central Asia once worked

for the large state farms, yet they have limited experience in sustainable agricultural management practices.

Institutional reforms are underway in Central Asia, but the complete transformation of agriculture from a state-controlled sector to a thriving, entrepreneurial industry has not yet occurred. Meanwhile the residual effects of historical institutional arrangements and resource management decisions will continue to constrain agricultural productivity and limit the success of efforts to improve water management. In addition, the diversion of large volumes of water from the Amudarya and Syrdarya Rivers likely will continue, as some portion of the water now is needed to support the livelihoods established in agricultural regions such as the Ferghana Valley, which includes portions of Uzbekistan, Kyrgyzstan and Tajikistan.

In addition to the absence of clearly specified property rights to water, many farmers in Central Asia have little incentive to use irrigation water wisely, given the absence of meaningful volumetric prices. In Uzbekistan, farmers receive water at no charge from the central government. In other countries, farmers are assessed a small fee per hectare for irrigation service, but not all farmers pay the fees in a timely fashion. Due partly to insufficient recovery of irrigation service fees, inadequate investment in scheme-level and farm-level water delivery infrastructure has resulted in systems that operate with notable inefficiency.

As a consequence of government intervention in agricultural markets, the prices and availability of key inputs in Central Asia do not respond freely to changes in farm-level demands. In Uzbekistan, the prices farmers receive for their cotton and wheat are restricted by government policies that require farmers to sell their output to the state for prices that are substantially below market levels. As a result of government interventions, farmers are not able to generate savings accounts or obtain loans that would enable them to invest in irrigation system improvements or other activities that would enhance their productivity.

It is essential to consider the underlying agricultural economy when examining opportunities to improve water management and develop measures for accommodating uncertainty. Agriculture must provide the revenues needed to ensure food security and enable investment in adaptive measures, such as irrigation ponds, tubewells, small pumps, sprinkler and drip systems, land leveling, and fertilizer. If the agricultural economy is distorted in a manner that restricts farm incomes, investments in adaptive measures will be similarly constrained.

Leaching fractions of 40% (p. 145) are excessive and likely are making the soil salinity problem worse, rather than better. Monitoring soil salinity and mapping variation across farm fields will be helpful, but capacity building is required to inform farmers of soil–water–plant relationships, and to ensure they know that excessive irrigation deliveries complicate efforts to maintain soil salinity within acceptable ranges. When farmers understand the cause-and-effect relationships involving their irrigation practices—and when they face correct prices for irrigation water, other inputs, and their products—they will irrigate more wisely and they will achieve better results.

The formation of water user associations (WUAs) in Uzbekistan (p. 150) is indeed a very positive development. Water ministries and donor organizations in the region have been cooperating in this institutional enhancement for several years (Horinkova & Abdullaev, 2003; Abdullaev *et al.*, 2010). It is encouraging to learn that WUAs with greater social capital have higher crop yields and smaller water needs, although one might wonder about the direction of causality. Perhaps farmers who have found the means to

improve crop production have developed a greater stake in the potential benefits of an effective water user association. It would be helpful to know also if some of those farmers produce fruits and vegetables, thus enabling them to generate incomes that are not subject to the same taxation as returns to cotton and wheat production.

To the list of necessary conditions for achieving efficient water management and a sustainable water user association (p. 151), one might add: (1) A clear, farm-level financial stake in the successful functioning of the association, made possible by (2) a vibrant agricultural economy in which farmers have access to affordable inputs, including technical assistance, and they can sell their products in competitive markets with the prospect of retaining most of their returns, subject to moderate income taxes.

The Nile River Basin

The Nile River Basin also receives substantial international attention, due partly to its notable role in the development of ancient civilizations, and also to the critical importance of resolving the increasing competition for Nile River water in a region with many pressing development needs. The nine countries through which the Nile River and its tributaries flow participate in the Nile Basin Initiative, which endeavors to develop Nile River resources in a sustainable and equitable manner.

Achieving success in peacefully sharing the Nile River among the nine countries will require substantial analysis, cooperation and trust. Each country can assist also by establishing water management policies that promote efficient water use within each country. Yet, as described by the authors, the current policy framework in the Nile Basin is characterized by inappropriate policies and the inability to translate policies into action (pp. 159–160). While national governments promote the importance of conserving water when participating in regional dialogues, the policies they implement domestically constrain agricultural development and provide limited farm-level incentives to improve water management practices. Property rights to land and water are not well defined in the region, water supplies are not priced or allocated appropriately, and water users often are not aware of national goals and perspectives regarding water resources.

In Egypt, for example, the national government promotes water conservation and encourages improvements in agricultural water management. For many years the government, together with several international donors, has invested large sums in farm-level irrigation improvement programmes (Moustafa, 2004). Yet many farmers in the Nile Delta do not share the national perspective regarding water scarcity. Many farmers observe full canals of irrigation and drainage water flowing past their fields. Farmers at the head ends of water supply canals obtain healthy supplies of irrigation water, while farmers at tail ends struggle to meet crop water requirements (Kotb *et al.*, 2000). Many of the tail-end farmers supplement their fresh water supplies with drainage water, despite the risk of accumulating salts in the soil profile. The water scarcity conditions that motivate national policy dialogue are not communicated effectively to farmers in the Nile Delta (Oad & Azim, 2002).

Increasing population pressures and deepening poverty in the region will continue to determine how resources are managed at the household level. Deforestation, erosion and degradation of riparian habitats will continue as long as these conditions persist. The authors mention briefly (p. 167) the possibility of ‘sharing the benefits’ of water resources along Nile River, rather than ‘sharing the water’. Such an approach, which might involve sharing the financial or energy benefits of hydropower development or enhanced trade in

goods and services, could be helpful in overcoming some of the resistance to allocating water among the riparian countries (Whittington *et al.*, 2005; Abdalla, 2008).

As the discussion of international cooperation in the Nile Basin shifts to consideration of benefit sharing mechanisms, it will be helpful to keep in mind the large investments that are needed to improve agricultural production and enhance livelihoods in the region. Policies that support farm-level enterprises and market development are needed also, and these should accompany any investments that are made using the revenues generated through benefit sharing agreements. The right policies and investments could greatly improve livelihoods, while also enabling households and communities to participate more actively in implementing adaptive management strategies.

The Orange River Basin

Widespread poverty and economic hardship are noted by authors as the most obvious and pervasive problems in the Orange-Senqu Basin, one of the largest river basins in the world. Listed among the primary issues of concern in the region are highly variable levels of human well-being, due partly to high rates of unemployment, low rural literacy, and high levels of HIV–AIDS. High levels of rainfall variability and inadequate investment in water delivery infrastructure in rural areas contribute to the struggles faced by many households in the region. The mining industry provides employment opportunities for many families, but also degrades the quality of groundwater and surface water resources.

The severity of poverty in the region and the notable challenge of improving livelihoods likely will constrain efforts to implement adaptive water management strategies across the river basin. Yet this is the precisely the challenge that should motivate us to develop effective tools and approaches within the context of adaptive water management.

Rather than pursuing poverty and livelihood impacts directly, the authors describe their work in valuing the ecosystem goods and services derived from wetlands in the region. Some of those benefits accrue to crop and livestock agriculture, and they likely help sustain rural livelihoods. Wetlands also provide materials for roof thatching and handicraft production, and many tourists visit wetlands each year to watch birds and photograph animals. Estimating the value of such benefits is interesting, but a broader and deeper discussion of the implications of poverty on the potential to implement adaptive water management strategies, and on the potential impacts of adaptive water management on poverty, might be more helpful in the context of the Orange-Senqu River Basin.

In their opening and concluding sections, the authors provide a sense that the problems of poverty, at-risk livelihoods, subsistence farming and mining in this region with 19 million residents are severe and constraining, and they are likely to persist for some time. Yet the discussion of adaptive water management seems largely decoupled from this bleak, yet serious, scenario. In addition to evaluating wetland benefits, the authors describe application of a water vulnerability index and a group model-building exercise in the Upper Vaal catchment in South Africa. It is not made clear how these efforts will contribute to solving the most pressing problems in the region.

The specific actions that might be taken in conjunction with adaptive water management (p. 181) seem very straightforward. Certainly water quality is important, and direct discharges of pollutants to rivers should be based on assimilative capacity, licensed, and monitored. Yet the contribution of an adaptive water management approach in this discussion is not clear. To the authors' list, one might add: (1) gaining a much better

understanding of household interactions with water resources in urban and rural areas; (2) measuring the degrees to which livelihoods are constrained by inadequate access to water volume and water quality; (3) exploring technical and policy interventions that will enhance household access to water, while ensuring also that all households are encouraged to use water resources wisely; and (4) examining policy distortions that directly or indirectly cause the inefficient or inequitable distribution of water among residents of the region.

These are challenging endeavors, but the rewards for success in understanding these issues from a truly adaptive management perspective will be substantial. Such analysis might also contribute nicely to transboundary discussions in the Orange River Basin regarding international cooperation to improve water allocation and management, while alleviating poverty and promoting economic development (Mokorosi & van der Zaag, 2007; Heyns *et al.*, 2008; Kistin & Ashton, 2008).

Summing Up

The seven case studies involving river basins in Europe, Central Asia, and Africa provide very interesting reading, particularly for those with a view towards conducting similar research and policy outreach activities. As noted above, the issues that require attention and the implications of uncertainty vary substantially between industrialized and less developed countries. In Europe, it would seem we have the experience, tools, and institutional frameworks needed to address water management issues in a sufficiently collaborative and integrated fashion, provided that stakeholders are convinced there is value in participatory processes. In many areas of Central Asia and Africa, stakeholders have much less experience with collaborative efforts, and the existing institutional frameworks require additional work before they will be viewed as supporting the types of dialogue and outcomes that should arise when exploring adaptive water management strategies.

The roles and implications of uncertainty also deserve special attention when considering water resource issues in less developed countries. In most countries and in most geographic settings, households with savings accounts can adapt to changing conditions and cope with unexpected situations much more readily than households with no savings. It is essential for reasons of agricultural development and for the goal of truly achieving adaptive management to enable households everywhere to retain the financial rewards of their labor and their enterprise. Successful adaptive management begins with the households who manage and apply the resources that gain our attention at communal and global levels. The information we gain from large-scale studies involving data collection, modelling, and simulation of river basin responses to changing conditions will have limited usefulness if we do not retain sight of the critical role that households play in managing scarce resources, and the policy environment that determines their daily choices.

Additional Observations

The first three chapters of the AWRM Handbook provide a helpful introduction to the notions of IWRM and AWM. While much of the discussion is placed within the context of the NeWater programme, the authors also describe the important roles of capacity building, social learning, and participatory processes when seeking to design and

implement programmes that reflect integrative and adaptive principles (Tippett *et al.*, 2005; Pahl-Wostl *et al.*, 2007). Many readers with an interest in pursuing an AWM approach might find the following subsections of Chapter 3 to be most helpful:

Section 3.2. Participatory modeling,
Section 3.3. Uncertainty and policy making,
Section 3.4. Indicators and monitoring to support AWM,
Section 3.5. Analyzing dynamic vulnerability,
Section 3.6. Integrated assessment tools and decision support systems, and
Section 3.7. Climate change impacts and adaptation options.

These sections would also comprise a meaningful reading assignment in a course on integrated water management at either the graduate or undergraduate level.

Chapter Four of the book comes closest to the notion of a handbook, as the authors discuss how to build capacity to understand adaptive water management through training and also in training-the-trainer workshops. Helpful recommendations based on experience gained and lessons learned in the NeWater programme are provided in Chapter 12. In Section 12.3, the authors describe the importance of committing to address uncertainty explicitly during policy discussions and when considering programmes and interventions. Within an adaptive framework, policies and programmes can be viewed as experiments that continuously generate information regarding how natural and human systems respond to policy choices. The information gained should then form the basis for revising and improving the underlying policies and programmes.

As in many edited compilations, the quality and depth of material presented in each chapter varies throughout the book. There is a small amount of duplication in some sections, and some of the chapters could have been enhanced with additional citations to existing literature. Yet generally the book is well written and nicely organized. Many scholars and practitioners will appreciate the thoughtful discussion of adaptive management strategies in the context of seven case studies.

References

Abdalla, K. M. E. H. (2008) Institutional and legal arrangements in the Nile River Basin: suggestions to improve the current situation toward adaptive integrated water resources management, *Water Science and Technology*, 58(10), pp. 2031–2040.

Abdullaev, I., Kazbekov, J., Manthritilake, H. & Jumaboev, K. (2010) Water user groups in Central Asia: emerging form of collective action in irrigation water management, *Water Resources Management* 24(5), pp. 1029–1043.

Berlekamp, J., Lautenbach, S., Graf, N., Reimer, S. & Matthies, M. (2007) Integration of MONERIS and GREAT-ER in the decision support system for the German Elbe River Basin, *Environmental Modelling and Software*, 22(2), pp. 239–247.

Biswas, A. K. (2004) Integrated water resources management: a reassessment—a water forum contribution, *Water International*, 29(2), pp. 248–256.

Cots, F., Taàbara, J. D., McEvoy, D., Werners, S. & Roca, E. (2009) Cross-border organizations as an adaptive water management response to climate change: the case of the Guadiana River Basin, *Environment and Planning C: Government and Policy*, 27(5), pp. 876–893.

Gregory, R., Failing, L. & Higgins, P. (2006) Adaptive management and environmental decision making: a case study application to water use planning, *Ecological Economics*, 58(2), pp. 434–447.

Hesse, C., Krysanova, V., Blažková, Š., Martínková, M., Košková, R., Möllenkamp, S., Gräfe, P. & Wechsung, F. (2007) Problems and research deficits in the Elbe River Basin: results of an opinion poll among stakeholders, *Hydrologie und Wasserbewirtschaftung*, 51(2), pp. 82–86.

Heyns, P. S. V. H., Patrick, M. J. & Turton, A. R. (2008) Transboundary water resource management in Southern Africa: meeting the challenge of joint planning and management in the Orange River Basin, *International Journal of Water Resources Development*, 24(3), pp. 371–383.

Hooijer, A., Klijn, F., Pedroli, G. B. M. & van Os, A. G. (2004) Towards sustainable flood risk management in the Rhine and Meuse River Basins: synopsis of the findings of IRMA-SPONGE, *River Research and Applications*, 20(3), pp. 343–357.

Horinkova, V. & Abdullaev, I. (2003) Institutional aspects of water management in Central Asia: water users associations, *Water International*, 28(2), pp. 237–245.

Jeffrey, P. & Gearey, M. (2006) Integrated water resources management: lost on the road from ambition to realization? *Water, Science and Technology*, 53(1), pp. 1–8.

Johnson, B. J. (1999) The role of adaptive management as an operational approach for resource management agencies, *Ecology and Society*, 3(2), article 8. Available at http://www.ecologyandsociety.org/vol3/iss2/art8/.

Kistin, E. J. & Ashton, P. J. (2008) Adapting to change in transboundary rivers: an analysis of treaty flexibility on the Orange-Senqu River Basin, *International Journal of Water Resources Development*, 24(3), pp. 385–400.

Kotb, T. H. S., Watanabe, T., Ogino, Y. & Tanji, K. K. (2000) Soil salinization in the Nile delta and related policy issues in Egypt, *Agricultural Water Management*, 43(2), pp. 239–261.

Lawler, J. J., Tear, T. H., Pyke, C., Shaw, R. M., Gonzalez, P., Kareiva, P., Hansen, L., Hannah, L., Klausmeyer, K., Aldous, A., Bienz, C. & Pearsall, S. (2010) Resource management in a changing and uncertain climate, *Frontiers in Ecology and the Environment*, 8(1), pp. 35–43.

Matthies, M., Berlekamp, J., Lautenbach, S., Graf, N. & Reimer, S. (2006) System analysis of water quality management for the Elbe River Basin, *Environmental Modelling and Software*, 21(9), pp. 1309–1318.

Medema, W., McIntosh, B. S. & Jeffrey, P. J. (2008) From premise to practice: a critical assessment of integrated water resources management and adaptive management approaches in the water sector, *Ecology and Society*, 13(2), article 29. Available at http://www.ecologyandsociety.org/vol13/iss2/art29/.

Middelkoop, H., van Asselt, M. B. A., van' T Klooster, S. A., van Deursen, W. P. A., Kwadijk, J. C. J. & Buiteveld, H. (2004) Perspectives on flood management in the Rhine and Meuse Rivers, *River Research and Applications*, 20(3), pp. 327–342.

Mokorosi, P. S. & van der Zaag, P. (2007) Can local people also gain from benefit sharing in water resources development? experiences from dam development in the Orange-Senqu River Basin, *Physics and Chemistry of the Earth*, 32(15–18), pp. 1322–1329.

Moustafa, M. M. (2004) Can farmers in Egypt shoulder the burden of irrigation management? *Irrigation and Drainage Systems*, 18(2), pp. 109–125.

Mysiak, J., Henrikson, H. J., Sullivan, C., Bromley, J. & Pahl-Wostl, C. (2010) *The Adaptive Water Resource Management Handbook* (London: Earthscan).

Nunneri, C. & Hofmann, J. (2005) A participatory approach for integrated river basin management in the Elbe catchment, *Estuarine, Coastal and Shelf Science*, 62(3 Special), pp. 521–537.

Oad, R. & Azim, R. (2002) Irrigation policy reforms for rice cultivation in Egypt, *Irrigation and Drainage Systems*, 16(1), pp. 15–31.

O'Hara, S. L. (2000) Central Asia's water resources: contemporary and future management issues, *International Journal of Water Resources Development*, 16(3), pp. 423–441.

Pahl-Wostl, C. (2007) Transitions towards adaptive management of water facing climate and global change, *Water Resources Management*, 21(1), pp. 49–62.

Pahl-Wostl, C., Sendzimir, J., Jeffrey, P., Aerts, J., Berkamp, G. & Cross, K. (2007) Managing change toward adaptive water management through social learning, *Ecology and Society*, 12(2), article 30, Available at http://www.ecologyandsociety.org/ vol12/iss2/art30/.

Qadir, M., Noble, A. D., Qureshi, A. S., Gupta, R. K., Yuldashev, T. & Karimov, A. (2009) Salt-induced land and water degradation in the Aral Sea Basin: a challenge to sustainable agriculture in Central Asia, *Natural Resources Forum*, 33(2), pp. 134–149.

Sendzimir, J., Magnuszewski, P., Flachner, Z., Balogh, P., Molnar, G., Sarvari, A. & Nagy, Z. (2008) Assessing the resilience of a river management regime: informal learning in a shadow network in the Tisza River Basin, *Ecology and Society*, 13(1), article 11. Available at http://www.ecologyandsociety.org/vol13/iss1/art11/.

Spoor, M. (1998) The Aral Sea basin crisis: transition and environment in former Soviet Central Asia, *Development and Change*, 29(3), pp. 409–435.

Tippett, J., Searle, B., Pahl-Wostl, C. & Rees, Y. (2005) Social learning in public participation in river basin management, *Environmental Science & Policy*, 8(3), pp. 287–299.

Videira, N., Antunes, P. & Santos, R. (2009) Scoping river basin management issues with participatory modelling: the Baixo Guadiana experience, *Ecological Economics*, 68(4), pp. 965–978.

Whittington, D., Wu, X. & Sadoff, C. (2005) Water resources management in the Nile Basin: the economic value of cooperation, *Water Policy*, 7(3), pp. 227–252.

Zwolsman, J. J. G. & van Bokhoven, A. J. (2007) Impact of summer droughts on water quality of the Rhine River—a preview of climate change? *Water Science and Technology*, 56(4), pp. 45–55.