The Adaptive Water Resource Management Handbook



Edited by Jaroslav Mysiak, Hans Jorgen Henrikson, Caroline Sullivan, John Bromley and Claudia Pahl-Wostl

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List of Acronyms and Abbreviations

AM	Adaptive Management
AMIS	Adaptive Monitoring Information System
AWM	Adaptive Water Management
BBN	Bayesian Belief Networks
CART	Classification and Regression Trees, Salford Systems
CCM	conceptual and cognitive modelling
DA	decision analysis
DPSIR	Driving Pressure State Impact and Response Model
DSS	decision support system
DWAF	Department of Water Affairs and Forestry
EC	European Commission
EDMI	Egalitarian Decision-Making Indexes
EEA	European Environmental Agency
EU	European Union
FRD	Flood Risk Directive
GCM	General Circulation Model
GMB	Group Model Building
GVA	Gross Value Added
GWP	Global Water Partnership
GWSP	Global Water System Project
HDSR	Hoogheemraadschap De Stichtse Rijnlanden
IAM	Integrated Assessment and Modelling
ICPE	International Commission for the Protection of the Elbe
ICPR	International Commission for the Protection of the Rhine
IPCC	Intergovernmental Panel on Climate Change
ISD	Indicators of Sustainable Development
IWRM	Integrated Water Resources Management

KnETs	Knowledge Elicitation Tools
LHDA	Lesotho Highlands Development Authority
LUA	Environmental Agency of Brandenburg
MGP	Mathematical Goal Programming
MP	Mathematical Programming
MTF	Management and Transition Framework
NAPAs	National Adaptation Programs of Action
NBI	Nile Basin Initiative
NeWater	New Approaches to Adaptive Water Management Under Uncertainty
NL	The Netherlands
NWR	North Rhine-Westphalia
PA	Participation and Awareness
PEAG	Plan Especial del Alto Guadiana
PM	participatory modelling
PRUDENCE	Prediction of Regional Scenarios and Uncertainties for Defining European Climate change risks and effects)
RCM	regional climate model
RTD	Research and Technological Development
SANBI	South African National Biodiversity Institute
SEPA	Sidestream Elevated Pool Aeration
SIDA	Swedish International Development Agency
SWIM	Soil and Water Integrated Model
TMLNU	Thuringian Ministry of Agriculture, Nature Protection and Environment
TRB	Tisza River Basin
TWQR	Target Water Quality Range
UGB	Upper Guadiana Basin
UNCED	UN Conference on Environment and Development
UNDP	United Nations Development Program
UPM	Technical University of Madrid
VCH	village council heads
WAP	Water Abstraction Plan
WEAP	Water Evaluation and Planning
WFD	Water Framework Directive
WISE	Water Information System for Europe
WPIS	web portal input system
WUAs	Water User Associations
WVI	Water Vulnerability Index

1
Introduction: Making a Strong Case for AWM

1.1 Challenges of river basin management

C.A. Sullivan

Of the estimated 1.4 billion km^3 of water in the world (Maidment, 1992), only about 2.5 per cent of that is freshwater, with just a fraction actually accessible by humans. In most places, water does not arrive where, or when, it is needed. Only about 40 per cent of all rainfall enters our river systems, equating to some 40,000km^3 of water per year.

Water resources of the Earth are part of a finite closed system and, in any time period when human populations are rising, the per capita amount of water available is inevitably decreasing. Added to this, as economies grow, the level of water consumption increases, and in today's world, those economies that are growing the fastest also happen to be those with the largest populations (India and China). This explains why it is likely that global water stress is likely to increase at an exponential rate.

In the face of this increasing pressure, it is increasingly recognized that this relatively small amount of water must currently be shared, not only by the huge number of humans depending on it, but by all other terrestrial species as well. In addition to this, society is increasingly faced with situations where the availability of water is limited by its quality, a consequence of our long history of neglect of this precious resource. While developed countries now struggle to address this changing view, increasing degradation of water bodes goes on across the globe. In Europe, the EU Water Framework Directive (EC, 2000) has been put in place as a mechanism to ensure human actions will no longer have an irreversible impact on the services provided by life-supporting ecosystems, and similar efforts have taken place in Australia (Heaney and Beare, 2001) and South Africa (Rowlston and Palmer, 2002).

Securing ecological integrity through wise water management is, however, a cornerstone of sustainable development, and there is no doubt that the future of our own life support system depends upon this (McNeely et al, 1990). When we recognize that without water storage, human societies would be dangerously vulnerable to the impacts of climate variability, it becomes clear that securing ecological integrity will be increasingly difficult without a regulatory process. Such global efforts as embodied in the World Commission on Dams (WCD, 2000), the World Summit on Sustainable Development (WSSD, 2002) and the World Water Forum (WWC, 2003 and 2006) are testimony to the increasing degree of public and political awareness of this need. The way development has been viewed in the past has changed, with the realization that a simple increase in per capita income does not necessarily bring about positive changes in human wellbeing. Similarly, we now recognize that the unregulated and excessive use of resources to achieve economic growth is unlikely to generate long-term benefits for society as a whole.

This whole issue of distribution of resources, and the benefits accruing from them, is crucial to our future. We are now at a point in our history where we need to formalize certain assumptions, and identify crucial social and biophysical processes which underlie our very existence. At the international level, the response to this today is in the marshalling of resources to make progress towards the agreed targets outlined in the Millennium Development Goals (UN, 2000). These have been designed to provide guidance on the consideration of how development should proceed in a sustainable and equitable way. While progress towards these goals is varied, there is no doubt that the lives of millions of people today are much improved as a result. Furthermore, the use of both terrestrial and aquatic resources is considered much more carefully than before.

Since climate conditions and water resources are parts of the same global hydrological cycle, attention has become more focused on the need to consider how these interlinked global processes are likely to change in the future. Increasing public awareness of this issue has placed it on a higher level of political importance, as demonstrated by the increasing degree of disparate protest groups active at global political meetings such as the governmental meetings of the G8 and the meetings of the Intergovernmental Panel on Climate Change (IPCC).

Stakeholder involvement is a crucial issue in water management, and the participation of a range of stakeholders in decision making is considered to be an important prerequisite to sustainability. The formalization of this concept in water legislation has become increasingly recognized, although as yet rarely fully implemented, in practice. This new type of water legislation not only supports the general process of government decentralization that is occurring in many places, but promotes the more active involvement of stakeholders at the basin level. This involvement of stakeholders is an important dimension of what we refer to as Integrated Water Resources Management (IWRM) and, while some consider this issue of *integration* purely on a disciplinary or sectoral basis, the IWRM process is in fact actually much more than this. Recognition of the importance of the human and social dimensions of resource utilization is a cornerstone of what is meant by the term *adaptive* water management, and stakeholder engagement at all levels is an essential criteria for its success.

In the NeWater Project, seven globally important international river basins were selected as case studies. These provided the opportunity to strengthen research capacity in the participating countries of the basins, and to promote the development of international research networks between multidisciplinary teams. At the operational level, these case studies had the opportunity to have international research carried out in their domains, with thematically targeted research to address their water-related concerns. How this has been manifested varies considerably across the basins, but in each of them, significant progress has been made towards some aspect of integrated and adaptive water resources management. While this is an achievement in itself, the project has also served to promote a better understanding of the importance of *adaptability* within that process, and this has been carried forward through a series of very diverse capacity building workshops, and formalized training courses.

Throughout the world, people everywhere are vulnerable to both environmental and socio-economic shocks. Our ability to cope with these shocks determines how vulnerable we are, and any examination of historic catastrophes demonstrates that human vulnerability has social, economic and ecological dimensions. The degree of impact of any catastrophe is determined by our ability to adapt to changing circumstances in such a way as to reduce the impact of any negative changes. An important aspect of the work in the NeWater project attempted to address this, by considering how both social and biophysical systems can cope in the face of change. Furthermore, other research looked specifically at how these systems, when acting together, could bring about unexpected outcomes, and the uncertainty associated with this has been of major interest. An analysis of the challenges associated with building resilience and adaptability in the water management domain has been carried out at various levels, and institutional and infrastructure solutions have been examined to address a number of recurrent issues. Examples of this can be seen in the 'Room for the River' approaches adopted in the lower Rhine case study as a way of dealing with floods, or in the massive infrastructure put in place in the Lesotho Highlands Water Project in the Orange Senqu River basin. In this case, where the Republic of South Africa supports the economy of Lesotho on the basis of water transfers, many valuable lessons and innovative approaches can be learned.

As in the other African case, the Nile, many of the case study basins are involved in the development of River Basin Commissions. These are international bodies formed specifically to promote more integrated management of water resources between the various countries of the basin. Since there are over 200 major rivers in the world that are shared by more than one country, this is an important and increasingly topical issue. A variety of studies in the NeWater project have addressed this crucial issue of water sharing in transboundary basins, and again there are important lessons to be learned.

Through local, micro level studies, and studies based on national databases, several different issues have been considered in the project. This research has ranged from a detailed anthropologically based examination of poverty and gender issues in Central Asia and in Africa, to complex hydro-meteorological modelling in the Elbe and other basins, based on local climate records and downscaling of global models. This multi-scale approach to better understanding is a characteristic of the NeWater Project.

Ecological concerns always have priority when systems break down. When non-point source pollution brings about a state of eutrophication in water bodies, local people (where possible) tend to take action quickly to remedy the situation. Increased recognition has developed of the importance of ecological services, as part of a wise water management strategy. This has generated interest in how various ecosystems in particular (such as wetlands) can be given higher priority under Adaptive Management regimes. In the Tisza case study, for example, institutional development and stakeholder processes have brought about great progress in promoting more communication about pollution events, while other work has highlighted the important role played by wetland geomorphology. Such situations as these are good examples to illustrate the concept of indicators, which are used to monitor progress and measure impacts. A number of different aspects of the NeWater work have involved the use of indicators of both a biophysical and socio-economic nature, and an integrated monitoring system has been developed to support adaptive water management.

In the following chapters, many examples will be provided of the ways in which knowledge generation and sharing can be achieved. This can include the use of sophisticated mathematical modelling, or more fuzzy approaches such as agent-based modelling and the application of Bayesian Belief Networks. In the Guadiana basin in particular, where water management is highly developed, these techniques have been used as a means to promote clearer dialogue between potentially conflicting parties. In many ways, these tools serve as a heuristic device, not specifically requiring or producing a right answer, but instead promoting a more integrated and meaningful process of dialogue as needed by an adaptive water management approach.

1.2 Integrated Water Resources Management (IWRM)

P. van der Keur and G.J. Lloyd

By the 1990s there was a growing recognition of the general failure of existing water resources management approaches, based on supply-driven, highly sectoral, top-down thinking. Decision making based on a short-term, sectoral view is rarely effective in the long term and can result in some very expensive mistakes – in terms of unsustainable gains, unforeseen consequences and lost opportunities. A new approach was needed that could take into account the interests and needs of various stakeholders and natural systems. This led to the emergence of the Dublin Principles – a set of concise guidelines aimed at promoting improved water resources management that was formulated at the International Conference on Water and the Environment in Dublin, 1992.

The four Dublin Principles state that, firstly, freshwater is a finite and vulnerable resource, essential to sustain life, development and the environment; secondly, water development and management should be based on a participatory approach, involving users, planners and policy makers at all levels; thirdly, women play a central part in the provision, management and safeguarding of water; and fourthly, water has an economic value in all its competing uses, and should be recognized as an economic good.

These principles significantly contributed to the Agenda 21 recommendations adopted at the UN Conference on Environment and Development (UNCED) in Rio de Janeiro, 1992. Since then, these principles have found universal support from the international community as the foundations of IWRM, 'A process which promotes the coordinated development and management of water, land and related resources in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems' (GWP, 2000). IWRM is a comprehensive approach to the development and management of water, addressing its management both as a resource and a framework for the provision of water services.

In response to requests from the international community for a coordinating organization that could promote IWRM via a worldwide network; the World Bank, the United Nations Development Program (UNDP) and the Swedish International Development Agency (SIDA) created the Global Water Partnership (GWP) in 1996.

As explained in the following section, adaptive water management (AWM) can be viewed as an extension of the IWRM concept. Consequently, to be able to fully appreciate AWM, an understanding of IWRM is highly useful.

The application of IWRM involves a seven-step cycle that is illustrated in Figure 1.1 on the following page. In Figure 1.1 the following seven stages can be identified:

1 *Establish status*. The starting point of the IWRM process is the critical water resources issue seen in the national context. Progress towards a management framework is charted within which issues can be addressed and agreed, and overall goals achieved.
2 *Build commitment to reform*. Political will is a prerequisite and building or consolidating a multistakeholder dialogue comes high on the list of priority actions. Dialogue needs to be based on knowledge about the subject matter and raising awareness is one of the tools to establish this knowledge and participation of the broader population.
3 *Analyse gaps*. Given the present policy and legislation, the institutional situation, the capabilities and the overall goals, gaps in the IWRM framework

can be analysed in the light of the management functions required by critical issues.

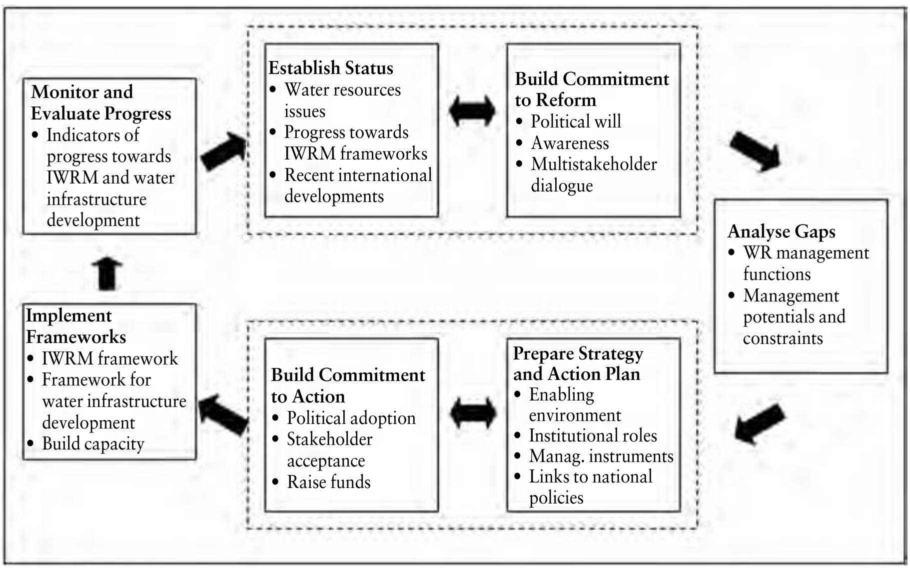
4 *Prepare strategy and action plan*. The strategy and action plan will map the road towards completion of the framework for water resources management and development and related infrastructural measures. A portfolio of actions will be among the outputs, which will be set in the perspective of other national and international planning processes.

5 *Build commitment to action*. Adoption of the action plan at the highest political levels is the key to any progress and full stakeholder acceptance is essential for implementation. Committing finance is another prerequisite for the transfer of planned actions into implementation on the ground.

6 *Implement frameworks*. Realizing plans poses huge challenges. The enabling environment, the institutional roles and the management instruments have to be implemented. Changes have to be made in present structures and the building of capacity and capability, taking into account infrastructure development, need to take place.

7 *Monitor and evaluate progress*. Progress monitoring and evaluation of process inputs and outcomes serve to adjust the course of action and motivate those driving the processes. Choosing proper descriptive indicators is essential to the monitoring value.

By 2008 UN-Water reported that a total of at least 58 countries around the world had adopted IWRM and were in the process of implementation (UN-Water, 2008). However, it is widely recognized that implementing IWRM is invariably a long-term process involving many challenges. In practice, this



Source: GWP, 2004

Figure 1.1 *The IWRM cycle*

means giving water an appropriate place on the national agenda; creating greater 'water awareness' among decision makers responsible for economic policy and policy in water related sectors; and encouraging people to think 'outside the box' of traditional sectoral definitions.

As GWP (2000) acknowledges, 'The nature, character and intensity of water problems, human resources, institutional capacities, the relative strengths and weaknesses of the public and private sectors, the cultural setting, natural conditions and many other factors differ greatly between countries and regions… There is a clear need to update and add specifically to the [IWRM] principles in the light of experience with their interpretation and practical implementation'.

1.3 Adaptive Water Management in terms of development and application within IWRM

P. van der Keur, P. Jeffrey, D. Boyce, C. Pahl-Wostl, A. Hall and James G. Lloyd

AWM adds value to the IWRM approach

The central contribution of Adaptive Water Management (AWM) within the context of Integrated Water Resources Management (IWRM) is that it provides added value through explicitly embracing uncertainty. AWM acknowledges the complexity of the systems to be managed and the limits in predicting and controlling them. This implies an integrated management approaches which adopt a systemic perspective rather than dealing with individual problems in isolation.

Management actions will always have to proceed with an incomplete understanding of a system and the effects of managing on it. Therefore, adaptive policies are designed and guided by hypotheses regarding the range of possible responses of the system including both environmental processes and human behaviour to management interventions. This also takes into account possible changes in external influence (e.g. climate change) over time. In other words, some management actions are taken explicitly to learn about the processes governing the system.

AWM can therefore be considered an important adjunct to the IWRM approach, enhancing its relevance when operating under uncertain and complex conditions with respect to, e.g. climate change and socio-economic changes. This relationship is explored in more detail below.

AWM implementation at the level of the river basin

A fundamental aspect of the IWRM approach is the involvement of many different actors, each with their own interests and management approaches, many with responsibility for specific issues. Their respective interests may be conflicting or incompatible, and management approaches can therefore become polarized and fragmented. Involving even a small group of diverse stakeholders can create complexities that become obstacles to the development of a satisfactory integrated plan in the absence of a strategy to incorporate a range of perspectives and options for changes in an iterative way.

Uncertainties may arise where knowledge is insufficient to provide clarity by observation, or where underlying variability or randomness means that a factor may be unpredictable. Integrated water resource management thus aims to address these strong challenges affected by uncertainties surrounding climate change and population growth (Medema et al, 2008). Building adaptive capacity to navigate an uncertain future can thus add value and such approaches have been gaining momentum in recent years. A major concern is that with increased uncertainty, and with increased demands from different sectors and water users, planning becomes more complex.

In order to obtain the most benefits from the IWRM approach, taking into account complexities and uncertainties as they develop or emerge over time, is required, leading to potentially improved management practices. Such practices should lead to a beneficial impact, and avoid neglecting problems which could neutralize benefits or degrade resources.

AWM and social learning

Adaptive Water Management, as defined by the NeWater project, recognizes explicitly that water management strategies and goals may have to respond to emerging circumstances over time through a process of social learning (Pahl-Wostl, 2007). Social learning in river basin management refers to developing and sustaining the capacity of different authorities, experts, interest groups and the public to collectively manage their river basin (Pahl-Wostl et al, 2007a). Therefore AWM has been defined as being a means of improving water management via a systematic approach; accommodating change through a learning process, taking into account the outcomes of implemented measures, intended to be an iterative process, involving 'learning to manage by managing to learn' (Gleick, 2003).

AWM involves implementing policies and management activities as mechanisms to fill critical knowledge gaps. As a process it entails problem assessment, design, implementation, monitoring, evaluation and feedback. Using an AWM approach to IWRM holds the promise of constructing resilient systems built on principles of equity and efficiency. Social learning builds the capacity for good governance which is transparent, equitable, accountable and thus more fair, and reasonable and effective.

Advantages and disadvantages of AWM

The following advantages can be achieved when learning is treated as an objective throughout the AWM process: firstly, meaningful stakeholder involvement and problem framing, i.e. explicitly taking into account different viewpoints from stakeholders in the AWM process; secondly, organizational framework: creating an organizational routine and measurable outcomes for learning fosters creation of a learning plan; and finally, decision process enhancement, i.e. opportunities for learning and adjustment; creation of a performance measure for learning; creation of alternatives to achieve learning objectives; explicit consideration of tradeoffs between learning and other objectives.

Despite the appeal and attractiveness of the AWM concept, however, potential disadvantages can also be identified: firstly, focus on perfecting models rather than field testing them; secondly, the expense and risk of undertaking large scale experiments; thirdly, fear among research and management organizations that adaptive management and an explicit recognition of uncertainty may undermine their credibility; and finally, fundamental conflicts among diverse stakeholders regarding ecological values. Other obstacles include: high costs of information gathering and monitoring; resistance from managers who fear increased transparency; political risk due to the uncertainty of future benefits; difficulty in acquiring stable funding; and fear of failure.

Through an analysis of implementation of the AWM framework in the Florida Everglades, Gunderson (1999) concluded that three major barriers for its successful implementation are: inflexibility in social systems, little resilience in ecological systems, and technical challenges associated with experiment design. However, one of the major challenges posed by AWM to be successfully implemented is that it requires learning to occur at spatial and temporal scales relevant to the defined management task. In order to match 'science' and 'management', it is therefore crucial to integrate field research with on-going efforts to formulate policy and improve practices and methods at different scales and levels. Building the enabling conditions for efficient and effective AWM may require major transitions in the whole water management regime (Pahl-Wostl et al, 2007b; Pahl-Wostl, 2007).

1.4 Tools for adaptive management

J. Bromley and J. Mysiak

Chapter 3 describes tools that are useful for adaptive management. Those presented do not represent an exhaustive set; many other tools are suitable for AWM, if applied correctly. A survey among the project end-users about their perceived needs identified the following three categories of tools: i) tools to improve the effectiveness of stakeholder engagement; ii) tools to deal with uncertainty, and iii) tools to facilitate integration between disciplines.

Sections 3.1 (Management of participatory processes), 3.2 (Participatory Modelling) and parts of other sections in this book provide some guidance for stakeholder engagement in water management practices. Well conducted public participation processes increase the transparency, legitimacy and accountability of water policy making, a keystone of good governance. Adaptive management presupposes flexibility (regulatory discretion) to tighten or relax the policy provisions to fit local circumstances. The involvement of public interest groups helps to increase monitoring of policy implementation and ensure that flexibility does not compromise response, and that uncertainty is not used as an excuse to deter action when not warranted. Group modelling exercises are another valuable instrument for this end; they help to attain a shared understanding of what is at stake and to understand what consequences, intended or not, may be prompted by a policy.

Sections 3.3 (Uncertainty and policy making) and 3.5 (Dynamic vulnerability) explain how adaptive management is equipped to cope with uncertainty. Section 3.3 provides a basic overview of uncertainty, its sources, manifestations and policy responses that take into account incomplete knowledge. Evidence, even if in some aspects inconclusive, may be useful for decision making. If properly accounted for and communicated, uncertainty prompts caution and contemplation of all reasonably expectable outcomes, including those with low probability but large impacts. Section 3.5 gives a complementary account; it explains how uncertainty about future conditions or events can be dealt with by reducing vulnerability and/or enhancing resilience to the adverse effects of these conditions/events. Public participation and uncertainty/risk assessment go hand in hand; where there is uncertainty about the existence of a problem or how to best address it, the most appropriate course of action is a matter for public debate and conciliation.

Sections 3.4 and 3.6–3.8 describe useful tools for in-depth analysis, assessment and the synthesis of policy relevant knowledge. Section 3.4 (Indicators and monitoring to support AWM) provides examples of environmental indicators and their frameworks, and discusses surveillance systems set up to monitor the performance of adaptive management policies. Well designed and implemented monitoring systems are vital to the learning exercises upon which AWM stands or falls.

Section 3.6 (Integrated assessment tools and decision support systems) describes formal integrated modelling and decision support tools and their variants suited to inform AWM. These tools rely largely on mathematical models, both to understand the underlying complexity of water-related issues and to assess the impacts of adaptive policy interventions.

Section 3.7 (Climate change impacts on water resources and adaptation options) provides an overview of the expected impacts of climate change on water resources and their uses/users. It summarizes and reviews the results from global and regional climate models for different emission scenarios, and discusses adaptation measures which, to some extent, moderate the expected impacts of an altered hydrological cycle.

Section 3.8 (Management and Transition Framework, MTF) describes a tool developed in the NeWater project to support a thoughtful analysis of the structure and dynamics of water management regimes. MTF helps to identify priorities, structure problems, assess solutions to water related problems and aim towards a more adaptive regime.

Finally, section 3.9 (Internet portals and services for knowledge transfer) briefly describes the role of Internet based services – portals, file sharing platforms, news services and blogs – for conveying research results to policy audiences. These tools are badly needed because the transfer of research results to policy and practice has produced frustrating results. NeWater has created a section dedicated to AWM within the Wise-RTD portal (the research branch of the 'Water Information System for Europe') to better disseminate the project's results; an overview of these efforts wraps up section 3.9.

1.5 AWM concept in terms of training and capacity building

D. Ridder, S. Rotter and P. van der Keur

Introduction

As described in the sections 1.1 and 1.2, water management today faces severe challenges due to various uncertainties in the water management process relating to factors such as insufficient data, variability of data available, lack of knowledge on natural and socio-economic processes, growing and competing uses of water in addition to ongoing climatic changes.

While traditional water management relied on the 'predict and control' principle and mainly sectoral approaches, AWM builds on the concept of IWRM while placing particular emphasis on the attempt to address uncertainties by building on flexibility and learning in water management. In this process knowledge transfer and capacity building play a very important role. In order to render operational capacity building in AWM, the distinction must be made between 'why, how and when to conduct capacity building' and 'who should be trained?'.

Why should we train and how?

AWM includes not only new paradigms but also new methodologies – or well known methods and tools which are applied in a new setting with a different objective. For example, the method of Group Model Building can be applied when training a group of experts in team learning, it may also be used to elicit further knowledge from a group of non-experts for the later development of computer-based models (Hare, 2003). AWM confronts practitioners – but also scientists – with new ideas, terminologies and methods in water management. Capacity building and training seems to be the most appropriate way to share this new knowledge on AWM to the user community and enable its application. A distinction made by Dietz and Stern (2008) on capacity in the context of 'public participation in environmental assessment and decision making' can also be adapted for capacity building and training on AWM. Accordingly practitioners and scientists too, should be trained in order to:

- be better informed and more skilled at effective implementation of AWM;
- become better able to employ the best available scientific knowledge and information on the topic;
- develop a more widely shared understanding of the key issues and decision challenges of AWM.

Capacity building can make use of a wide range of tools and instruments from various disciplines to form a process-driven methodology (cf GTZ 2005). Hence, in most cases we can expect a series of training courses. If capacity building is used to support different phases of an undertaking, we need to discuss a capacity building cycle in accordance with a specific regional, cultural and institutional context and the specific needs of the selected phase of the policy cycle of AWM (see Chapter 4).

The capacity building conducted in the NeWater project focused on providing support for practitioners and researchers. With regard to its case studies, the NeWater approach anticipates participatory research in close cooperation with representatives of authorities and other stakeholders who may later use the NeWater results or who may be influenced by them. This approach itself could already be considered as the first step in capacity building: subsequent users of results are involved in their development and hereby gain deeper insights on the benefits of selected methodologies, the functioning of tools and also their limitations. As the task for researchers and stakeholders to work together in a highly collaborative manner was relatively new to them, a need for initial training was identified. Participation and social learning should be understood as important concepts in AWM and training should ensure these concepts become an inherent part of research undertakings.

1.6 The importance of (social) learning for AWM

AWM is described as a systematic approach in improving management and accommodating change by learning from the outcomes of management policies and practice (Holling, 1978, Walters, 1986). On the one hand this comprises of learning to manage by managing to learn (Gleick, 2003) but on the other hand it also involves gaining knowledge on the further developments of the AWM concept and its potential application. How can this be achieved? One important aspect here is that the evaluation stage of an adaptive management process must be developed as an objective activity. Too often evaluation schemes are constructed to prove correct decisions were made in planning and implementation stages, instead of considering it as an opportunity for the project team to critically reflect and improve the planning and implementation of activities accordingly. To facilitate this reflectivity it should, for example, become a more common procedure to seek external help. From a psychological viewpoint it is advisable that the initiative to change comes from outside the company, authority or project team, in order to avoid internal conflicts. This aspect of enhancing reflectivity in (participatory) processes is highlighted in the concept of social learning which is assumed to be crucial for the transition towards and for sustaining adaptive management practices (Pahl-Wostl 2007, p 56).

But what is Social Learning?

One definition of social learning is 'learning in and by groups to handle shared issues...' (Ridder et al, 2005, p 96). Management involves collaboration between stakeholders, since, typically, no one has all the resources (e.g. time, money and knowledge) to do this satisfactorily on their own. To manage together, stakeholders need to learn more than just technical aspects of their river basins in question. They also need to learn about and recognize each other's concerns and points of view. They need to arrive at a shared understanding of the issues at stake and of possible solutions. Finally, they need to reach an agreement and pool resources to implement this agreement.

In the short term, social learning can result in water management that better serves the interest of all the stakeholders involved, thereby easing implementation. Long term, it can also result in improved management capacities: Trust may develop, relations may improve, new skills may be acquired and new knowledge and insights may be obtained.

Who should be involved?

Social learning in river basin management and AWM refers to developing and sustaining the capacity of different authorities, experts, interest groups and the general public to manage their river basins effectively. Collective action and the resolution of conflicts require people to recognize their interdependence and their differences, and learn to deal with them constructively. In considering who to involve in AWM processes it is important – at an early stage – to think about:

- Who may contribute to or block decision making?
- Who is needed for or who may block implementation?
- Who is directly or indirectly affected by, or may have an interest in the issues at stake?

Following these questions, potential stakeholders are short listed. Stakeholders may typically include water companies and associations, water and environmental authorities, environmental NGOs, farmers associations, industrialists, anglers associations, water sports associations and water transport authorities. If needed, a thorough stakeholder analysis can provide a more complete picture of the situation to avoid the exclusion of key stakeholders at an early stage.

Advantages and limitations

Social learning supports each step of the AWM cycle; for example, by changing people's perceptions and behaviour. It can lead to an increased understanding of why individuals and groups of people act in a certain manner. Consequently, it can assist processes of transformation by supporting adaptive management's exploration of mutually beneficial outcomes. Social learning not only supports the analysis and the planning phase in water management processes but also supports the implementation of water management tasks through its reflective component and the improved collaboration of team members.

Social learning – and the learning about social learning – teaches us to pay more attention to the performance of our water management system and to the context in which it takes place, rather than to prescriptive routine activities.

One of the desired results is that the collective knowledge base – meaning all stakeholders involved – will increase. Social learning and AWM require a new style for personnel management. Critical self-reflection and an open dialogue on the strengths and weaknesses of an implementation process cannot be taken for granted. The necessary training and capacity building will probably require time and money especially in the initial stages of the process.

Despite the fact that a transition to AWM would almost invariably be a positive step towards more sustainable water management, there may be additional factors which make this transition more urgent.

So when is it recommended to employ AWM?

- When information is insufficient to predict direct and indirect consequences of project implementation.
- When information is insufficient to develop an operating plan where external factors dictate the timing for the implementation of measures.
- When disagreements exist regarding the reliability of predictive model outputs and projected operational scenarios.
- When overall uncertainties are associated with various stages in the project planning process.

To better assess the need and urgency of AWM according to the aspects mentioned earlier (cc Clair et al, 2006), a well founded level of knowledge is indispensable. Training and capacity building raises the awareness of the potential of AWM and provides practitioners with the knowledge to make informed judgments.

So what does capacity building for AWM mean in practice?

Regarding the building capacity for transition to and implementation of AWM, the NeWater project aimed to develop a broad range of training courses including training material to support the dissemination of knowledge, concepts and tools on AWM. Great emphasis was placed on the developed training material covering all steps relating to a transition towards AWM. The project's function as a role model was also taken into account. Accordingly it is important to make the distinction between two goals: (1) to enhance people's knowledge on AWM and provide them with the means to start an AWM; and (2) to disseminate tools and methods which enable practitioners to further improve their attempts in implementing AWM.

To summarize the contributions of capacity building in AWM

- Training and capacity building is needed to disseminate ideas and increase the understanding of AWM, therefore supporting knowledge transfer;
- Training and capacity building is needed to facilitate social learning and increase reflectivity among project members or stakeholders of water

management projects as a major precondition to the implementation of AWM;
- Training and capacity building is needed to support knowledge elicitation processes in project teams or stakeholder groups dealing with AWM;
- Continuously updated and adapted training and capacity building should become an inherent project management task to guarantee effective communication and information flow.

A more detailed description of training courses that have been developed, target groups, obstacles found and their identified solutions, such as the 'broker concept, in addition to further lessons learnt, can be found in Chapter 4: Capacity Building and Knowledge Transfer.

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2
Working Towards AWM

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2.1 Key outcomes and benefits of AWM

Nothing characterizes adaptive management better than the call to embrace uncertainty, and to be proactive in the design of better policies to avoid unpleasant surprises. Firstly, this means that uncertainty of all forms is acknowledged, and its consequences explored. Secondly, by taking on the challenges this uncertainty poses, we can take full advantage of the opportunities for better analysis, robust and flexible policy design, and efficient learning institutions. Finally, the implementation of adaptive water management (AWM) provides greater resilience in the face of those unexpected conditions and uncontrollable, possibly irreversible changes, which inevitably may give rise to huge negative impacts on both ecosystems and society. Accepting this, we need to consider the measurable outputs and outcomes that research and policy are supposed to deliver.

To make a distinction between outputs and outcomes is paramount to any heedful assessment. Outputs are usually activities or their straight achievements, milestones and products. Take for example a training and awareness-raising workshop meant to promote and diffuse the principles of Integrated Water Resources Management (IWRM) or AWM in management practice. The activities leading up to a workshop, where an avenue for dialogue is explored, and the workshop itself, are observable and measurable outputs. Outcomes on the other hand are accomplishments reached through these outputs and in terms of pursued objectives. For example, the number of participants or institutions who actually apply the knowledge gained during the workshop in their practical work and the degree to which this itself makes any difference, may constitute an outcome.

What distinguishes outputs and outcomes is that the former are not an end in themselves, but a mean to achieve these ends. Sure enough the link between them may not be straightforward. The degree of uptake of any new ideas in management or elsewhere depends on many other factors besides the acquired skills and initial enthusiasm of their sponsors. The legislative mandate may for instance limit the extent to which regulatory decisions may be flexible or their compliance negotiable. Also a hierarchical organizational set-up, and expertise dispersed among many institutions may not help to successfully experiment with bottom-up public engagement. Thus it may be difficult to assess the effects of such research or the resultant policy, on the basis of their eventual, long term outcomes (NRC, 2008).

The overarching goal of sound natural resource management is an equitable, efficient and sustainable use of managed resources (e.g. water, forests, and species stocks). The governance systems put in place in democratic societies to reach this goal must respect the principles of good governance, as laid down in the EC White Paper on Governance (EC, 2001): to be transparent and accessible, inclusive, effective, coherent and accountable. Good environmental governance is both an end in itself and a means to reach higher level environmental goals. This suggests that the ultimate research and policy outcomes of projects and initiatives towards AWM may be measured by how closely these goals both can be, or have been, achieved.

Adaptive management provides guidance on the means of reaching these goals, in situations where our knowledge of the underlying system processes is limited, and a high level of uncertainty exists. Thus the ultimate and overarching (long term) outcomes of adaptive water management are flexible and adaptive institutions, resilient society and ecosystems, and the ability to cope with those occasional extreme events which inevitably will come along.

Figure 2.1 describes examples of short-, medium- and long-term outcomes of the AWM process, and their relation to environmental goals and principles of good governances. Notice the mutual reinforcing effects between governance and AWM outcomes: we believe that institutions can only be flexible and adaptive in the sense described in this book if they operate within a bottom-up policy process.

In the four years of the NeWater project, work has produced a number of outputs and short-term outcomes. Formal outputs include all deliverables accessible from the project's web site and the WISE-RTD research portals. The 12 synthesis products of which this book is a part, incorporate most of them. The numerous training, dissemination, horizon-scanning and foresight workshops that have been held throughout the project, have engaged thousands of individual end-users such as public authorities and their scientific staff, scientific and public-interest groups, and of course citizens themselves. This has promoted and informed dialogues about how to initiate and deploy flexible and robust policy responses to the management challenges faced in a variety of different social and geopolitical contexts.

The list of short-term outcomes includes better analysis and appreciation of

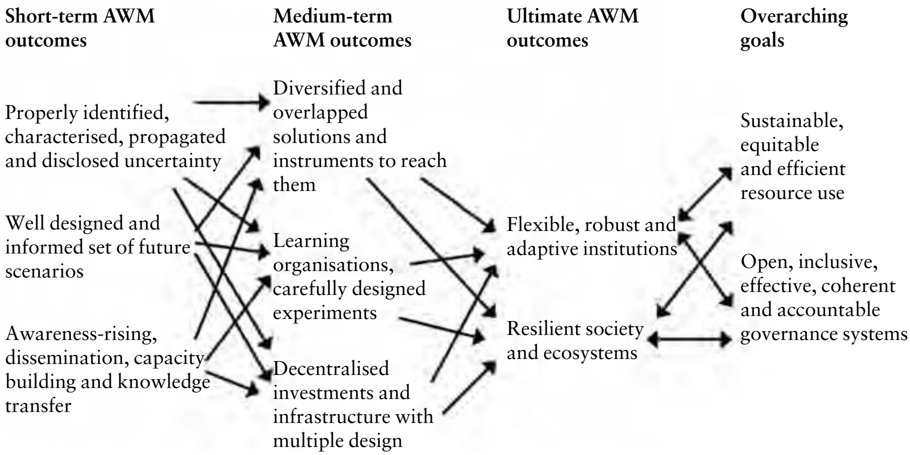

Figure 2.1 *Examples of short-, medium- and long-term outcomes of the AWM practices in relation to overarching goals of natural resource management and principles of environmental governance*

uncertainty in the various policy contexts of the river basins included in this study. This would include the assessment of feedback loops and unintended consequences set-off by otherwise well-intentioned policies, an assessment of future changes to the water cycle due to shifting climate, the design of monitoring campaigns in data poor situations, and many other issues (see also Table 2.1). Taken together, these short-term NeWater outcomes have provided improved knowledge about the practical implementation of adaptive management efforts, and have put 'seeds' to support such efforts into the policy contexts of the case studies. Many of the short-term outcomes will bring discernible results in the medium term, but it is too early now to see their full extent. How this *policy seeding* has been achieved in these cases studies is described further below, and in Chapters 5–11 (in this book).

The 'sowed seeds' (i.e. initial inspiration for adaptive course of action) fare better under the conditions described in Table 2.2 below (Pahl-Wostl et al, 2008). These conditions are to a large extent the same as for IWRM (GWP, 2000). This is why it is easier to unfold the potential of adaptive management in situations with already established IWRM regime.

A look at Figure 2.1 above suggests that, in the short term, it is easier to implement adaptive management thoughts and principles in the context of a single project or policy measure planning, as the path from AWM outcomes to overarching goals is relatively straightforward. It is far more difficult to reform existing entrenched institutions to become more adaptive in their promotion of further, autonomous improvements. To make this point clearer, we distinguish between *learning* (awareness raising, producing new measures and learning processes) and *system innovation* (transition toward more adaptive regimes).

Table 2.1 *Catalysts of adaptive management*

Management paradigm	Shift to a learning process with learning from the outcomes of management strategies instead of 'command and control' management approaches
Governance style	Polycentric, horizontal, broad stakeholder participation also focusing on managing uncertainties, instead of centralized, narrow stakeholder participation
Sectoral integration	Cross-sectoral analysis. Identify emergent problems and integrates policy implementation instead of analysing sectors separately
Information management	Open shared information sources that facilitate integration. Comprehensive understanding filling gaps instead of fragmented understanding
Infrastructure	Appropriate, decentralized, diverse sources of design, power delivery instead of massive, centralized infrastructure, single sources of design, power, delivery
Finance and risk	Financial resources diversified using a broad set of private and public financial instruments instead of financial resources concentrated in structural protection
Transboundary management	Analysis of multiple scales and transboundary issues instead of exclusive focus on analysis and management at a sub-basin and/or national level. These properties do not necessarily apply to all cases

Table 2.2 *Examples of AWM outcomes (outputs and benefits of AWM)*

Definition of outcomes	*AWM outputs (short-term) (intermediate outcomes)*	*AWM benefits (long-term) (ultimate outcomes)*
AWM learning cycles	Awareness about ambiguity, frames and uncertainties. Scenario planning, hypothesis and experimental approaches	Viable pilots and innovative measures have been implemented and performance evaluated based on monitoring and learning
AWM System innovation in management regimes	System is in a transition toward a more mature AWM management regime. Experiments and monitoring is initiated	System has reached a more mature AWM management regime (more resilient/adaptive). System performs better in situations of change

AWM learning cycles can produce innovative outcomes such as adaptive management plans, negotiated agreements, coping strategies, and protocols for learning experiments, all of which can eventually lead to behavioural change in management circles.

'System innovation' or change of the management regime, implies that profound changes of the entire system are happening, where the system has developed its adaptive capacity, and learning is not only restricted to new strategies (and new measures), but also provides overall change in the structural conditions that stabilize the current regime. This is characterized in general by institutional changes, not only in terms of regulatory frameworks, but also in norms and values.

System innovation benefits should comply with the requirements for adaptive management, which are robust strategies (or regimes) that both perform well under variable yet uncertain future developments, but which, if necessary, can be easily and cheaply reversed. System innovation benefits towards adaptive management will thus be the progress in institution building, as well as making the whole system more flexible and sustainable in the face of change. System innovation benefits here refer to the elements that make the system more sustainable, as well as the spin offs towards other sectors, regions, and levels which become more integrated.

Table 2.3 provides an overview of the project activities in the case studies.

Table 2.3 *Overview of AWM properties and issues in case studies*

Outputs and benefits in NeWater case studies	*Amudarya*	*Tisza*	*Guadiana*	*Rhine*	*Elbe*	*Orange*	*Nile*
AWM properties							
Management, learning	x[1]	x		x	x		
Transboundary	x	x		x		x	x
Uncertainty	x	x	x	x	x	x	x
Scenarios		x	x	x		x	x
Monitoring	x	x					
Farmers' knowledge	x	x	x				
Stakeholders' involvement	x	x	x	x	x	x	x[2]
Public participation		x	x	x			
Info management	x	x	x	x			
Sectoral integration	x	x	x	x		x	x
Non-technical	x	x	x		x	x	
Planning, measures				x	x	x	
Capacity building, awareness raising	x	x	x	x	x	x	x
Issues							
Water shortage	x	x	x	x	x	x	x
Floods		x		x	x		x
Groundwater			x				
Water quality	x					x	
Ecosystems, wetlands	x	x	x			x	
Environmental flows (ecological water requirements)	x	x				x	

Note: 1, rigid at top and local learning; 2, country level.

2.2 Summary of outcomes from NeWater case river basins (outputs and benefits)

In the project, seven case studies focusing on large river basins in Europe, Africa and Central Asia have been deployed to explore the potential of adaptive management. Each of them faces a unique set of environmental changes and challenges, out of which we have been able to address only a few in each case.

Four European river basins, the Rhine, Elbe, Tisza and Guadiana exemplify various morphological, environmental, political and social circumstances in and beyond Europe. Entirely within the EU boarders are Guadiana and Elbe, while both Tisza and the Rhine originate outside the EU (Ukraine and Switzerland respectively). As they cut through Europe, they sometimes mark borders between different nations, and pass through large and important cities and industrial areas. They drain into three different seas: the North Sea (Rhine and Elbe), the Atlantic Ocean (Guadiana) and the Black Sea (Tisza). These basins all fall into three climatic regions: Mediterranean (Guadiana), temperate maritime (Rhine and parts of Elbe), and continental, in parts hemi-boreal (Tisza and parts of Elbe) climates. Together they are more than 4500km long (for comparison, the distance between Lisbon and Helsinki is 'only' 3360km). Taken together, these basins have a combined total area of more than 550,000km^2), exceeding one eighth of the entire EU territory, and supporting millions of residents across the EU.

Still, this is not impressive compared to the African rivers we looked into. The smaller African basin, Orange, is less than half the combined length of the EU rivers (2200km), and its basin is more than double in size, at some

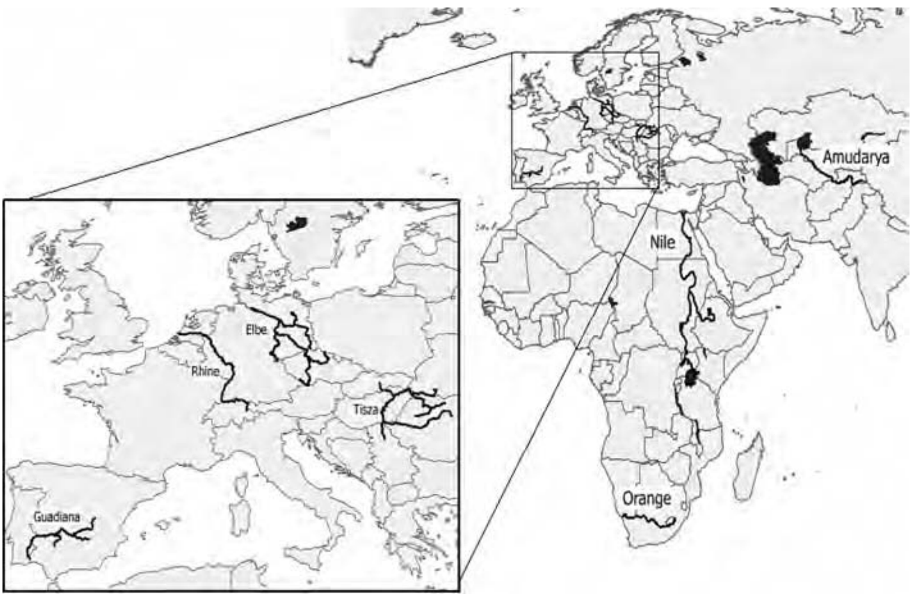

Figure 2.2 *Seven NeWater case studies*

970,000km^2). The Orange drains into the Atlantic Ocean and forms borders between South Africa and Namibia and between South Africa and Lesotho, and contains large areas of the nation of Botswana. The second African river studied in NeWater is the Nile, the world's second longest river (6600km long), with a basin area of 3.4 million km^2, covering some 10 per cent of Africa). The Nile flows through Uganda, Kenya, Tanzania, DR Congo, Rwanda, Burundi, Eritrea, Ethiopia, Sudan and Egypt, before it drains into the Mediterranean Sea.

The Amudarya is the longest river in Central Asia, slightly longer than the Orange, with a basin area comparable in size to all European case basins taken together. It originates in the Pamir and Hindukush mountains, above 6000m in altitude and fed by the Pamir glaciers. It forms the border between Afghanistan and Tajikistan, Uzbekistan and Turkmenistan, and later between Uzbekistan and Turkmenistan. If there is any water left in the river, it drains into the Aral Sea.

Amudarya River Basin

Potential contribution of AWM (Outcomes and Benefits)

Given the context of this river basin, the adoption of an AWM approach would help to achieve discernable improvements in coping with extreme events. Particularly, AWM would enhance the system's capacity to adapt to high variability of the river flow. This would help in overcoming the traditional and often inefficient water management approaches based on the development of large infrastructures for water storage and distribution. Such a new approach, in contrast, should aim to define flexible and robust water management policies, and be able to cope with unforeseeable conditions. To achieve this, water managers need to be able to monitor and assess the effectiveness of water management actions, and to introduce an appropriate strategy of required adaptations.

In this river basin, the general goal of better water management can be achieved introducing two important innovations, that is the adoption of a multi-scale approach, and the investigation of management actions' impacts on different components of the socio-environmental system. The adoption of a multi-scale perspective, which is fundamental for AWM, can help water managers to cope with problems at the river basin scale, without losing attention to the policy impacts at local scale. It is important to highlight that the impact of a given management action may vary at different scales (e.g. the impact can be positive at local scale and negative at larger scale or vice versa). A potential practical contribution of AWM in the Amudarya river basin concerns the development of a multi-scale monitoring and evaluation system able to assess the effectiveness of water management strategies both at the basin scale and at local scale. The assessment of water policies also requires the adoption of an inter-sectoral approach. Current management practices tend to focus only on one aspect (i.e. water allocation for irrigation) neglecting the effects on other components of the system. This leads to an incomplete and erroneous evaluation of policy effectiveness.

NeWater activities

The activities carried out in NeWater contributed to making some progress toward the achievement of the above mentioned outcomes. Particular efforts have been made to develop a new monitoring programme able to integrate locally-based information with the current monitoring practices. This information aims not only to increase the availability of environmental information, facilitating the evaluation of management actions, but also to enable monitoring to collect information on the effect of management actions at local level.

Moreover, work in this case study has made a start in the integration of environmental flow analysis into the framework of institutional water management. The related output is a strategy aiming to facilitate the definition of an integrated assessment of management actions. A set of indicators have been developed to take into account the effects of water management strategies on the livelihoods of people living in the wetlands area. A strong participatory process has been implemented to identify the aspects of local community life to be taken into account in the evaluation.

After successfully having been introduced, methods of stakeholder participation and the potential to elicit the views of diverse stakeholders was demonstrated by the NeWater initiated learning processes. Regional managers showed an interest in learning about the needs and interests of 'their' farmers to improve local water management. The methods of stakeholder participation, particularly group model building, and the resulting more holistic view of the issue in question were received as useful tools by local stakeholders. More practical studies also gave confidence to the stakeholders by using farmer's knowledge to enhance soil salinity monitoring at low costs and developing a procedure to integrate this knowledge into the existing monitoring structure.

Tisza River Basin

Potential contribution of AWM (Outcomes and Benefits)

The main contribution that AWM could give to this river basin concerns the potential it has for the improvement of flood risk prevention and reduction of system vulnerability. The increasing frequency of flood events is due to both climatic conditions and factors linked to human activities, which are inducing a reduction of the water storage capacity of the watershed, a change in river regulation, a decrease of forest coverage and an increase in the area of impermeable surfaces (urban development).

Traditionally the flood risk has been seen only as a hydrological phenomenon. Flood risk management has therefore been directed almost exclusively toward curative methods. Dykes and dams have attempted to contain the floods while crisis management and insurance have compensated for losses. This approach often results in an increase in management costs due to the high inflexibility of the strategies, which are not able to undo decisions which turn out badly without losing all the process up to that point.

As a contribution to the management of the river basin, AWM can extend the epistemology of natural hazard to include the concept of system vulnerability. According to this novel approach, flood risk management is based on the reduction of vulnerability rather than on curative methods. It encompasses natural, technical and social sciences as well as stakeholder experience, and forces more flexible strategies to create more durable solutions in flood risk prevention and management. Flexible strategies could concern land use planning, agricultural practices, selection of the crops, etc. To define these strategies, the perception of stakeholders of their own risk is significant as it will ultimately influence their behaviour.

NeWater activities

The activities carried out in NeWater mainly concern the integration between local and expert knowledge, leading to the development of a strategy for flood risk management and preparedness, which take into account alternative options for both flood mitigation and risk adaptation. Among them, access to information, and local information management as well as education on floods, received particular attention. Knowledge elicitation and structuring methods have been applied to elicit local knowledge and mental models about flood risk and flood preparedness strategies to cope with flood. It is important to highlight that the activities carried out during NeWater implementation have resulted in an increase in awareness about the importance of public participation in elaborating strategies for flood preparedness. Moreover, knowledge transfer has taken place during the debate, making the participants more aware of the importance of non-technical measures to cope with flood risks, e.g. improved information access and local information management. This integration among different sectors has been achieved through the involvement of stakeholders working in different domains.

The results of NeWater initiatives in both parts of the basin were twofold: the participatory design process of model, tool and game development on the one hand and the result of that process (e.g. models, games) on the other, has started a process which in the long term may result in benefits in the form of both learning and system innovation. Combined with local initiatives, such as the promotion of soft flood risk measures, NGO-driven initiatives towards more sustainable floodplain management etc. have put in place a foundation for actions such as the program of comprehensive flood protection of the Tisza basin in the Transcarpathian region, Ukraine (2002–2006, updated until 2015).

Guadiana River Basin

Potential contribution of AWM (Outcomes and Benefits)

The intermediate outcome of stakeholder involvement by the NeWater activities was the increase of farmers' knowledge and learning about the negative effects of groundwater exploitation. Other intermediate outcomes were the strong sectoral integration that facilitated knowledge transfer and shaped farmers' knowledge and public participation for raising awareness about key issues. Several agricultural and water policy scenarios (stakeholder- and policy-driven) were simulated and evaluated by groundwater models and Bayesian Belief Networks, and further supported by other tools, such as *water footprint* analysis, to feed directly into decision support tools relevant across the basin. This information management enhanced the managers, farmers' and conservationists' understanding of the environmental and economic problems related to irrigation and over-exploitation of groundwater resources. The whole process contributed to greater transparency, and as a result of stakeholder involvement, sectoral integration encouraged social learning by the exchange of information and a diversity of views.

The potential benefits and the success so far of this stakeholder involvement supported by the NeWater project, has been recognized by the Guadiana River Basin Authority and the Ministry of the Environment, and by the inclusion of selected local NeWater team members in the participatory process for the elaboration of the so called *Special Plan of the Upper Guadiana Basin* by 2009 (supporting the application of the WFD).

NeWater activities

The La Mancha Occidental setting is subject to a series of complex disputes, where measures to mitigate these have fallen short of expectations. Causes for this can be found in the lack of truly participatory mechanisms and a lack of transparency in water management, either on the part of the Guadiana Water Authority, or on the part of farmers who use groundwater for irrigation. In the absence of sufficiently strong political will to address these problems, and where there is little likelihood of win–win solutions, negotiations between the main actors have been further hampered.

NeWater has addressed these challenges by setting up two main activities (participatory processes) in the basin: Initially, the stakeholders defined the research objectives, asking for an implementation of a groundwater flow model of the aquifer in order to carry out a collective vulnerability analysis of the hydrological system under a series of plausible management scenarios. This was presented in a series of meetings between April 2005 and November 2006, followed by a second participatory modelling initiative. This second process focused on the development of a *Bayesian Belief Network,* addressing the need to evaluate the social and economic consequences of the implementation of the Special Plan of the Upper Guadiana basin in meetings held between May 2007 and Autumn 2008.

Overall, the joint synergies of using different tools for the development of Scenarios paved the way for learning, sectoral integration, and information management. This has been an attempt to initiate a process of change in the basin, providing support for the building of social capital and trust.

Rhine river basin

Potential contribution of AWM (Outcomes and Benefits)

In the Rhine basin, several water management issues have been addressed. Of particular interest has been the investigation of how AWM potentially contributes to the improvement of transboundary cooperation for flood management. Several severe flood events have demonstrated that riparian countries are mutually dependent in several aspects of water management. Unilateral actions in these basins are often ineffective, inefficient, or simply impossible. The challenge of AWM is even more complex in the context of transboundary river basin, because it requires coordinated and aligned changes in the institutional frameworks and management paradigms in the riparian countries.

In order to facilitate cooperation at transboundary level, AWM would lead to interventions in two fundamental aspects of water management, i.e. the structure of institutions for water governance, and information management in such river basins. Concerning the first point, the legal framework should be defined in order to lead the cooperation among the different hierarchical levels of the institutional framework, both within and across borders. According to AWM principles, international rules and agreements should be reviewed and evaluated periodically, in order to introduce adaptations if needed. This means, that AWM would lead to flexible legal framework for transboundary cooperation (Raadgever et al, 2008).

NeWater activities

The activities carried out during NeWater implementation have been mainly focused on the role of stakeholder involvement and public participation in water management. In the Wupper, a stakeholder process established by NeWater and the local water management association has led to an experiment to try out a new water allocation system in the sub-basin in a learning cycle. The process concerned the Dhünn catchment, a sub-basin of the Wupper, where the main problems are related to artificial water flows resulting from the Dhünn dam, and other multiple barriers such as small weirs and canalized stretches of the river which threaten ecological continuity and ecomorphological quality influencing fish population in the river Dhünn. The decision by the basin stakeholders to start an experiment with a changed flow regime in itself is already a direct intermediate outcome, as well as a good example of the potential benefit of an AWM approach.

During an interactive planning process in the Kromme Rijn region, it became clear that the stakeholder group 'farmers' had differing interests: low water level was desired by the dairy farmers, while fruit farmers preferred high water supplies to protect their fruit trees against frost. One of the benefits of the process was the reframing of the problem. The water board learned that the farmers were not just one homogenous group, but in fact were made up of two groups with opposing water interests. Each had specific water management requirements: level control for the grassland of the dairy farmers, and reliable water supply for the fruit farmers. The interactive process in which these differences were discussed led to the building of trust and a reframing of relationships. The water board also realized that they themselves were a stakeholder with a stake in the management of water and limitations as to how much they were able to maintain a certain water level and provide a water flow that would meet all the water needs. The new water management plan can be considered as the output of this NeWater activity. Moreover a handbook on interactive planning processes that is being written by the water board shows the learning that has taken place. Finally the interactive planning (AWM) approach has improved the potential of water board and stakeholders to collaboratively adapt the plan when necessary in the future.

Elbe river basin

Potential contribution of AWM (Outcomes and Benefits)

As reported previously in the Tisza river basin, AWM has the potential to lead to improvements in flood management shifting the focus from curative methods to actions aimed at decreasing system vulnerability to extreme events. To this end, the different components of the system should be taken into account. Among them, the vulnerability of the social system plays a crucial role.

In order to reduce such vulnerability, AWM would require the adoption of a strong polycentric management framework based on active stakeholder involvement to build commitment and the social capital required for social learning. This is based on an increasing social awareness of the threat of flooding and of the role played by human activities in flood prevention. Adopting measures for flood protection at the household and community level will build community resilience, and contribute to a reduction in the impact of extreme events.

To this aim, it becomes fundamental to organize participatory processes based on open access to easily understandable environmental information. To support involvement in the decision making process, participants should be fully and equally informed about both the state of the environment and the potential effects of any actions. Information should not be presented in an authoritative way, but in a facilitative way, to stimulate reflection by the stakeholders about what is possible, and about what it is they want. Different means for information dissemination should be applied, i.e. web-based information systems, workshops, documents, media, etc.

NeWater activities

It is hoped that the outcome of this case study is the adoption of an adaptive approach to cope with the impact of flood and drought. A participatory process has been implemented in the basin, resulting in the *Integrated Flood Protection Strategy*, which represents an agreement between stakeholders, scientists and decision makers. In order to increase the adaptability of the plan, the technical measures concerning infrastructure development and management have been integrated with adaptive measures such as on extension of the floodplain and its incorporation into management, the enhancement of infiltration and water retention, a review of agricultural practices reducing runoff, and the development of forecasting and warning systems. Reactive measures also remain important, e.g. increasing the efficiency of water management structures in non-stationary conditions, the efficient delivery of information and warnings to the populations at risk, timely evacuation of people, and post-flood recovery plans.

The identification of feasible and adaptive measures has been based on the integration of participatory process and modelling techniques. The integration of models in the process allowed stakeholders to be more fully informed about the possible consequences of management actions. Moreover they were aware of other participants' interests. Furthermore, different scenarios have been developed in order to verify the impacts of each proposed management strategy under different circumstamces. A positive outcome of the process was that technical staff came to support these participatory learning approaches.

Orange river basin

Potential contribution of AWM (Outcomes and Benefits)

The most pressing problems in the Orange basin, and the wider region, concern inadequate water availability and declining water quality. These problems are the result of several natural, climatic and socio-economic drivers. In these conditions, AWM has the potential to lead to improvements in water quantity and quality, by increasing human capacity to investigate the impacts of these drivers on both livelihoods and the state of the ecosystem within the basin, and to identify the most suitable measures to be taken.

Due to the complexity of the real world, it is not possible to define a perfect scenario. AWM attempts to address the complex system of relationships, feedbacks and loops existing within any system, with a view to generating better preparedness by decision makers and stakeholders for the various possible alternative futures that may arise.

As a consequence, the decision-making process does not aim to identify the most suitable course of action in clearly defined conditions. Rather it looks for 'robust' strategies, able to perform reasonably well under future conditions which are uncertain. In the case of the Orange basin, there are several drivers with unknown effects on system changes, with major, yet unclear cross-cutting impacts. This gives rise to interesting possibilities to elaborate sequential strategies of decision making. In a sequential strategy, the decision is split into several subsequent commitments which are influenced by knowledge emerging in each phase. According to this approach, the number of possible solutions decreases with the increase of the knowledge level. Thus, the set of potential alternatives is wide at the beginning of the process, but through consultation and investigation, it is gradually narrowed down to a realistic set of possibilities.

In the Orange basin, the focus has been placed on the role played by various ecosystem attributes in the support of local livelihoods, and the role played in that process, by both water and population change. This has also enabled an exploration of both intended and unintended consequences of policy measures, and to facilitate participatory resource evaluation and model development.

NeWater activities

Among the different activities carried out in the Orange river basin, the involvement of local stakeholders and experts in the development of alternative scenarios is particularly interesting. As a result, a user-friendly book for water managers to facilitate their comprehension of possible future scenarios, under different climatic and socio-political conditions has been produced. Moreover, several training sessions have been organized in order to increase the capabilities of local managers and stakeholders to manage water in uncertain futures.

In consideration of water quantity and quality issues, stakeholder consultation revealed that information relating to wetland functionality was severely lacking, and this knowledge gap had given rise to poor management practices which had resulted in severe wetland degradation. To address this, a detailed study of ten wetlands was carried out in the upper Orange-Senqu basin, and key functionalities were both identified, and valued economically. The information from this has been summarized in a user-friendly book which has been distributed to stakeholders, to raise awareness of the need for better wetland management to address both these quantity and quality issues. This is of particular relevance to the Lesotho Highlands Development Authority who have responsibility for catchment management in the Lesotho part of the basin, and also for private landowners who may not have been aware of the value of wetland functions. A major objective for this work was to secure a continued flow of wetland benefits to support both the more vulnerable groups in society such as women and children, and also to support economic development at the municipality scale.

The other major component of the Orange basin case study focused on an examination of water vulnerability, particularly under conditions of climate change. This involved the generation of a detailed hydrological model of the whole of the Orange basin, linking land use and water resources, then taking account of alternative futures from model information downscaled from a selection of models used in the IPCC. This work enables an examination of different possible hydroclimatic futures across the basin, which in itself is very useful to authorities in understanding potential changes in the flow regime of the river.

To examine water vulnerability more explicitly, comprehensive data on aspects of vulnerability of water users and water systems was collated from national datasets, and presented at the municipal scale. This information was then used to calculate a Water Vulnerability Index and this was applied across 187 municipalities in the South African part of the basin. This enabled the identification of those parts of the basin where people may be most vulnerable to changes in the water regime, both at present, and in the future.

Other work carried out in the Orange basin examined institutional challenges associated with the management of this large transboundary river, and different participatory modelling techniques were developed and used to examine linkages between different agents in the system. As a spin off to the case study activities, the local NeWater team has been charged with developing procedures to determine Resource Quality Objectives for the Republic of South Africa, giving rise to clearer possibilities to support the implementation of AWM, which creates the possibility to build adaptive management strongly into this procedure in South Africa.

Nile river basin

Potential contribution of AWM (Outcomes and Benefits)

The Nile River Basin is a complex river system passing through many climatic zones linking communities with specific socio-economic development and cultural backgrounds. However climate change and variability is expected to occur in the region with impacts on water quantity and the ecological state of the river. The main concern in the Nile is cooperation between riparian countries, further complicated by the political instability in this stratified region. A further impediment to the water development of the basin is the 1959 international agreement which provides Egypt with the exclusive rights to veto projects upstream that may change the water allocation of that country. In order to develop from this rigid top-down management, a more adaptive basin-wide platform was created. The Nile Basin Initiative (NBI) has been a praiseworthy initiative to bring the water sector of the riparian countries together to solve a broad number of water issues of transboundary nature. The main motto of NBI is 'to share the benefits of the water rather than to share the water resources itself'. A next important step towards adaptive management is to provide the member states with a tool to discuss and negotiate on the water resources in a transparent way, linking the common Nile interests with their own development options.

NeWater activities

Given the unique position of Nile Basin Initiative, the NeWater decided to work at the integrated basin level and to operate under the umbrella of the existing NBI activities. NeWater focused on the relation between water management and spatial planning through the Waterwise model – a tool to integrate spatial planning with strategic water management decisions, stimulating discussions between stakeholders competing for limited water and land resources. In this way the member countries can make the effect of their land and water use on the total river basin visible, and the critical flows for the delta in Egypt. Basin-wide, one can compare optimum land use scenarios in the member states which support an adaptive water management regime. Based on the scenarios the countries can negotiate their new ‘water’ rights and reformulate their spatial planning to support their socio-economic interests. An important spin-off for the region is that the frustrating discussion on cubic metres of ‘real water’ evolves towards a more ‘virtual water’ approach, where the benefits of good water management (agricultural output and energy) become available to support the socio-economic development of the region and the diversification of their economies. It must be noted however that any implementation of new approaches in this basin is a painfully slow process due to the political complexity of the relations between the riparian states.

2.3 Experiences and identification of lessons learned from piloting AWM

We have described that a prerequisite for outcomes of AWM is the initiation of new learning processes (see Figure 2.1). Without such learning processes new measures or any system innovation can not take place. Even if learning processes are initiated, there is no guarantee that they will bring any medium-term or long-term outcomes, especially if there is not full support from the government, authorities and stakeholders to initiate these processes. Furthermore, AWM requires adequate resources, time and support from all vertical levels and horizontal networks in order to achieve long-term outcomes, social learning and building of social capital, which takes time and requires the development of a sense of ownership to the approach. Without any IWRM tradition (in Europe WFD) and leadership support the implementation of AWM cannot realistically be achieved. Indeed we can consider AWM as a handy (additional) tool for IWRM in cases where challenges, uncertainties or complexity requires a dedicated effort to reduce the potential for water-related conflicts. For many, IWRM was more an administrative burden, than a way to solve practical (local) problems. In such areas IWRM may not have been practised as much as it could have been. Here, the option of using AWM could also be appealing. In fact, some of the experiences from NeWater (e.g. from the Nile and Amudarya) seems to have helped water managers and stakeholders to realize, after piloting AWM, that the IWRM approach is indeed useful and needed.

Experiences from the NeWater case studies (Chapters 5–11 in this book) shows that leadership is needed and broad support from institutions is of vital importance. Government support is crucial for long-term adaptation, implementation of participatory processes, carrying out monitoring programmes, and for the enforcement of adaptive measures. Without engaged leaders and followers (of participating organisations, scientists and communities) AWM will have very little chance to be successful (it must be noted that AWM will be difficult to introduce or implement in areas where there is no practical tradition for IWRM).

Scenario development and analysis has an important role in making uncertainty more tangible. Participatory learning, and integrated assessments are essential to address policy and science integration, and the identification of innovative measures and needs for institutional system innovation. AWM makes sense of scientific evidence and points to policy interventions that are sufficiently robust to work well under different future conditions. Social learning and application of a diversity of tools used in combination is needed for integration and uncertainty analysis. AWM requires explicit acknowledgement of a broad range of scientific and policy uncertainties throughout the scenario development and decision-making process. Scenario development and integrated analysis and decision making under scientific, as well as policy uncertainty, are an integral part of AWM. Integration is needed at various levels and fields, between policy making and science, modelling and monitoring, and between natural science, technology and social science.

Full engagement of stakeholders is required for AWM, not only for information and consultation. AWM requires proper resources and time and proper support from all levels in order to deliver long-lasting outcomes. When real engagement happens, learning processes can become more efficient. Ownership of ideas plays a crucial role and trust is a key issue which takes time to develop. Windows of opportunity for change need to be utilized when they are open. Trust, transparency and a sense of ownership are of paramount important to AWM. Besides properly engaging and training local trainers in the application of tools and models it is important that the tools are properly selected for the participatory process. The participating actors feel an ownership of the selected tools, so that rather than reducing options they can provide more options for change, learning and innovation.

Integrated performance assessment by use of appropriate indicators, monitoring and modelling tools is important in AWM. AWM requires a proper combination of modelling (in fore- and hindsight), monitoring and public dialogue. Some tools, such as very complicated models, may be important for performance assessment e.g. under climate change, but they can also have a tendency to dominate environmental disputes if not used in a participatory way. Tools used in combination can provide synergy, e.g the combined use of stakeholder analysis, stakeholder engagement tools, participatory modelling by use of numerical groundwater–surface water quantity and quality models etc., can provide powerful information to support decision making.

Awareness raising is a long-term process which is an essential part of AWM. Policy diversities is beneficial and can provide a foundation for alternative approaches which can be especially robust in situations of climate change and economic change. Training in tools and processes are important for AWM to be efficient. Education and community involvement are pivotal for a long-term and solid understanding of the AWM concept, which is difficult to understand and easily misunderstood by researchers, water managers, policy makers and the general public. But again such efforts require a long-term strategy.

AWM may be more difficult for large river basins because the number and scale of conflicts may exceed the potential of AWM to instigate collaborative problem solving. In these cases, the application of multiple scale 'experiments' offers one way to shape the approach through a focused selection.

Build capacity	Commit to uncertainty	Think twice before deciding	Dare experiments	Plan for adaption
Based leadership	System analysis	Toolbox	Level of focus in pilots	Supported leadership en route
Effective leadership and sustained financial support are crucial. Horizontal and vertical coordination and harmonization are essential to facilitate change.	Integrated and forward-looking approaches need to take into account new realities and challenges. Short and long term scenario analysis can inform policy and specify learning goals. Commitment to uncertainty results in robust policies.	Diverse tools are needed to explore vulnerability and resilience, encourage systemic learning and create opportunities for adaptive water management.	Experiments can be put in place at different institutional levels. Successful small-scale pilot studies can help to instigate new management approaches. Integrated performance and compliance assessment require apposite monitoring.	Stakeholder engagement, education and the creation of bottom-up user associations are crucial steps to attaining adaptive surface and groundwater management.
Lighthouse	Explorer	Apparatus	Researcher	Nurture
L	E	A	R	N

Figure 2.3 *Box 1 Five metaphors and lessons learning from piloting AWM in NeWater case studies*

Based on these reflections over experiences from the seven case studies the following five lessons learned (see Figure 2.3) have been identified, and are introduced here with the five selected metaphors: Lighthouse, Explorer, Apparatus, Researcher and Nurture.

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3
Tools and Instruments for Adaptive Management

3.1 Management of participatory processes

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Management of participatory processes

Public participation is a term with many different meanings. In this guidebook we focus on participation in the policy process by the organized stakeholders and unorganized groups (the 'general public') as an instrument for Adaptive Water Management (AWM) (see Mostert, 2003). According to Pahl-Wostl et al (2008), 'the transition to more adaptive and integrative water management requires a paradigm shift towards participatory management and collaborative decision-making'. Hence, the question is no longer whether we should make water management more participatory but how.

In planning a participatory process, we need to answer several key questions. The first one is: why do we need participation? The most commonly cited advantages and benefits of participation include gathering additional information, gaining new perspectives on problems and the development of more creative solutions. Moreover, hearing relevant interests can increase the legitimacy of decision-making, leading to more 'ownership' of the resulting decisions, less litigation, fewer delays in implementation, and generally better implementation. Finally, participation may increase the transparency and accountability of government. As such, public participation reflects the changing role of government in policy-making. It can reduce the distance between environmental managers and the public as well as increase the responsiveness of the state to the concerns of the public (see Gooch and Huitema 2008). In addition to participation in decision-making, there is participation in research. In this guidebook we are only interested in participation in research if that research actually contributes to decisions in water resources management.

Different levels of participation can be envisaged. The 'ladder of participation' (Arnstein, 1969) distinguishes between 'informing stakeholders and the public', 'consulting them', 'joint decision-making' and even 'joint implementation'. A more recent approach distinguishes between different purposes of participation: 'notification', 'advisory', 'consultative' and 'decision-making' (Cowie and Borret, 2005).

Participatory processes that aim to support AWM do not need to be designed differently from other participatory processes. However, it is essential that participation goes beyond consultation and achieves active involvement. Only then is it likely that the participatory process will result in reflection and short feed-back loops that support AWM (see Pahl-Wostl et al, 2008).

How to design and start a participatory process?

There are well written handbooks to help people design participatory processes (e.g. Wates, 1999; Ridder et al, 2005). The reader is strongly advised to consult these or similar works if organizing a participatory process. These handbooks give an overview of issues one may need to pay attention to and describe a number of key principles to be respected in participatory processes. Moreover, they present different tools and methods to implement and support the process. Major questions concerning the design of participatory processes are the scope of the problems to be discussed and, related to this, the stakeholders to be involved. This is not a one-step decision but an iterative process in itself. Thorough stakeholder analysis can help to identify the major stakeholders to be involved and the major points of view to be considered. In addition, professional facilitation and committed leadership are needed to maintain motivation and momentum.

In practice, participatory processes often face strict deadlines and budget constraints, and the scope of the discussion topics is often pre-defined. This places huge demands on the organizers. They need to be very selective in whom to involve and whom to exclude, while not forgetting influential stakeholders that may block the implementation of decisions. Moreover, the organizers may need to be a little bit flexible with respect to the scope in order to make participation interesting enough for the stakeholders.

Ownership is an important aspect of the process. If ownership of the process and the knowledge it generates is in the hands of the participants, participation is much more likely to be a success and provide a basis for future problem solving. This is shown by the participatory process in the German Dhünn and in the Dutch Kromme Rijn (both part of the NeWater Rhine case study). The informal forum that was set up in the Upper Guadiana in Spain, while not directly related to any formal management process, did enhance trust and mutual understanding and provided the basis for future joint decision-making.

What do tools and methods have to do with participatory processes?

Participatory tools and methods can support participatory processes during different phases (i.e. problem definition, analysis, planning, implementation or monitoring and evaluation). In NeWater, different participative methods were used to inform research and public policy making throughout the seven case studies. The suitability of a specific method depends on its characteristics – e.g. the expertise and facilities needed, the intensity of interaction that it allows and the level of formality – and on the demands of the process at a given time – e.g. objectives and intended level of participation, background of the stakeholders and the available budget and expertise. Tools and methods should only be used if their possibilities and limitations are well understood and if these match with current requirements and available resources!

In this section, we briefly present different methods and their possible uses. More information is available on the NeWater web portal. As for methods enabling more active participation and interactivity between the participants, for instance, focus group discussions and mapping techniques were applied in NeWater. Other methods used, such as Q methodology (see Chapter 7 in this book), aim at eliciting individual knowledge and hence do not require interaction among participants. Mostly, the primary purpose of the methods used in NeWater was to elicit knowledge, e.g. through Knowledge Elicitation Tools (KnETs; see Chapter 8 in this book) or card sorting in order to improve research and be able to deliver results that are more relevant for practice. In addition, the participants were enabled to share perspectives with each other, e.g. by using Bayesian Belief Networks (BBN, see Chapter 6 in this book) or through Nominal Group Technique (NGT).

Applying participative methods is often a time consuming task. However, some methods, such as card sorting or the seasonal calendar, require considerably less time than other, more complex methods, such as BBN, role play games and citizen's juries. Still other methods, such as community walks or break out groups, may be kept very short or extended according to the needs of the situation. Apart from special software requirements for some methods (Q methodology, BBN), there are hardly any special facilities, equipment or materials needed.

Some participative methods require the use of several participative tools, as in case of KnETs, where interview, protocol analysis, card sorting/hexagon method and mental mapping/frames analysis are combined.

Every participatory method has its own drawbacks and challenges. Q methodology for instance is most appropriate for in-depth analysis but demands a considerable amount of time from the participants and requires careful interpretation of sophisticated statistical analysis by the analyst. In focus groups, a frequent problem is that individuals may dominate a discussion which can put the whole exercise at stake once it sways the opinion of the group or discourages others from taking part. This can be prevented by an experienced facilitator.

Different methods enable different kinds of learning. In general, the more interactive a method the more likely learning will occur. Thus, methods that work with groups such as group model building (GMB, see Chapter 8 in this book) or role playing games are especially important for AWM as they are triggering learning more easily than individually based ones. In group settings participants are exposed to different perspectives on an issue, possibly conflictive views can be identified and hence the participants are enabled (or forced) to think about it in more detail. That way, they are likelier to adapt or change their own points of view. Experience with participatory methods in NeWater showed that this can take people out of their 'normal' way of thinking. This may happen particularly within a research context as often there are no real decisions at stake even if the discussion evolves around real life problems. In such a setting participants tend to be more relaxed, creative and open to new ideas. This relaxed atmosphere is important for building trust, which is essential for taking on others' ideas and modifying one's own.

In order to adapt to new developments and improve the process, monitoring and evaluation activities are needed. If jointly conducted by process organizers and stakeholders, these activities not only improve project planning and management, but may even strengthen organizations, promote institutional learning and inform policy (see Estrella, 2000). A well evaluated and documented process makes it possible to improve the ongoing process and future processes, and generally to gain a better understanding of risks and benefits of participatory processes. Video recording would be an ideal way of documenting these processes, but often this is not possible and there is always the risk that some stakeholders might object.

Meeting the challenge of participation

One result of participation in the sense of active involvement is assumed to be social learning (EU, 2002). Social learning can be defined as 'learning together to manage together' (see HarmoniCOP handbook, Ridder et al, 2005, p 2). It could be argued that this is what is really needed to put AWM into practice. Social learning may start once different actors have come together to handle an issue in which all have a stake – such as the management of a river basin. It requires that the stakeholders recognize their interdependence and their differences and learn to deal with them constructively. Social learning does not require completely equal power relations, but if strategic considerations become paramount, no learning will take place.

Time and money are frequently reported problems in participatory processes. Depending on the scope of the problem, a participatory process may last from one month to several years and the costs vary accordingly. The Organization 'Involve' (2005) in a study on the costs of participation concludes that, although there is growing evidence that participation has many advantages, the costs are often hard to judge because they belong to different budgets or financial years (and sometimes are not explicitly budgeted for and are therefore hidden). To avoid growing scepticism on the usefulness of participation, mechanisms for measurement of costs would be helpful.

Participatory processes bear risks. Simple 'working rules', on communicating with the stakeholders for instance, need to be agreed upon and respected. This applies to researchers, too. Conditions and purpose should be made clear before starting a participatory approach. Experiences in NeWater showed this with respect to various methods such as cognitive mapping or card sorting. Not respecting the basic rules may result in dissatisfaction and ineffective participation (see Ridder and Pahl-Wostl, 2005, p 189). These risks should not deter anybody who really believes in participatory processes from giving participation a try. Often, participation is organized by people with little or no training and experience in the field. This too creates some risk, but the lack of expertise may be compensated, at least partly, by a strong motivation on the side of the organizers to turn participation into a success, by continuous monitoring of the process and a willingness to detect and implement possibilities for improvement.

3.2 Participatory Modelling

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Approaches to Participatory Modelling

For centuries people have developed and used models as a means to transparently simplify and generalize key features of the complex world they live in. Such models allowed society to thoughtfully communicate, deliberate over, and decide amid the uncertainty of a changing world. Graphic tools such as conceptual models open the discussion of complex systems to include people who find verbal descriptions too long and complicated. Often a single model replaces pages of text required to describe all of the variables and their interactions (Magnuszewski et al, 2005; Sendzimir et al, 2007). Systems thinking methodology provides an easily accessible graphic language (variables and links between the variables are the basic elements of this language). This enables us to carefully and rigorously develop a mutual understanding between stakeholders from very diverse backgrounds spanning policy, science, business and local practice and forge these diverse experiences and perspectives into a common conceptual model or family of models. Decades of group model building experience have developed a tradition of successful diagnosis and coordinated implementation of solutions of complex problems in the business world (Sterman, 2000; Vennix, 1996; Bertsche et al, 1996). Expanding beyond this state of the art to the broader world of policy formulation and implementation at the much larger scales of society and nature has proven much more challenging. Where long-term studies or experimental manipulations in the field are not possible (as is often the case in complex ecological–economic systems) representative models can help to fill knowledge gaps (Costanza et al, 1993). However, rare but compelling successes from around the globe point toward the frontier of using systems modelling to integrate policy, science and local practice (Van den Belt, 2004).

Modelling for prediction vs. Modelling for learning

Society commonly expects professionals, such as managers and scientists, to lower uncertainty, thereby placing a high value on predictive power. Modelling has a long history as a predictive tool with notable successes in very complex river systems. The power to predict is always contestable (Walters, 1986) but can be decisive. Forrester (1995) pointed out throughout his career that any relationship can be suggested in a group model building exercise with a variety of experience present. However, he insisted the validity of that relationship is unknown until one has described it mathematically and seen whether the resulting dynamics make sense let alone closely resemble historical data. Even if it is achievable, predictive power is very expensive, as it requires prolonged efforts of data gathering and highly skilled modelling. Checkland and Scholes (1990) counter with the question – How do we meet the needs of communities in danger who lack the resources to provide sufficient data with which to calibrate predictive models? River managers face similar challenges of managing uncertainty with little data about the relevant biophysical, economic and socio-political variables.

Moreover, the pertinence of expert-created integrated water models designed to inform policy decisions, or quantitative risk analyses to determine levels of 'acceptability', has been more broadly questioned due to the unrepresentative nature of these experts' values-based decisions (Fischer, 2000; Daniell and Daniell, 2006; Rayner, 2007). Apart from issues of capacity in representing a variety of world-views and values of concerned parties, it is unusual that one institution or individual possesses all the relevant knowledge and is in control of all the resources required to successfully make and implement decisions. Managers are therefore increasingly obliged to work in a participatory manner with other institutions, stakeholders, experts and the general public to create more acceptable models and plans, and to implement management actions (Loucks, 1998).

A number of participatory modelling approaches have been developed where the emphasis on learning establishes a goal achievable even with little 'hard' data. A learning environment may facilitate the most rigorous science possible under these circumstances by allowing access to information quite difficult to gather: how stakeholders really see the world and how they will interact with policy decisions. An open learning process can minimize conflict which can eventually translate into policy resistance. The group modelling process provides the means to firstly clarify and then, secondly, integrate diverse perspectives and transparently share what really is known and what is not.

A wide range of media have proven useful to convey complex mixes of values underlying goals and intentions of key stakeholders facing decisions about river systems. Conventional devices, such as lists, tables, and matrices, can accumulate and juxtapose ideas in ways that suggest interesting connections as one develops an overall synthesis. However, group exercises that use or create pictures, collages, and maps have also successfully revealed some of the psychological and social complexity that influences how stakeholders see the world, decide what is true or false, and react alone or in groups to various trends or policies. The web of relations that link the variables which stakeholders consider important can be captured rapidly with cognitive mapping (Axelrod, 1976; Eden, 1989), Rich Pictures (Checkland, 2000) or Mind Maps (Bryson et al, 2004). More complex relations (involving feedback loops and delays) can be explored using Causal Loop Diagrams (Vennix, 1996; Sterman, 2000). All these are considered 'conceptual models' that establish a qualitative understanding of the key concepts and their relations, since no single relationship has been verified against empirical data. However, such graphical representations show how all the assumptions of stakeholders are related to one another and work together to generate the trends that signify to the stakeholders that a problem exists ('reference mode'). The variables, the individual links between them and the entire model structure as a whole constitute hypotheses that can be tested and provide a comprehensive framework in which to set a research agenda that is relevant to policy options a manager is considering.

The qualitative understanding established with the conceptual models can be enhanced when the modelling processes challenge participants to describe the assumptions (links in the model) more precisely as mathematical relationships. For the stakeholders and water managers this clarifies the dynamic implications involved if the world actually operated according to the assumptions underlying those links. With little real world data on which to calibrate the model, such 'Microworlds' or 'Management Flight Simulators' do not represent any specific system in reality. However, Microworlds succeed when their output dynamics are sufficiently credible to participants and managers such that they feel confident to use such models to explore various policy options (Martin et al, 2007). The process of building the model step-by-step as a group culminates when the stakeholders decide what are the key questions and/or policies they want to test. These are then prominently placed as buttons on a user-friendly interface that allows managers and other stakeholders to explore how the world might qualitatively respond to various interventions they anticipate will or can occur.

Attempts to elicit the knowledge and underlying values of stakeholders have expanded beyond questionnaires and interviews to include participatory exercises such as role-playing games. Such games are models in that they are simplifications of the world. But instead of simplifying with pictures, variables or mathematics, the game offers a framework to look at the basic roles played by stakeholders themselves in crucial situations in their community. The challenge of portraying a role in 'public' has often so engaged stakeholders that a wider range of information about how people think and react becomes transparent to the group than would have been available from interviews. Such 'human models' can be also abstracted mathematically as 'agent-based' models (Janssen, 2002; Barreteau, 2003) which can be used to explore a wider variety of circumstances (longer time period, more actors, different sets of rules or policies, etc.) than possible in group exercises.

Participatory modelling processes offer access to tacit knowledge, the knowledge which is specific to local experience and very difficult to communicate to outsiders. This is possible mainly when specific protocols are used, profiting by the wide range of media available. Games or interactive settings such as policy exercises or group model building shorten the chain of translation from stakeholders to the model. Moreover the diversity of media allows us to grasp tacit knowledge, which is difficult to express in common language during interviews that often occur out of the current context in which crucial issues are at stake. Situation simulations, for example, provide a stakeholder with his/her own usual environment. Within the familiar surroundings of the current context we can observe and consider how people understand and act based on this locally-situated knowledge, where the situation might be as mundane as the constraints due to the use of a specific tools that they use.

This section very briefly introduces a diversity of participatory modelling approaches that have been used for research and to support policy formulation in river and other socio-ecosystems. Many approaches (e.g. Daniell et al, 2006; Daniell et al, 2008) are hybrids that employ more than one method in series or in parallel. Different circumstances (Table 3.1) can dictate the feasibility of employing PM. But on the whole it affords water managers access to information (ecological, economic and social) that greatly enhances their power to predict whether certain management policies will succeed or will not be accepted by society.

Table 3.1 *General Rules for implementing Participatory Modelling (PM) that involves collaboration between stakeholders (SH) (after van den Belt, 2004)*

Reasons not *to use PM*	*Reasons to include SH in PM*	*Reasons to exclude SH in PM*
SH not prepared to cooperate on a voluntary basis.	To create a rigorous process where very different perspectives can inform each other.	Including SH input is too costly in terms of time and money.
SH not prepared to communicate with each other and be open to other perspectives and solutions.	Foster an open democratic process whose transparency increases trust and long-term support for policies proposed by the process.	SH group is not representative of all perspectives in the communities and will generate a biased set of solutions that will be sabotaged by the groups left out.
Problem is not complex or dynamic enough to require PM.	To gain more and better (local) data that any one discipline, sector or institution etc. could not access.	Deficiencies in the SH group (bias) and the process itself (lack of resources) generates results that erode credibility in the process and the policies proposed.

3.3 Uncertainty and policy making

M. Brugnach, P. van der Keur, J. Mysiak

Introduction

If you take a brief look at the Upper Guadiana story (see Chapter 6), you will find many different uncertainties relevant to public policy judgements and decisions about the use and protection of fresh-water resources. The basin's water withdrawal is predominantly for farm water usage. The sustained overexploitation of groundwater reached the point of threatening the existence of the immensely valuable and dependent wetlands. The policy taken to solve the issue has not brought about the expected results, on the contrary, the situation/relationship grew worse between those with a stake in the water resources. Insufficient information about the extent and quality of water resources still available, the impact of continued withdrawal on the basin's environment, and the extent to which the withdrawal licences are complied with, are only a part of the problem. Other uncertainties exist regarding what is a legitimate use of water, who's right to water is more important and what can or should be done to address the causes of water stress.

Uncertainties of this kind can obstruct water management processes in many ways. How much water is actually being abstracted and is irrigated farming a sustainable option as water availability decreases? What is the impact of groundwater pumping, in many cases illegally taken, on dependent wetlands? How much could market and non-market value be protected by preventing illegal withdrawals? What would be the reaction of stakeholders to a stronger control of water entitlements? How much water could be saved if modern irrigation technologies were applied? For the Upper Guadiana, these are only a few of the questions that arise in the presence of uncertainty. Furthermore climate change and its associated impacts on stream and groundwater hydrology are connected with further uncertainties of even greater magnitude (see Section 3.7 for more detail). If the uncertainties are not taken properly into account, then the measures meant to establish good ecological conditions in European water bodies could fail.

Scientific and policy uncertainty

Scientific uncertainty can stand for lack of knowledge, existence of contrasting accounts, or inconsistency between a theoretical explanation and empirical evidence. It can upset our understanding of what happened in the past, what the present conditions of environment are and what changes can reasonably be expected to occur in the future. Some uncertainty can be reduced by further research, whilst others cannot. Thanks to the late MIT meteorologist Edward Lorenz we know that weather can only be forecast for the next few days, beyond that it is anyone's guess.

The levels of uncertainty may also vary. In the best case we know the probability of all possible future courses. In the worst case we are not even sure even about the direction of changes, e.g. whether the soil will remain a sink of atmospheric carbon dioxide or whether the increased temperature will turn it into a source.

Policy uncertainties on the other hand are associated with the different ways a problem is viewed and framed (ambiguity), and the values and expectations held. It is sensible to base environmental policies on sound science, but scientific aspects are not the only ones to be contemplated. Wider considerations which must not be overlooked include financial (e.g. are the costs disproportionally high), legal (e.g. can we effectively ensure implementation) and ethical implications (e.g. who bears the bulk of burden) in the choice of policy options. In addition, there may be different legitimate views in what constitutes the problem in hand and how it should be dealt with. Many differences are rooted in the diversity of stakeholders' expectations and the values they hold, which also prompts disagreement on how water resources should be managed (problem and solution framing). Scientific uncertainty makes these trade-offs even more difficult.

Policy making involves value judgements and impartial assessment of facts. The former is the 'preserve of political decision makers', the latter is the 'domain of science'; the relation between the two is 'one of constant mutual frustration' (Boulding, 1975). This frustration has many roots. Scientists' assertions are often accompanied by caveats, whereas policy makers would prefer definitive answers. This practice once upset a US senator to the point of him calling for 'one-armed' scientists (i.e. scientists who do not rush to debate their previous claim). Scientists in their own right are frustrated as they are not being listened to, or because they fear for their independence. Most often however, the frustration is due to the different beliefs as to what extent scientific evidence compels certain policy responses.

Uncertainty in AWM

The increasing awareness of both scientific and policy uncertainties led to a re-assessment in the way natural systems are managed, ultimately encouraging more adaptive and integrative processes of river basin management (Pahl-Wostl, 2007a). AWM and other strategies explained further on in this section can handle uncertainty e.g. by creating flexible solutions that are able to adapt to unknown, unexpected or changing conditions. To this end, the type of solutions sought are those which can work in a range of future conditions, and at the same time be successively adjusted and corrected as new knowledge is gained. Decisions, alongside scientific assessment, are informed by a range of legitimate opinions, expectations, values and beliefs of those affected.

In AWM, long-term uncertainties, often associated with key drivers such as energy policies, demographic development and climate change are particularly difficult to deal with. Learning from the past is not sufficient and needs to be complemented by 'learning from the future' (Scharmer, 2007). To enable such learning, more focus is needed on proper scenario development, using tools which support dialogue between stakeholders and assessments of uncertainty associated with WFD policy measures.

AWM puts an emphasis on the integration of a broad spectrum of knowledge, constant monitoring and built-in revision of policies. In addition, when dealing with natural resource problems, conflicting views regarding the problem may further obscure the definition of operational targets and management goals and may lead to strong disagreement about managing options. Adaptation requires political will, flexible planning and inclusive decision processes and tools (see Section 3.1). This uncertainty can only be addressed by stimulating learning processes, useful AWM tools (see Chapter 4) and guidance.

Strategies to deal with uncertainty

What can be done in situations in which uncertainty is considerable and therefore has important implications for the choice of policy options?

Firstly, and an important prerequisite, is to explore and acknowledge the full extent of uncertainty. It makes sense to examine the sources and magnitude of critical uncertainties, i.e. uncertainties which would significantly affect the performance of the policy measures considered. This is also important because in overemphasizing some sources and types of uncertainty, attention is called to approaches to reduce this particular uncertainty, rather than to encourage a comprehensive assessment of all practicable actions.

Secondly, at least in some situations, thoughtful policy analysis can reveal a policy which satisfies all involved parties, despite the persistent uncertainty. Tools which facilitate cooperation, conflict analysis and social learning (see Section 3.1), problem analysis and qualitative model building (see Section 3.2) are instrumental for this purpose. These techniques are set up to deal with multiple and conflictive views (ambiguity) and are the most appropriate for dealing with deliberative policy making, dialogue and negotiation. The solutions in these cases are typically robust under various future conditions or involve a combination of measures with complementary impacts.

More often than not, however, the regulatory decisions do infringe on the interests of some parties who may seek to underplay or overplay scientific uncertainty in order to compel or postpone preferred policy courses. In these cases, the policy gridlock may not be resolved even if some of the emphasized uncertainty is reduced or eliminated by further research. Delay in adopting the necessary policies therefore needs to be based on an assessment of how reducing uncertainty would help to single out the most appropriate policy response. This decision needs also take into account the costs of delayed action. For cases where it is reasonable to invest in reducing scientific uncertainty, sensitivity analyses and uncertainty methods can support the identification of uncertainties to be focused on in the first place. When future developments are afflicted with deep uncertainty (Kandlikar et al, 2005) for which little if any information exists, scenario analysis is most appropriate.

Thirdly, negative outcomes which are the result of uncertainty can be averted or transferred, so that their final impact is less alarming. The former include measures to reduce exposure or vulnerability to harmful events, or increase resilience and coping capacity (see Sections 3.5 and 3.6). An example of the latter is insurance (e.g. against farm losses by droughts) or other economic instruments such as catastrophe bonds. Another strategy is to impose liability on those who have caused or contributed to any damage which has occurred. The Precautionary principle is a strategy to avoid devastating consequences, by choosing policies which in the worse case, perform best, and is similar to the approaches above.

Finally, adaptive management includes all the options above, and offers more. Choosing robust policies means adopting policies which perform well under a range of prospective conditions. Alternatively, policy responses can be split into a set of subsequent commitments which can be reviewed (and reversed without prohibitive costs) as new knowledge comes in.

Where to look for help

Imagine a case in which decision makers have to choose whether to base their decisions on the currently available, if uncertain, information, or whether they mandate further data collection and pay for it. This choice is not a question science alone can give a response to. Various guidance documents exist which can help policy makers make these decisions.

In the Upper Guadiana case, substantial uncertainty exists about how much water is abstracted for irrigation. The existing monitoring system clearly shows that the depth of the groundwater level has dropped. A Modflow-MIKE-SHE model has been set up to analyse the overall water balance of the primarily rural area. The model results are imprecise because of the uncertainty in the model's input and structure, and because of model's adjustment to the basin's specific conditions (parameterization). To make the model represent the basin's specific conditions, one would need to gain better information regarding the hydrogeological characteristics of the aquifer, i.e. by drilling a hole and analysing the cores. Alternatively, it would be necessary to gain better information about the actual water withdrawal. The financial costs and time requirements necessary for these improvements are considerable.

Recently, within the framework of WFD implementation in the EU, uncertainty guidelines, especially for use in modelling, have been developed e.g. the HarmoniCA (Refsgaard et al, 2007) and HarmoniRiB uncertainty guidelines (Van Loon et al, 2005). Similar other guidance documents are listed in the online supplementary material. These guidance documents help model users and policy makers to better appreciate the sources, extent and ramifications of the various uncertainties. What we suggest is still missing, is the guidance that can aid the process of social learning and the changes that adaptive management entails. This is important, as otherwise uncertainty can obstruct cooperation and social learning, and negatively affect the commitment of the actors (Henriksen et al, 2008; Brugnach et al, 2008). To this end, under the umbrella of the NeWater project and building on previous work, a set of guidelines are being developed, in which concepts and tools that aid decision-making practitioners to deal with scientific and policy uncertainty are readily available (van der Keur et al, accepted).

Closing words

However odd it sounds, uncertainty is a valuable piece of information when it comes to choosing what to do. Uncertainty is frequently regarded as a deficit to be corrected by gathering additional information and by pursuing more research. Under this view, what is known for sure is not fully exploited. Even if deferring actions may be sensible in some situations, in others the time to act may be lost, sometimes irrevocably so. More is not always better. As adaptive management suggests, a more effective way to deal with uncertainty is to create the capacity, through learning and adaptation, to respond flexibly and effectively to unknown conditions.

In Guadiana, data from different sources differ widely and this divergence is used as an argument in policy debates. Disagreement about facts encourages civil disobedience and non-compliance with water regulatory decisions. Local government's limited ability to control compliance makes this even worse. On the other hand little has been done to encourage the shift to non-irrigated agriculture and less thirsty crops, or to a greater enrolment in voluntary agri-environmental schemes. A reduction in farmers' vulnerability to dwindling resources would ease the emphasis on the uncertainty about facts and the role it plays in water resources policy making.

3.4 Indicators and monitoring to support AWM

Caroline Sullivan, Carlo Giupponi and Raffaele Giordano

Indicators provide a means of communicating information about progress. This may be towards an overarching goal (such as sustainable resource management), or towards specific targets, such as those included in the Millennium Development Goals. They provide a convenient method of summarizing large amounts of data into a single value, which can then be compared over time, or between countries and regions, to reveal the process of change and the existence of significant differences in a simplified manner. In most countries of the world, the Consumer Price Index (Retail Price Index) provides a good example of an important and widely used measure which influences policy on a daily basis. For this, data is collected on the price of goods and services by measuring 'baskets of goods' that are representative of consumer spending patterns in a particular region. The items in each basket are used to create price indicators and are combined together to produce an index, giving an average measure of the change in the prices of all the relevant goods and services. This provides a measure of the change in overall prices which can then be used to support wage increases etc.

The challenge of a good indicator is to be able to create an alternative form of representation which captures a general picture of a situation which can then be used as a guide to conditions overall. This means that it may be possible to evaluate conditions of a region using a relatively small sample. 'Indicators must simplify without distorting the underlying truth (and) reduce the complexities of the world to a simple and unambiguous message'. The thorough design of an index is therefore essential in order to ensure that it achieves this accurately.

There is an extensive literature about indicators and indices, and those related to water resources management can relate to both quantity and quality measures. Some attempt has been made to include water indicators into UNDESA's Indicators of Sustainable Development (ISDs), but these are still to be fully developed, and tend to relate mostly to service delivery rather than water resources management. Sustainability provides the foundation for the multi-sector and multi-disciplinary analyses required by IWRM/AWM, and this type of indicator can provide guidance and support in a variety of ways for decision making at all levels of policy making. In general, they can translate physical and social science knowledge into manageable units of information which are then digestable by decision makers. Another crucial role of indices is that of providing a means of measuring, monitoring and reporting on progress towards agreed policy goals. Importantly they can facilitate the communication of ideas, thoughts and values (UNCSD, 2001). In the context of water management, indicators can support the assessment of the effects of policy measures (ex-ante), on the basis of scientific and social monitoring and analysis, and effectiveness of those measures (ex-post), by judging to what extent the observed effects match the stated objectives (EEA, 2001). In order to assess whether policies are working, and to fine-tune them in order to reach their ultimate objectives, indicators can be used to provide feedback to policy makers. In the context of AWM, this can then lead onto the next stage of an iterative learning and policy development process.

A review of current indicators

Most international institutions dealing with the environment and socio-economic development have provided their own methodological approach and set of indicators. It is not possible here to provide a comprehensive review of the various approaches used, but in the water sector specifically, an attempt has been made in the World Water Assessment Programme (UNESCO, 2001, 2006) to summarize these into a key set of indicators. Many different approaches have been published, and they vary depending on the specific context of their application: the scope, the appropriate spatial and temporal scale, and the policy framework and objectives. One well-known approach which attempts to provide a holistic integrated measure for water management is provided by the Water Poverty Index (Sullivan et al, 2007). This measure attempts to link water availability and provision to human well-being, and is particularly relevant to the international development agenda of the Millennium Development Goals.

In general, the development of appropriate indicators depends on consideration of the questions to be answered, and by identifying key issues of concern, the most suitable indicators can be designed and implemented. Formalizing these questions helps to get a good balance in the indicator sets. Moreover, combining relevant indicators into a composite index may reveal the available evidence more effectively than just simply using individual indicators (ICSU, 2002).

Linkages between policy and indicators

The effectiveness of indicators may depend also on the availability of a general conceptual framework, and within that scope, the European Environmental Agency (EEA) has adopted the DPSIR model. This involves the identification of appropriate indicators to represent the Driving force – Pressure – State – Impact – and Response resulting from a particular situation. Moreover, the EEA proposes the combination of the DPSIR framework with a classification of indicators into five categories (CEC, 2001; EEA, 1999). These five categories have been identified as:

- Descriptive indicators – in the stage of problem identification, these may identify alarming developments in the state of the environment, or impacts upon it. They will be mainly State indicators, that may give rise to policy reactions, for example they may describe the sudden decline of a particular species or of surface water quality. This function of state indicators is thus limited in time: as soon as a problem is recognized politically, the attention shifts to pressure and driving force indicators.
- Performance indicators – providing insights into any changes in driving forces and pressures, are the most widely used, since policymakers aim to focus on what they can actually influence to change performance of any attribute within a system.
- Eco-efficiency and policy effectiveness indicators – these are used in the next and longer stages of the policy cycle (formulation of policy responses, implementation of measures and control). These indicators support and document policy decisions plus the level of acceptance and uptake of specific measures. They also can serve as tools for measuring the degree to which the stated objectives are met, particularly with respect to the involvement of stakeholders.
- State indicators – these are used in the final control phase of the policy cycle, serving as a further means to monitor the rate of recovery of the environment.

Addressing the challenges to develop effective monitoring systems for AWM

Learning in Adaptive Management leads to a focus on the role of feedback from implemented actions. Such feedback-based learning models stress the need for monitoring the discrepancies between intentions and actual outcomes. Thus, a monitoring system for AWM has to be able to support the identification of changes in system behaviour due to management actions, possibly through the use of thresholds. A threshold can be broadly defined as a breakpoint between two states of a system. In AWM, exceedence of negative thresholds indicating undesirable system development is particularly important as part of this process. This then leads the way for renewed actions to support recovery. This highlights the importance of maintaining long-term datasets, and the fact that an effective monitoring system for AWM should be designed to support a long-term perspective, by providing a framework for repeated data collection and information provision.

Ideally, a monitoring system for AWM should address certain issues related to complex system dynamics. The issue of spatial and temporal scale must be tackled, since complex systems have structures and functions that cover a wide range of spatial and temporal scales. The impact of a given management action may vary at different scales. Also the time horizon itself influences how the impacts can be evaluated. Collecting long time series of data allows trends in system dynamics to be defined, facilitating the identification of system changes. Moreover, structures and processes are also linked across scales. Thus, the dynamics of a system at one particular scale cannot be analysed without taking into account the dynamics and cross-scale influences from other relevant scales. This emphasizes the importance of gaining reliable information about different parts of these spatial and temporal continua, and recognising that information at one scale may not be appropriate for application at a different scale (Sullivan and Meigh, 2007).

Taking into consideration these issues, AWM often results in a need to monitor a broad set of variables, with prohibitive costs if the monitoring is done using only traditional scientific methods of measurement, impeding the economic sustainability over time of the monitoring system. Thus, the development of an affordable monitoring programme to support Adaptive Management involves substantial scientific innovation in both method and approach, to facilitate the design of systems and information management. These innovations can be grouped into three main points.

Firstly, the sustainability of the monitoring system relies on its integration into the decision-making framework. The water management agency may waste money in a useless data collection task if the information is not appropriate to support the decision process. Therefore, it is fundamental to stress the importance of the interaction between the decision-making process and the information production process. To address this issue, contrarily to the traditional approach, in which the elicitation of information needs has been a top-down process, the design of a monitoring system for AWM should begin by bringing together all interested parties to discuss their understanding of the system, the management problem, the information needed and how this information should be used.

Secondly, a monitoring system for AWM has to be adaptive and flexible, able to deal with environmental changes and to adapt to changes in the political context and societal values, to incorporate new information, technologies and the findings of scientific research. Monitoring can be said to be adaptive by the degree to which it relates to the significance of the feedback between information production and the decision-making processes. An adaptive monitoring approach would not only incorporate feedback on management actions but would also rely on feedback to applied monitoring practices. From a practical point of view, the update of the monitoring plan is based on a critical analysis of the results of monitoring activities. Critical thinking involves an extensive series of reflective events, occurring alongside the data collection process. Therefore, during the monitoring design phase, it's important to plan learning as a series of events. In AWM the process of monitoring design (i.e. information needs definition, indicator development, etc.) is as important as the results of the monitoring activities themselves.

Thirdly, the design of an effective monitoring programme for AWM should include and integrate various kinds of knowledge. Particularly important is the integration between monitoring and modelling. This integration may increase the potential to usefully extract more information from available data and integrated modelling data, enhancing information utilisation. The integration of monitoring and models is fundamental in order to analyse the implications of water policies. It allows difficulties in understanding dynamic feedbacks of the system to be overcome. Such feedbacks can be particularly difficult in the environmental context because they are confounded by many interrelated factors. This process allows monitoring networks to be re-designed in the light of new model results. Conversely, the availability of new data promotes the revision and updating of models.

In practice, it is important to try and make use of existing information and measures which are already in place. This can be enriched by monitoring the body of knowledge held by a specific group of people about their local environmental resources, based on the hypothesis that local knowledge should not be seen as a simple counterpart of scientific knowledge, but should be combined as partialities of a whole knowledge system, leading to a broad hybrid view of local resource management issues. The integration of local knowledge in monitoring has several benefits for both water management agencies and local communities. For the communities, the benefits obtainable through public involvement are mainly related to the promotion of public awareness of environmental issues, the enhancement of collaboration and cooperation, and the promotion of a 'two-way' information exchange. In addition, environmental management agencies could increase available information without increasing the cost of information collection, enhancing the sustainability of the monitoring programme over time; they could base their strategies on more integrated knowledge, and on information on management effects at the local level, often omitted by scientific monitoring.

Development of an Adaptive Monitoring Information System (AMIS)

The conceptual architecture of a monitoring system for AWM has been defined within the NeWater framework (see Figure 3.4.1). This system has been designed to be adaptive itself, and so it has been called AMIS.

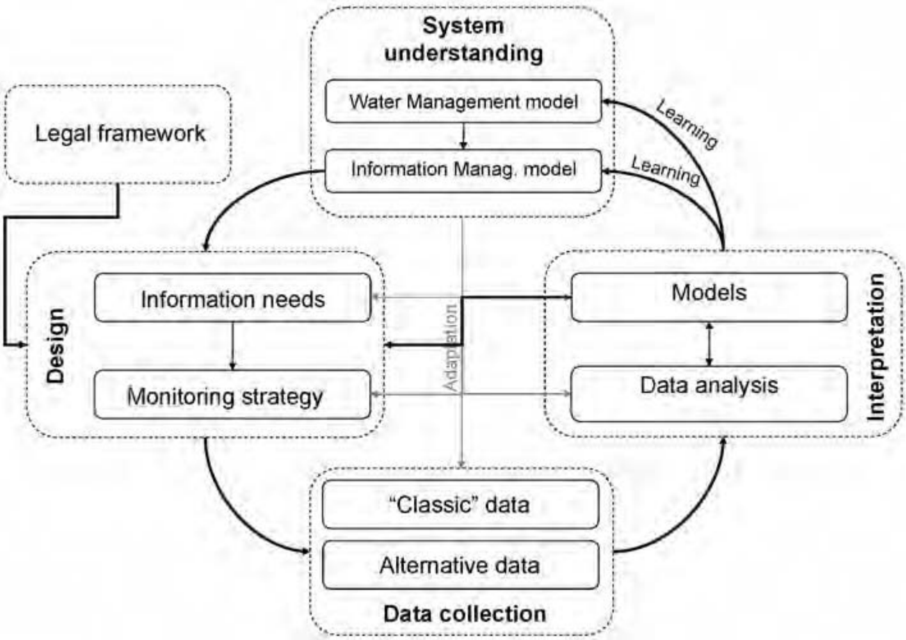

Figure 3.4.1 *Conceptual architecture of the Adaptive Monitoring Information System (AMIS) Source: Giordano et al (2008)*

The basis for the AMIS design is the conceptual model of the system, which simplifies the system and makes the key components and interactions explicit. The definition of this model is based on the integration between a participatory process, allowing experienced stakeholders to provide their understanding of the system, and models able to simulate future scenarios. Two different conceptual models, i.e. the 'water management conceptual model' and the 'information management conceptual model' are defined as the basis of AMIS. The former concerns the interpretation of the problem considered, while the latter concerns the information needed to solve the specific problem under consideration, and the 'frames' used to interpret the information.

The AMIS architecture consists of four main boxes, i.e. Conceptual model elicitation, Design, Data Collection and Interpretation. The links between them represent the iterative process of monitoring design, which is at the basis of AMIS. The cycle depicts a framework where information users and producers communicate information needs which link the monitoring and decision processes.

An important innovation in AMIS concerns data collection methods. AMIS is considered as the shared platform through which traditional monitoring information and innovative information sources (e.g. remote sensing monitoring, community monitoring, etc.) are integrated and made available for decision support. Two possible learning processes can be identified within this system. The first concerns the water management conceptual model. It may be that information may prove the initial models to be wrong, leading to debate between actors resulting in a revision of models, through reflection and negotiation, in a social learning process. This learning may, in turn, support changes in the water management conceptual model. Moreover, feedback on management actions may generate new questions or new insights. This may make the originally agreed information base appear inadequate, resulting in new information needs. The second learning process relies on feedback from applied monitoring practices. As a result of experience in implementing the monitoring programme and assessing its results, adaptation of the monitoring process itself may be needed.

A further activity within the NeWater project involving the design and use of indicators has been the development of a Water Vulnerability Index (Sullivan, Deiderichs and Mander, 2009). This has been developed in the context of the Orange basin case study, where water stress is a major challenge in most parts of the basin. In this composite index framework, information about both water users and systems has been collected from municipalities, and collated and incorporated with other relevant information in order to provide an easy-to-use measure by which water managers at the municipal scale can both identify 'water vulnerability hotspots', and determine priorities for remedial action. More information on this approach is provided later in the chapter on the Orange Basin case study.

Overall, in the context of AWM, it is important that indicators are designed and used in such a way as to provide holistic and reflexive insights into prevailing conditions. The information provided by such indicators should be explicitly related to particular management questions, supporting an iterative, adaptive process allowing dynamic management of the system as a whole. Within the NeWater project, the two novel approaches to water monitoring and indicators described in this section provide a foundation on which refinements can be made to support further progress towards the implementation of AWM at the basin scale.

3.5 An introduction to analysing dynamic vulnerability

S. Bharwani, J. Hinkel, T. Downing and R. Taylor

The uncertainty of current predictions of future climate change and the complex nature of dynamic socio-economic and natural systems need a faster and more responsive coping and adaptation cycle than in the past, which includes both expert and lay knowledge (Pahl-Wostl et al, 2007). This implies that new vulnerabilities may emerge which further complicate the ability to plan for successful transitions to a sustainable and resilient management regime. Managing these inevitable uncertainties requires an improved learning and adaptation mechanism in place of traditional command and control methods (ibid.). A key barrier to facilitating successful transitions is path dependence which is a consequence of investments in previous technologies and practises, resulting in 'lock-in' effects (even with an awareness that the current pathway is unsustainable) (ibid.).

Identification of factors that contribute to long- and short-term vulnerability allows the discovery of learning and adaptation mechanisms that have both worked and failed. The reasons for the successes and failures of these strategies may provide a broader range of adaptation responses (resulting from expert local knowledge) and thus less investment in one particular development pathway, potentially reducing 'lock-in' effects which inhibit innovation and experimentation when dealing with uncertainty (Liu et al, 2007).

Bridging the qualitative and the quantitative

By drawing out the differing levels of complexity, understanding, and actor differentiation in various approaches to vulnerability assessment, appropriate methods can be selected for addressing specific vulnerability questions (Bharwani et al, 2008).

Indicators selected in an inductive sense can be used in cases of rapid vulnerability assessment (Stephen and Downing, 2001) and in more detailed comparative vulnerability questions (Brooks et al, 2001). However, they are less helpful in regard to vulnerability reduction questions as they are not necessarily related to the causes of vulnerability in the same way as deduced indicators are (Tol and Yohe, 2007; Blaikie et al, 1994). Neither the inductive nor deductive indicator approach captures 'surprise' nor the emergence of new vulnerabilities which are difficult, though critical, to plan for.

Static indicators may have a place in the initial stages of analysis where we would like to identify hot spots at a macro level for further research (e.g. Sullivan et al, 2008). The predictive power of the causal factors of particular development pathways is limited as there is the assumption that the chosen set of indicators is an adequate explanation of the drivers of change in the system, even when tested under different pathways and scenarios. However, when exploring the dynamics of complex systems (where there are numerous unpredictable drivers) under conditions of uncertainty (which includes climate change), this assumption is not sufficient. Furthermore, if we are interested in new and emerging vulnerabilities which we may be unaware of, indicators (and other types of analysis) do not allow for the exploratory analysis of unknown or unforeseen factors. As is often the case with vulnerability research, we may not be asking the right questions at the beginning of the analysis, and we need to have enough flexibility to allow new questions to emerge.

Aggregated models (e.g. system dynamics, Bayesian Belief Networks) used in integrated assessment can also answer comparative vulnerability questions at national and global scales. For example, they are useful in assessing the aggregate costs of a given vulnerability reduction policy, but lose information on the distribution of vulnerability through the aggregation process. The Water Evaluation and Planning (WEAP) tool provides spatial representation but treats stocks and flows (e.g. water user associations) at a fairly aggregated level.

Agent-based models can be used in policy assessment and exploration, in order to study vulnerability (e.g. assessing the impact of a poverty reduction intervention), though they are difficult to validate. The approach potentially captures surprise in the form of how local properties propagate to a higher level (emergence) thus creating potential new vulnerabilities.

While the use of indicators may be efficient for rapid identification of vulnerable regions, one must recognize the limitations of extrapolating such indicators using socio-economic scenarios since the relationships between social variables are often poorly understood and the structure of vulnerability frequently changes. That is, while the causality of vulnerability may change, the structure of the indices does not and therefore they cannot reflect changing drivers (see Figure 3.5.1). As a result one must remain open as to whether hot spots of vulnerability identified at a macro-level are recognized as such at the micro-level, and if so, whether the cause of the vulnerability is the same as that assigned to indicators used for macro-level analysis. A synergy between these two levels of analysis may be beneficial.

Ultimately the choice of method (static, conceptual, dynamic, or model driven) depends on the research question, the required outcome, and the target audience. Thus, complementary methods may be desirable at different stages of analysis and have different conditions of applicability.

Integrating dynamic vulnerability into local water management

Vulnerability is complex and by definition it encompasses many attributes or multiple stresses (social, political, economic and environmental) which change at different speeds (slow and rapid change) and is therefore dynamic. If this is the case, we cannot assume to be able to capture vulnerability state per se, using static indicators as it cannot be bounded, even if we attempt to incorporate many differing viewpoints of vulnerability using participatory processes. The system changes faster than it can be assessed (or perceived in many cases) and indicators do not capture the functional processes of the system or the interrelationships between these processes.

One point of departure in attempting to integrate dynamic vulnerability into water catchment planning is the six attributes discussed in Downing et al (2006).

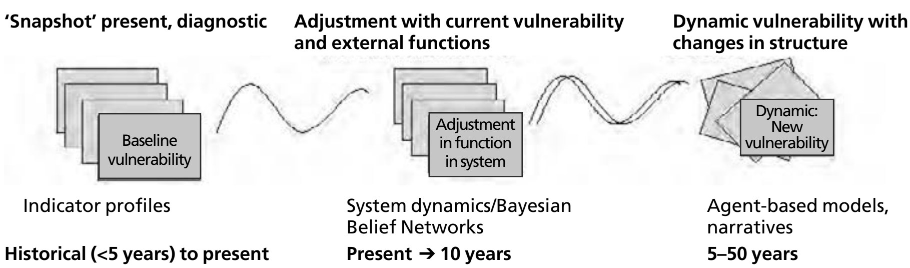

Figure 3.5.1 *The dynamic and transient nature of vulnerability*

1. Vulnerability is the differential exposure to stresses experienced or anticipated by different exposure units.
2. Vulnerability is not static – it is constantly changing on a variety of interlinked time scales.
3. Social vulnerability is rooted in the actions and multiple attributes of human actors.
4. Social networks drive and bound vulnerability in social, economic, political and environmental interactions.
5. Vulnerability is constructed simultaneously on more than one scale (e.g. economic impacts at national or international scales can have cascading and unpredictable impacts at the local, micro-economic scale).
6. Multiple stresses are inherent in integrating vulnerability of peoples, places and systems.

In seeking to situate the vulnerability of local communities in Lesotho in the Orange River basin, within the wider framing of dynamic vulnerability and adaptive management theory, we have conducted an analysis of local users of ecosystems services, and institutional bridges and barriers for the preservation of wetlands areas. The Lesotho Highland communities utilizing ecosystems services illustrate complex aspects of social vulnerability, particularly as it has changed over time in socio-cultural, ecological, institutional and economic terms. The dynamic vulnerability and resilience of this socio-ecological system is explored using the six attributes of vulnerability mentioned above. The method explores potential pathways of transition to resilience and sustainability or to decline and degradation. For more information, see Bharwani et al (2007).

Agent-based modelling

One approach to dynamically modelling complex socio-ecological systems suited to including risk, perceptions, imperfect information and uncertainty is agent-based modelling. This uses different decision rules (including preferences, perceptions and perspectives) for every actor in the model, and can be derived on the basis of empirical observation. This differs from many economic approaches, which may base starting assumptions on actor behaviour in economic theory alone. Agent-based modelling enables the exploration of the effects of changes in the institutional, social, cultural, environmental, economic and political landscape with respect to agent preferences and interactions (including cognition, norms, beliefs and perceptions) (wikiADAPT, 2008; Bharwani et al, 2005, 2008). Running a model in order to project future outcomes on the basis of initial conditions can lead to 'emergent properties', surprises or new vulnerability in the evolution of the system. This is because such models cannot always be solved analytically, but must be iterated numerically. That is, any emergent results cannot be explained by the individual agent rules or separate drivers alone, but are the outcome of the complexity of the interactions of these rules and their feedback effects.

These emergent 'surprises' or new insights allow the formulation of new questions for empirical work and the identification of possible gaps in knowledge and understanding of the domain and the drivers of the issue. However, the drawback of models which try to capture complex social realities in their most reduced and abstract form is that they are difficult to validate and are therefore less likely to be used for prediction but rather for learning about the characteristics and relationships between variables in the system and different future scenarios (e.g. policy or climate-related scenarios). Much of what is interesting to ABM researchers is that which emerges from a close coupling of each agent to its natural and social environments, producing non-linearity, indeterminacy and path dependency. For more information and examples of agent-based models used as learning tools and their application to policy see wikiADAPT.[5]

Water management cannot take a sectoral, single stressor approach without the danger of perpetuating or even exacerbating a range of existing problems, but rather needs to be integrated to address the multiple and complex changing stresses that are faced daily. The success and sustainability of intervention measures will be contingent on a full understanding of the root causes of vulnerability and the potential impacts that different development pathways may have on this vulnerability at other levels.

Groups affected by changes in the resource base also use these resources differently and therefore place different values on them. These values, uses and dependencies impact on the nature of vulnerability and may be more difficult to uncover if we approach local issues through the narrow lens of hydrology, static indicators and physical infrastructure alone. A single stress, one-scale, snapshot approach would reach a different conclusion and would miss much of the detail that can be captured using integrated and dynamic frameworks which allow the emergence of unpredictable, non-linear outcomes.

3.6 Integrated assessment tools and decision support systems

C. Giupponi and P.E.V. Van Walsum

Introduction

Considering the involved complexities and uncertainties, finding adequate, robust, cost-effective, and acceptable solutions to water-related problems is a formidable task. This can be aided by technology that provides strong analytical capabilities and the ability to synthesize information. Technological tools are required to identify and apply existing knowledge to the challenges of water resources management.

Integrated Assessment and Modelling (IAM) links mathematical representations of different components of natural and social systems at local, regional or global level. As Risbey et al (1996) stress, IAM is more than just a model building exercise, it is a 'methodology that can be used for gaining insight over an array of environmental problems spanning a wide variety of spatial and temporal scales'. A 'Decision Support System' (DSS) goes a step further than IAM, by providing a user-friendly software environment in which models are used and results interpreted.

Theory and definitions

Integrated Assessment tools

Parker et al (2002) remark that that there is no generally agreed upon definition of what constitutes integration or, more specifically, what is IAM. It is commonly seen as an interdisciplinary process that combines, interprets, and communicates knowledge from diverse scientific disciplines in order for cause–effect interactions of a problem to be evaluated from a synoptic perspective with two characteristics: (i) it should have added value comparable to single disciplinary oriented assessments; and (ii) it should provide useful information to decision makers (Rothmans and Van Asselt, 1996). More specifically, Parker et al (2002) state that 'in IAM, a variety of stakeholders, scales, disciplines and models are integrated for the consideration of integrated environmental issues'. Not all of these elements are required in a specific case, but an essential feature of IAM is that multiple forms of integration are combined. The resulting complexity of the used tools and their interactions can impede successful application. A logical next step is to embed them in a sophisticated software shell, commonly referred to as a Decision Support System (DSS).

Decision support system tools

The most common definition of Decision support system (DSS) refers to a computer-based tool, a higher form of information system (e.g. Keenan, 1998). Currently DSS are intended as the combination of tool(s) and the process of structuring problems and aiding decisions. Since IAM encompasses computer-based procedures and tools to analyse and simulate the spatio-temporal behaviour of complex systems in relation to human planning and decision making, thus representing the basis upon which decisions can be made – a sort of pre-requisite for the development of DSS tools.

In general terms, DSS are set to aid decisions and structure problems by exploring multiple perspectives of the issue at hand; enhancing decision makers' insight into problem drivers and policy outcomes; and facilitating communication and knowledge transfer between actors involved in or affected by the decision. The DSS should therefore be intended as a tool (or set of tools) to support the process of decision making rather than providing answers to decision makers' questions.

Brief review

Integrated Assessment tools

With respect to IAM we will limit ourselves to the used integration frameworks. The framework in environmental economics provided by Mathematical Programming (MP) (e.g. Hillier and Lieberman, 2001) has three types of elements:

- decision variables, e.g. corresponding to land and water use options;
- constraints, providing a (simplified) system description;
- objective functions, relating to the so-called decision indicators.

This simple form of 'optimization' model has its limitations, especially in the representation of non-linear responses. For many types of problem this drawback is offset by the advantage of being able to explore the available decision space in a comprehensive manner, allowing the answering of 'inverse questions'. An example of the latter is: 'What change of land use is required to achieve a certain reduction of nutrient emissions at the lowest possible loss of agricultural income?' The Multiple Goal Programming (MGP) method (e.g. Laborte et al, 1999) used in combination with MP can also support managing interaction with stakeholders. In the MGP approach the stakeholders are provided with information about the range that an indicator lies within. If they are not satisfied with one of these ranges, then they can specify that the lower limit of one or more of the indicators should be raised. That will have consequences for some of the upper limits of the other indicators, thus narrowing the available decision space. These influences on the ranges are made explicit by running the integrated model. The WaterWise model, described in Van Walsum et al (2008) is an example of an MP model involving water, nutrients, agriculture and nature on a basin scale.

MP is not the only type of model suitable for IA. Ambitious projects like SEAMLESS-IF described by Van Iterrsum et al (2006) involve several types of models covering different scales and domains. OpenMI standard (www.openmi.org) is used for the integration of models, databases, expert rules and analysis tools.

Decision support tools

Many DSS tools consist of (IA) model(s), and/or techniques and methods for decision analysis. Models' roles are almost as diverse as the uses and modelling paradigms employed. The variety is comprehensible, given the critical importance of models as instruments for scientific investigation and policy making (Morrison and Morgan, 1999). Models can be used to:

- measure and represent;
- describe structure, behaviour and pattern;
- reconstruct past or predict future developments;
- generate and test theories and hypotheses;
- surface, encode, transfer, evaluate and interpret knowledge;
- guide development and assessment of policies; and
- facilitate collective learning and settlement of disputes.

Decision analysis (DA) helps to make judgements and decisions more compatible with normative axioms of rationality in complex situations beyond human oversight. The trade-offs or preferences are value judgements, which are frequently not observable and must be revealed or approximated. Such uncovered preferences are context-specific and depend on the description and framing of a problem, and how questions are formulated. Here stakeholder involvement is important, as it helps to make the context explicit, and the choice for boundary conditions clear. For example, to assess the environmental costs of irrigation, one must consider the value of wetlands and riverine ecosystems deprived by water abstraction.

A partial list of DSS tools for water management is reported in Table 3.6.1 and provides examples of the characteristics and capabilities of recently proposed DSS tools. The main point we want to make is that IAM/DSS tools are rarely applicable in a routine fashion. No IAM/DSS will have all the characteristics needed for a certain problem.

Table 3.6.1 *Main characteristics of the DSS tools examined (abbreviated list from Giupponi et al, 2007).*

Tool	*Domains*				*Sectors*			*Support provided*				*Users*	
	Surface water	Groundwater	Socio-economy	Ecology	Water management	Land	Urban	Communication	Decision analysis	Prediction of policy outcomes	Optimization	Water Authority	Stakeholders
Elbe-DSS	X		X	X	X	X	X	X	X	X		X	X
Mulino DSS			X	X	X	X	X	X	X	X		X	
RiverWare	X	X	X	X	X			X	X	X	X	X	
WaterWare	X	X	X	X	X		X		X	X	X	X	X
WSM DSS			X	X	X		X	X	X				

Support of AWM

Increasing the robustness of the water system

Future climate and global economic uncertainties can be anticipated by creating a robust system that can adequately cope with different scenarios. The mathematical programming models described above are well suited for this, as it is possible to design a water system with a basic structure that performs satisfactorily for a number of possible future ‘events’ like a wetter/drier climate. This multiple-event programming has been implemented in Waterwise and is being tested on a prototype model for the Nile basin.

Role of stakeholders

Stakeholders in a river basin are usually fully aware of others' influence via the land-water system although some surprises may arise if complex societal and ecological systems are involved. This awareness is usually qualitative and it is a common human trait to attach more weight to negative effects caused by others than to effects caused by oneself. Dissension between stakeholders about the relative importance of certain interactions has a negative impact on their willingness to cooperate with each other. The resulting inertia results in a low adaptive capacity, and a concomitant loss of benefits for the basin and its inhabitants as a whole. Integrated assessment and decision support tools can help formulate water–space partnerships needed for taking decisions as a collective. The full potential of a river basin can only be realized by fairly sharing costs and benefits of land and water measurement measures. Moreover, if these relationships have a solid foundation, then the river basin community can react rapidly to external pressures, thus enhancing their adaptive capacity. Transparency and ingenuity are the two main ways in which the shaping of the water–space relationships of stakeholders can be supported. The first is achieved by quantifying trade-off relationships between conflicting objectives in a basin, like between economy and ecology. The second is achieved by suggesting creative solutions for problems involving complex spatio-temporal interactions. By suggesting and facilitating management options that make efficient use of the integrated land-water system, the economics of the cost–benefit sharing will become more attractive for the stakeholders.

It is crucial to involve stakeholders from the very beginning of the process otherwise the problem definition will miss crucial aspects and/or include aspects that are not relevant for the involved stakeholders. The tool implementation stage should also involve stakeholders, otherwise they will not develop a bond with the methods used. This feeling of affinity and ownership is required for success in providing useful support. One main point is that IA/DSS have a structural problem in obtaining the right kind of data, since they require representations of poorly understood socio-economic mechanisms. If there is no benevolent feeling of the stakeholders towards the tools used, they can easily discard them by saying they are inaccurate and incomplete.

Brief guidelines for the exploitation of DSS tools' potential in the context of AWM

From a recent work by Giupponi et al (2007), in Table 3.6.2 we provide a (shortened) checklist of guidelines to be considered when applying an IAM/DSS tool. Setting up and customizing a system is a process that requires a substantial period of time, often years, and requires the involvement of various experts.

Table 3.6.2 *Steps in the implementation and customization of a DSS tool*

Step	*Description*
1	Investigate and describe the problem at hand, the resources available and the data issue
2	Identify the actors involved in the decision and explore the social context, arouse their interest
3	Understand the institutional and normative context
4	Identify and clearly communicate reasonable expectations
5	Define a clear strategy and work programme and include quality assurance
6	Adapt tools to the users' needs and not vice-versa
7	Assure flexibility
8	Accurately manage and communicate uncertainty
9	Provide effective documentation of the limitations of the results provided
10	Provide adequate documentation and support materials all together with the DSS tool
11	Train users

3.7 Climate change impacts on water resources and adaptation options

V. Krysanova and F. Hattermann

The vulnerability of water resources from the impacts of climate change is becoming a major concern for people and policy makers. Climate change has the potential to increase the frequency and intensity of extreme global events, such as increasing flood risk in some regions, increasing drought risk in others, and even increasing the occurrence of both floods and droughts in some parts of the world (IPCC, 2007). The challenge is to develop strategies and measures to guarantee an adequate water supply to multiple users, and to provide adequate protection against climatic hazards in river basins affected by climate change.

Therefore efforts are needed to improve information on expected climate change and its impacts, to increase public awareness and to facilitate the development of adaptation strategies. This section includes an overview of climate change in Europe based on observational data and model projections. It also outlines major impacts and possible adaptation options in water management and two water-related sectors.

Observed climate change in Europe over the last century

The water cycle is driven by temperature and precipitation, which are the most important climatic drivers, and changes in these characteristics are expected to have considerable impacts. Over the last century the temperature has shown an increasing trend of 0.8–0.95°C over Europe (EEA, 2004) in a relatively uniform manner. In winter the warming trend was stronger than in summer and was accompanied by an increase in the number of both warm and cold days.

The precipitation trends over Europe were more heterogeneous. A general global pattern is that the observed higher temperatures stimulate the global hydrological cycle; more evapotranspiration leads to more water vapour content in the atmosphere and hence higher precipitation amounts. However, observed regional trends are different, as precipitation patterns depend on regional circulation patterns and local orography. According to observational data, mean annual precipitation in Northern Europe increased by 10–40 per cent while it decreased in some areas of Central Europe and the Mediterranean region by up to 20 per cent over the last century (EEA, 2004).

As a result, some of the climate-driven impacts on the hydrological cycle are already being observed: extremely high precipitation events were recorded more frequently; prolonged drought periods in summer were reported for Central Europe, the UK and Southern Scandinavia; Southern Europe experienced extended winter droughts and reductions in river discharge in many catchments; an increase in the occurrence of heatwaves was observed; ten out of 12 European glacier regions were reduced in size; and sea levels in the North Sea and Baltic Sea have been rising over the last century.

Regional climate model

The dynamical downscaling method is used in regional climate models with a high resolution (typically 20–50km) using boundary conditions provided by a General Circulation Model (GCM) simulation. Due to several sources of uncertainty included in the projections of climate change, the use of ensembles of model simulations with different climate models, different initial conditions and varying assumptions of the future atmospheric composition is advantageous. Therefore, the EU PRUDENCE project (Prediction of Regional scenarios and Uncertainties for Defining European Climate change risks and Effects) produced an ensemble of Regional climate model (RCM) simulations for Europe. For each of the two driving GCMs HadAM3H and ECHAM4/OPYC3 (Räisänen et al, 2004), three 30-year runs were made using the Rossby Centre RCM: a control run for the period 1961–1990 and two scenario runs for the period 2071–2100, the latter being based on two different scenarios of greenhouse gas and aerosol emissions.

Projections of climate models for the 21st century

Although there are significant uncertainties in the projected changes, there is a general scientific agreement that the observed trends in climate will continue and are likely to accelerate in some regions. Depending on the dynamics of greenhouse gas emissions, projections anticipate that the mean European temperature will rise by 1.0–5.5°C by the year 2100 (IPCC, 2007). This range in estimations is due to differences between emission scenarios and uncertainties associated with climate models. Cold winters, which occurred on average once every ten years in the period from 1961 to 1990, are likely to become rare in Europe and will almost entirely disappear by 2080 (EEA, 2004). In contrast, by 2080 nearly every summer in many parts of Europe is projected to be hotter than 10 per cent of the hottest summers in the current climate (EEA, 2004). Due to the complexity and various interacting factors in climatic processes, the impacts of climate change on precipitation and river discharge show contrasting and site-specific trends in different European regions.

In Northern Europe, mean annual and winter precipitation is anticipated to increase, with the latter reaching values of up to 15–30 per cent by the end of the 21st century (Giorgi et al, 2004). Many modelling studies demonstrate that runoff in Northern Europe will most likely increase in winter and decrease in spring, due to the fact that less precipitation will fall as snow in winter and less snow will melt in spring. Annual runoff is expected to rise in correlation with increased precipitation: up to 10 per cent by the 2050s and 50 per cent by the 2080s. This would lead to higher water availability and hydropower production, but may be accompanied by higher flood risk. In North-Eastern Europe the magnitude of 100-year flood discharges might rise by more than 25 per cent by the 2080s (EEA, 2005).

In Western Europe, winter precipitation is projected to increase by between 15 and 30 per cent by the end of the century, whereas summer precipitation is expected to decrease by 30 to 45 per cent (Giorgi et al, 2004). Therefore, countries in Western Europe might experience recurring droughts in the future, and the longest dry-spells could increase by up to 50 per cent by the 2080s (Good et al, 2006). At the same time, floods will become more frequent, and the magnitude of a 100-year flood discharge is expected to increase by 10 per cent (EEA, 2005).

In Central Europe, significant reductions in summer precipitation could occur by the end of the century, from 30 to 70 per cent, depending on the scenario (Giorgi et al, 2004; Räisänen et al, 2004). In winter, precipitation and the risk of snow-melt floods are anticipated to increase. Overall, a reduction in annual water flows is expected.

According to model projections (Räisänen et al, 2004), precipitation in Southern Europe will experience pronounced reductions of up to 70 per cent by the end of the century. However, the occurrence of flash floods is likely to rise. According to the projected drying trend for the Mediterranean region, water availability is anticipated to decrease notably. Summer flows in South-Eastern Europe could be reduced by up to 50 per cent by the 2050s (EEA, 2005). Consequently, water stress is projected to rise, particularly in Southern France and Italy, Spain, Portugal and Greece.

It should also be clearly understood that the projections of climate models comprise inherent uncertainties, which result from differences in climate models as well as unknown future development paths which are illustrated by scenarios. Nevertheless, despite all uncertainties, some trends are very clear: higher temperatures will alter snow melt dynamics and change the timing of maximum discharge. This will reduce water availability during the spring and summer in river basins which are fed by snow and glaciers. On the other hand, rising temperatures will cause an intensification of the global hydrological cycle. Regional impacts will depend on local orography and regional circulation patterns, but in most European regions the frequency and intensity of extreme precipitation events and thus flood risk are projected to increase. The flood frequency and magnitude will most probably increase in the regions experiencing an increase in precipitation, while drought frequency will be higher in regions with a reduction in precipitation. According to the latest assessments, some river basins in Europe may experience an increase in frequency of both floods and droughts (Jacob, 2007), although uncertainties remain high. In coastal regions, flood risk would be further intensified by the anticipated rise in the sea level, which could reach 10–70cm by 2050.

Expected impacts and adaptation options in water-related sectors

Since many human activities rely on water supply, several key sectors of European economies are sensitive to changes in the availability of water resources and the frequency and magnitude of extreme events (i.e. droughts and floods). Sensitivity varies widely between sectors. We will shortly outline impact and adaptation options for water management, agriculture and energy production.

Water management

Although the impacts of climate change on water resources vary strongly between European regions, and a clear distinction is visible between Northern and Southern Europe, three main challenges to the water resources management can be identified: a) increased flood risk; b) decreased water availability during the summer season; and c) deterioration of water quality.

Ensuring efficient flood protection and preventing loss of lives and damage to assets in flood-prone areas may become a serious challenge in many European regions. The increase in intensity and frequency of extreme precipitation events is likely to put sewerage networks under additional pressure, and the current hydraulic capacity of the networks will be exceeded more frequently.

Water management under drought conditions in Southern and Central Europe will have to respond to additional challenges under a warmer and drier climate. Water supply services will face the problem of satisfying multiple water demands during periods of water shortages.

Both an increase and decrease in precipitation, along with climate warming, may negatively affect the quality of water in rivers and coastal zones. Excess water in river basins may have a negative impact on river water quality by increasing pollution load from diffusive sources and in addition river basins with a significant share of intensive agriculture may be seriously affected. On the other hand, reduced water levels mean that pollutants from point sources (sewage treatment plants) will become less diluted. This, in combination with increased water temperatures and reduced dissolved oxygen levels, could seriously affect the ecological balance of freshwater systems in the catchments where there are significant loads from point sources.

Adapting water management to climate change requires modifications in land use and water management. For flood protection, both structural (dams, dykes, etc.) and non-structural measures (increase of water storage capacity in river basins, enhancement of infiltration and retardation of water, agriculture practices reducing runoff, and zoning), along with social measures (education, awareness raising, warning systems, and insurance) are of importance. The management of water supply and demand can be improved by optimizing demand management, the application of water-saving technologies and by incorporating economic incentives (water pricing policies and water trading schemes) in order to encourage more efficient usage of water. Economic instruments required by the WFD could be widely applied to recover the costs of adaptation.

Water management related to extreme events is highly complex and involves uncertainty. Therefore, it should be approached from a broad perspective, taking into consideration interests of different related sectors, different spatial and temporal scales, as well as transboundary issues. This requires an application of the IWRM approach. Moreover, projections of the impact of climate change suggest that the goal of water managers should be to increase the adaptive capacity to better cope with uncertain future developments rather than solely relying on finding traditional optimal solutions.

Agriculture

Water shortages expected in a changing climate would have a significant impact on the agricultural sector. In Central Europe, the projected shifts in precipitation patterns would notably reduce water availability during the vegetation period in summer and notably increase the demand for irrigation water. Rising temperatures and evaporation rates would further aggravate the situation in Southern Europe, where the dependency on water for irrigation is already high. The consequences for farmers could be critical, starting with higher costs for irrigation, and potentially leading to production losses or the complete loss of land due to desertification. On the other hand, higher precipitation expected in northern latitudes is initially perceived as a lesser problem or even, as an advantage to agriculture. The anticipated increase in the frequency and intensity of floods in flood-prone agricultural areas will probably be the greatest risk associated with higher precipitation.

Adaptation options for agriculture include: improving irrigation efficiency, crop substitution to reduce dependence on irrigation, changes in farming systems from specialized to mixed farms and diversification of production, crop breeding, and harvest insurance mechanisms. The 2003 reform of the Common Agricultural Policy introduced more flexibility and the so-called decoupled payments (reducing incentives to grow water-intensive crops under water-scarce conditions). However, further decoupling may be needed.

Energy production

Changes in the availability of water resources and the occurrence of extreme events will influence all types of energy production: hydropower, thermal power plants and biofuel production. In Northern latitudes hydropower may benefit from increased hydropower potential, while in Southern and Central Europe this potential will decrease notably due to reduced river runoff. In areas with increased precipitation and runoff, dam safety may become a problem due to higher risk of floods. The generation of electric power in thermal power plants often relies on large volumes of water for cooling. This type of electricity generation may therefore be affected by climate warming and water scarcity. The discharge of cooling water may be restricted if temperature limit values are exceeded. In regions with increasing water scarcity, the use of water for cooling may conflict with other water uses.

The efforts required for adaptation vary according to the energy generation types. In countries where precipitation and runoff are expected to increase, adaptation measures for hydropower should focus on dam safety, whereas in countries with an increasing risk of droughts, the use of turbines with lower nominal power could be recommended. Thermal power plants have to adapt by reducing their water demand, increasing the efficiency of cooling systems or the overall efficiency of plant operation. The biofuel production in drought-prone regions should rely on crops that are more capable of withstanding water scarcity conditions. The overall vulnerability of the energy sector can be reduced by diversifying energy production and broadening the variety of energy types.

3.8 Management and Transition Framework

C. Pahl-Wostl, B. Kastens and C. Knieper

The NeWater Management and Transition Framework (MTF) has been developed to provide guidance for the analysis of complex water management regimes, and in particular to address the following questions (Pahl-Wostl, 2007a, 2007b; Pahl-Wostl et al, 2007a):

- What elements are needed to understand the dynamics of water management regimes and their ability to cope with future challenges such as climate change?
- How can one examine a water system's ability to adapt to different or changing conditions and which management strategies can enhance this ability?
- What are the barriers and drivers for the transition to adaptive management?
- How can one involve stakeholders in order to implement transition processes in adaptive management and how can progress be evaluated, given a wide range of different contexts?
- Which kind of guidance and tools are required for policy makers and practitioners to implement integrated and adaptive water management regimes?

The MTF supports a 'diagnostic approach' that allows the analysis and classification of water management problems. This is a condition required for the development of response strategies that are sensitive to the societal and environmental context. It also allows for the derivation of transferable insights from a range of similar cases.

Figure 3.8.1 gives an overview of major elements in the water system and their relationships which should be considered from an adaptive water management perspective. The coloured boxes reflect the different elements (or classes as used by the MTF) that compose the MTF. Starting from the green box in the upper left corner of the figure, ecosystems comprise abiotic and biotic components of the water system. They involve attributes, such as water availability, biodiversity and the degree of human influence on the ecosystem. Moreover, the class 'ecosystems' includes two further components, namely 'environmental services' which capture the role of the ecological system to serve as a resource for human beings (e.g. drinking water, hydropower), and 'environmental hazards', which are the threats posed by an ecological system (e.g. flooding). Ecosystems are affected by technical infrastructure (e.g. dams, reservoirs) and by the social systems existing in the basin. The latter comprises the societal

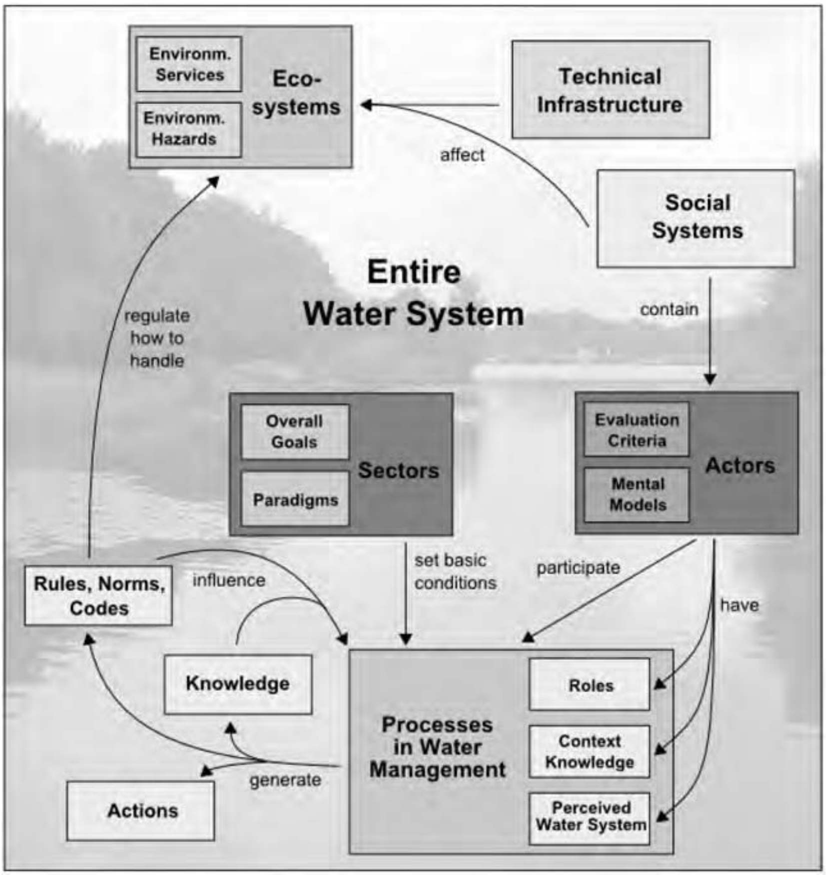

Figure 3.8.1 *Schematic representation of important elements in the water system*

context and refers in general to a nation's attributes, such as the size of the community, its cultural and economic properties, in addition to the effectiveness of formal laws and other regulations (institutions). Moreover, the social systems contain the class 'actors', who are individuals or organizations participating in water management processes. Evaluation criteria are used by actors to evaluate the degree of satisfaction with the observed state of the water system. Furthermore, actors hold mental models which describe their subjective notions on reality, and influence their behaviour. The actors hold different roles in the processes of water management and these roles together with personal information and experiences determine the actors' scope for actions and perceptions on the water system. The latter refers to an actor's personal evaluation of the water system. The indicators which are used reflect what is important for the actors to make a judgement about their individual satisfaction and the achievement of management goals. The basic conditions for processes in water management are set by sectors (e.g. water pollution control, agricultural policy or energy policy) and their overall goals and paradigms. Goals refer to management goals, such as to ensure good quality drinking water or to prevent flooding. Paradigms describe the dominating frame of water management issues in a group of actors. It is assumed that one paradigm dominates in a sector. The co-existence of several paradigms may be a sign for a transition, e.g. to adaptive management. The processes in water management generate actions, i.e. activities that lead to changes in the water system. They also generate knowledge as well as rules, norms and codes that in turn influence water management processes. These rules, norms and codes could be laws or principles, guidance on how to deal with a problem, or precepts for moral behaviour. These processes also influence the ecosystems, which finally leads to the closure of the MTF cycle.

In addition, the MTF provides a stylized representation of policy and learning cycles to guide an analysis of social learning and transition processes. The concept of adaptive management strongly suggests that learning processes should become an integral part of any management regime and should be included in the design of adaptive policies as an important adaptation strategy (Pahl-Wostl, 2007a; Pahl-Wostl et al, 2007b, 2007c). This is indicated in Figure 3.8.2.

Policy cycles comprise processes at various levels, concerning the development and implementation of measures together with underlying rules. Learning cycles can broaden established policy processes. They are partly informal and allow for exploring alternative options, which may perform better than conventional approaches. Learning cycles involve diverse stakeholders who bring in knowledge and new perspectives on a problem, in addition to possible approaches to finding a solution.

The typical phases of learning cycles not represented in detail in the figure are:

- problem restructuring and reframing;
- action plan development and mobilization of additional support;
- implementation of pilots/experiments.

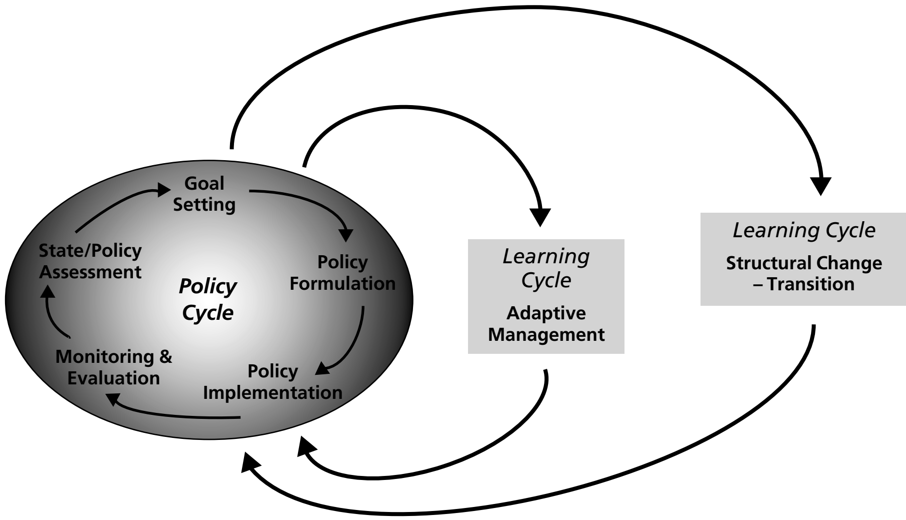

Figure 3.8.2 *Policy cycle and learning cycles connected to MTF. The processes take place at several levels (e.g. provincial – basin – national) and are far more iterative than the relatively schematic representation might suggest*

Learning cycles may be introduced as part of operational adaptive management, to test new approaches where significant uncertainties exist, for example the introduction of water trading or decentralized technologies at the household level. Often new approaches may require major transitions (Pahl-Wostl, 2007b; Pahl-Wostl et al, 2007c), which imply a change of prevalent customs, values and paradigms. This may become obvious when structural barriers are encountered (e.g. rigid legislation, prevailing habits of consumers, dominant technologies), which hamper the implementation of innovative measures. Structural changes (transitions) imply learning cycles at the early stage of goal setting and policy development. In most cases such transitions will involve a wider range of stakeholders. Structural changes may be required at a higher political or societal level than the planning process. It is a major challenge to implement learning cycles that have the required degree of freedom and sufficient resources (time, money) to develop a new perception of problems as well as potential solutions and to create innovative approaches. Learning processes should be linked to formalized policy and management processes to ensure that developed alternative approaches are adopted and lead to a greater change.

3.9 Internet portals and services for knowledge transfer

C. Knieper, D. Thalmeinerova and J. Mysiak

Through the Framework Programmes for Research and Technological Development, the European Community funded a vast number of research projects in

Europe and beyond. The funded research has produced many groundbreaking discoveries and high quality scientific outputs. However, attempts to bring this knowledge to bear on policy making often leads to frustrating results. To rise to the challenge of adaptive management, every piece of knowledge available will, however, have to be exploited.

The Internet provides a vast range of opportunities for better knowledge communication and transfer to policy arenas. Dedicated web portals such as WISE-RTD (www.wise-rtd.info), Learning for Sustainability's portal (www.learningforsustainability.net) provide access to a vast number of research results and encourage their utilisation for solving practical policy problems. The portals are special websites (gateways) which provide access to other sites and resources. Portals may also be connected to an online archive or repository. For example Policy Archive (www.policyarchive.org) provides a repository for public policy research outcomes from all around the world. File sharing platforms allow specialists to exchange water-related resources with each other. One of such file sharing platforms is the European system CIRCA, which offers a wide range of interest groups in different topics. Within these interest groups, users can share resources for various purposes, e.g. for 'Implementing the Water Framework Directive' (www.circa.europa.eu/Public/irc/env/wfd/home).

The information gathered in the portals are structured and presented in a way which best suits the intended audience. Some portals provide ways for interactive engagement of the users. For example, the platform Zukunftswald (Future Forest, available in German) allows the interested users to ask questions, in simple phrases, about any topics related to forest ecosystems and their sustainable management. The system generates responses which best match the question, while an animated photograph of a forester gives the illusion of talking to a real person.

Science news services such as those provided by the EC Directorate General for Environment (Science for Environment Policy, www.ec.europa.eu/environment/integration/research/research_alert_en.htm) or by the American Association for Advancing Science (Science Insider, www.blogs.sciencemag.org/scienceinsider) allow users to stay in touch with the latest science policy news.

A vast number of Internet blogs (online diaries) provide space for discussion and comments. The Dot.Earth blog (dotearth.blogs.nytimes.com) run by *New York Times* journalist Andrew Revkin or Colorado University's blog Prometheus (www.sciencepolicy.colorado.edu/prometheus/) are sites where the latest science and policy outcomes are reported and discussed.

Web portals for Integrated Water and Resources Management

In the field of Integrated Water and Resources Management (IWRM), two major international web portals focus on knowledge transfer from science to practical application: The GWP ToolBox (www.gwptoolbox.org) and WISE-RTD. Both offer up-to-date tools, guidance and case experiences for practitioners coming from various sources.

The GWP ToolBox was established by the 'Global Water Partnership' (GWP, www.gwpforum.org), an international organization that promotes IWRM. The web portal is a compendium of good practices related to the principles of IWRM presented under a structured reference framework. The GWP ToolBox allows water-related professionals to analyse the various elements of the IWRM process and facilitates the prioritization of actions aimed at improving the water governance and management. The GWP ToolBox consists of an organized collection of case studies and other reference documents such as articles, project reports and guidelines. Thus it creates a growing database of knowledge on IWRM processes.

WISE-RTD is a part of the 'Water Information System for Europe' (WISE, www.water.europa.eu), which aims to make water-related information available throughout the European Union. WISE-RTD is a platform where scientists and others can record resources for water management by means of meta-data. The products are then structured and presented in a way that is tailored to different target groups, namely water managers, stakeholders and researchers. WISE-RTD acts as a web directory and links the user to external websites with tools, guidance, etc. Users can find results in three ways:

- Free search: An easy and quick way to look for results. Users can type in a search term and combine it with keywords related to water management.
- Available information lists: In case the user looks for a product he is already familiar with. Detailed lists show what is in the system, structured by information types (e.g. policy guidance).
- Guided searches: The guided searches are tailored to different target groups. For example, they allow orientation in typical steps and tasks of a water manager's work.

Furthermore, additional filters allow search refinement in regards to geography and information type.

NeWater portal activities for AWM

NeWater cooperated with WISE-RTD and the GWP Toolbox in order to promote AWM.

The WISE-RTD web portal was extended and now has a section that explains the basic ideas of AWM and offers tools and guidance as well as case experiences helping to make management more adaptive. The AWM section supports the same search techniques as the rest of WISE-RTD, i.e. free search, available information lists together with guided searches.

Its core component is a guided search for practitioners (www.wise-rtd.info/mywise.cgi?id_people=159). This guided search is tailored to water managers who implement the Water Framework Directive (WFD) in their daily work. Resources for AWM are presented according to WFD management phases and common issues faced by water managers, e.g. dealing with uncertainty. Furthermore, the guided search helps water managers to become familiar with social learning, an important element in AWM. The main properties of social learning are explained and resources are provided for the different phases in learning processes.

Besides the guided AWM search for practitioners, which is orientated to processes in water management, there is also a guided search that takes on a system analytical view (www.wise-rtd.info/mywise.cgi?id_people=196&b_topics=118). It is aimed mainly at scientists, but can also be used by water managers. This guided search is structured around the elements in the water system, e.g. ecosystems, actors as well as rules, norms and codes. It describes how these elements and their relationships can be regarded from the perspective of AWM and explains what should be considered in order to make water management more adaptive. Research results are related to the elements of the water system.

The AWM section in WISE-RTD was created within the scope of NeWater. Here the user can find the project's main results. The section is not restricted to resources of NeWater. Everyone, who creates insights related to AWM, can contribute and – after a quality check – present their own results. The web portal input system (WPIS) allows the user to record resources by means of online forms. In this way, the knowledge base of the AWM section can grow and provide up-to-date tools, guidance and case experiences for practitioners and scientists, even after the end of the NeWater project.

NeWater cooperated with the GWP ToolBox in two ways. On the one hand, experiences from the project's case studies are published in the Toolbox. On the other hand, the 'ToolBox Partners' section contains a new NeWater area. It offers a selection of basic insights and resources from the project that contribute to a more adaptive water management.

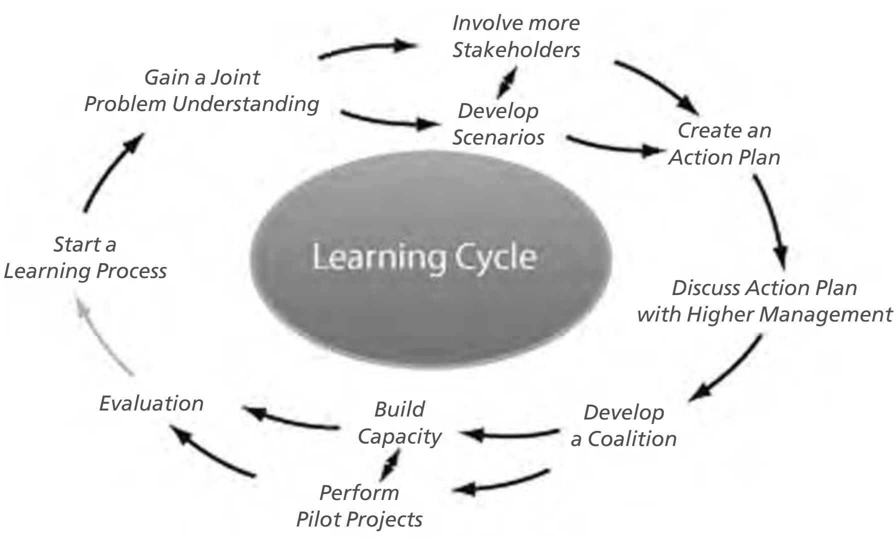

Figure 3.9.1 *Illustration of social learning in WISE-RTD's new AWM section*

TOOLBOX PARTNERS

- **AP Flood Management**
- **CapNet**
- **EU NeWater**
  - Core Concepts
  - Policy Briefs and Report Series
  - Guidebook
  - Further Resources
  - Training and Learning Documents
  - NeWater Case Studies
- **Ground Water – MATE**

Figure 3.9.2 *Selection of basic NeWater results in the partner section of the GWP Toolbox*

Notes

1 For more information on indicators and natural resource management, see Walmsley, J (2002), and on scale issues in water management indicators, see Sullivan and Meigh (2007).
2 World Health Organization: Environmental Health Indicators.
3 See for instance the EEA proposals at www.eea.europa.eu/themes/water/indicators, and the UN Millennium indicators at millenniumindicators.un.org/unsd/mdg
4 www.weap21.org
5 www.wikiadapt.org/index.php?title=Agent-based_modelling

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4
Capacity Building and Knowledge Transfer

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4.1 Introduction

One of the objectives of the NeWater project was to develop a holistic set of training courses including training material to support the dissemination of knowledge, concepts and tools necessary for the successful implementation of adaptive water management (AWM). The tools selected to support training are based on existing tools that have been enhanced within the project, as well as newly developed ones. The training courses and training materials for practitioners are based on the requirements of the NeWater case studies. The provision of a large number of thematic courses relevant for implementation of AWM-related activities provides practitioners with the opportunity to tailor training programmes according to their specific needs and the stage at which they are currently working within the AWM cycle (see Chapter 2.4). An overview and the selection of courses and training material can be found within the AWM section of the NeWater portal (www.wise-rtd.info/).

The capacity building activities of the NeWater project have also included the university sector through a range of initiatives aimed at incorporating AWM in university-level education programmes, and developing knowledge, skills and new attitudes among future researchers and water managers. Finally, the project's experience in involving interested organizations from outside a project consortium in capacity development activities is outlined.

4.2 Aims of the training courses

The main objective of the training courses for practitioners and instructors was to disseminate knowledge and experience collected and tools and methods developed in NeWater, and related research projects. The training courses are focused on the concept of AWM and the use of existing tools and methods as well as new tools that have been enhanced, in order to realize AWM. The resulting training courses were held in seven NeWater case study regions to support the ongoing process towards AWM in these basins.

4.3 Target audience for training

The target group for training comprised water managers and practitioners working at an operational level, normally within water management authorities. These people are water professionals responsible for the effective functioning of water management at all levels. They are involved in the day-to-day operation, decision making, data collection, planning and design, as well as regular communication with water users and other stakeholders. The objective was to target those most directly involved with water management. However, other pertinent groups in the process such as instructors, researchers and representatives of related sectors, should where possible, also be invited to participate. Students from the relevant fields of study who could utilize the training material in their education were an indirect target group of the practitioner training courses.

4.4 Obstacles encountered

In developing the training material and implementing the courses, a number of obstacles were encountered. It was considered important to link knowledge and expertise available within the project with the needs and interests identified in the case studies. On the one hand, training material could be developed solely on themes and tools that were familiar to project partners or, by bringing expertise into the project via external experts. As resources were limited however, this would occur only on a voluntary basis. On the other hand, it was clear that training material and courses would have to bring in new knowledge, meet case studies needs and support capacity building and knowledge transfer. Time and resource limitations also restricted the training to one course in each case study region.

Furthermore, English is not the local language in almost all case studies, and yet training provided by project partners was mostly in English. This made it more difficult to limit training only to water managers and practitioners, as language skills varied considerably. In order to reach the target group, it became important to cooperate with local educational institutions and ensure continuity in capacity building provided. This cooperation led to the process of securing an institutional framework for ongoing capacity development.

4.5 The 'broker concept'

In order to combine demand and supply it became apparent that a concept and demand-driven approach were needed to ensure that any training material produced was linked to the gaps and demands within the case studies. As a result, the 'broker concept' was established. In the 'broker concept' the project partners in charge of coordinating the project activities in the case studies, acted as brokers between the tool developer, the producer of training material and the needs of the case study. Initially, training options were offered to the case studies that provided feedback concerning their demands and needs in order to identify gaps. Where time, budget and personnel permitted, the training offered was adapted in close cooperation with the tool developer, the producer of training material and representatives of the case studies. This approach resulted in all case studies being able to access training courses on themes they considered to be relevant for their basin. Case study members also attended each others' workshops where appropriate.

Due to the fact that only one workshop could be organized in each case study and that NeWater trainers would hold the courses predominantly in English, it was decided that training workshops in which trainers were trained, in other words, train-the-trainer workshops, would be more effective in the longer run. These trainers drawn from institutions involved in education and training would later train water managers and practitioners in train-the-practitioner workshops.

4.6 Train-the-trainer workshops

In the first phase, NeWater partners provided training in English to case study members familiar with the issues of that region. These members would be in a position to further disseminate knowledge within their organization, either by working directly with practitioners or by delivering training courses. The 'trainers-to-be' participating in the train-the-trainer workshops were, however, selected because of their close link with water management institutions and/or their teaching or training experience. To support dissemination and improve understanding, the training material provided in some case studies was translated into the local language. The workshop also provided feedback on the presentation of the tools and their applicability and in the region.

4.7 Train-the-practitioner workshops

The main objective of a follow-up phase was to stimulate AWM training within a broader community in the basin through train-the-practitioner workshops. The planning and realization of the train-the-practitioners workshops would be implemented by local organizations/projects with the support of the participants of the initial train-the-trainer workshops, with the additional support of the project partners.

Although the train-the-trainer workshops were successfully implemented, the follow up train-the-practitioner workshops were only organized in one case study and appeared difficult to realize due to the fact that this local training activity had not been incorporated in the early stages of project planning.

Lessons learned

In summarizing the obstacles described above, the introduction of the 'broker concept' offers an effective way of combining demand and supply with the training courses provided. All case studies could access the training modules in which they were most interested.

The train-the-trainer courses were carried out successfully. Participants expressed their satisfaction with the opportunity to learn new methods in support of AWM, resulting in the transfer of concepts and tools that were used in many cases.

Attempts were made to link training courses and training material with established educational institutions in order to secure an institutional framework, financing and continuity. Although there was substantial interest in adopting the training modules by such institutions, the closer cooperation needed can only be established over a longer time frame.

To ensure continuity, contacts with formal training institutes need to be made in the very early stages of the project allowing time to develop relationships. In addition, a budget needs to be allocated and time limits need to be set for the organization of the train-the-practitioner workshops within the case studies areas.

In the case of participants from research institutes, the impact of the capacity building activities will be less immediate as they will either use the newly gained knowledge in their own research work or pass it on to students. This time factor would of course be even more relevant for the students who took part.

In conclusion, it is recommended that similar capacity development projects allocate more time and resources to the train-the-practitioner workshops to ensure greater effectiveness and sustainability of the train-the-trainer activities.

4.8 AWM in academic education

In order to share new knowledge on adaptive water management acquired in the NeWater Project with the upcoming generation of researchers and water practitioners, several capacity building initiatives were undertaken in close collaboration with Global Water System Project (GWSP): summer schools and short training courses for post-graduate students, the development of an online curriculum, and train-the-instructor courses for university lecturers interested in using this curriculum to bring AWM into their own teaching programmes.

The summer school series and short training courses combined lecturing together with small group exercises, interactive discussions and application to case studies in order to allow for reflection and improve understanding. Three summer schools took place over the course of the project led by instructors from the NeWater and GWSP partner networks and involving participants from more than 25 countries and all continents.

The teaching materials used in the summer schools included lectures, exercises, discussion questions as well as relevant literature and links to databases, tools and case studies. These were subsequently compiled, reformatted, annotated with explanatory text, and then uploaded as ***opencourseware*** (www.newatereducation.nl) for use by instructors wishing to teach AWM at the Master's and PhD levels.

To accompany the online curriculum, **train-the-instructor courses** have been organized for university lecturers in order to deepen their understanding of AWM, familiarize them with the material provided in the online curriculum, and help them to (re)design their own teaching course or programme. These training courses are also open to practitioners who wish to learn more about AWM and to train others in this field. Information on these courses is available on the website of the online curriculum.

4.9 Lessons learned in academic education

The academic capacity building activities were accompanied by a number of challenges – some anticipated and others not. In this section, the most important of these are outlined for each activity.

Summer schools and short training courses: The widespread dissemination of NeWater concepts, approaches, and methods was an important goal for the project. It was therefore most effective to provide financial support to prospective participants from developing countries and emerging economies, particularly those countries in the case study river basins (Nile, Amu Darya and Orange). With regard to the summer school programme, the intensive learning process involved led to gradual improvement in the agenda so that lectures were shorter and interspersed with lively group discussions, exercises and games. The latter are also very important for deepening understanding of concepts and methods taught. Depth is as important as breadth (of topics covered) and achieving a balance between the two can be challenging. A further challenge was the varying educational levels and cultural/experiential backgrounds of the participants. Much emphasis was therefore placed on careful review of applications to ensure an adequate educational foundation and preparation of participants through the provision of background readings for each of the topics taught. Cultural awareness and sensitivity on the part of the organizers and session leaders, and openness on the part of participants, was also of vital importance.

AWM curriculum: The design and implementation of a full curriculum is a significant undertaking involving a small team and several years of work. It also requires the willingness and cooperation of the instructors (i.e. authors) to provide the teaching materials for the various topics that comprise the curriculum in a timely manner. It proved most effective to request editing and annotation of teaching materials as soon as possible after completion of a summer school, or even before the course takes place if possible. In this way, the teaching content is still fresh in the mind of the instructor, and it is then less likely to be moved lower on the priority list and eventually forgotten.

Copyrighting issues also required careful attention: a thorough review was necessary to ensure full citations, and permission has been obtained for the publishing on the internet of third party materials (such as photos and diagrams). It is ultimately the responsibility of the authors to ensure that there are no copyright violations. However, in practice it proved to be more efficient to provide the authors of the teaching materials with support in reviewing materials and obtaining permission for use of third party materials.

Train-the-instructor for university lecturers: As with the summer schools and other training activities for young academics, it was important to allow for varying levels and backgrounds of the participants. At least one month in advance of the course, prospective participants were provided with background reading on the fundamentals of AWM and were asked to familiarize themselves with the online curriculum. A good understanding of IWRM was considered to be an important prerequisite. In addition to the standard post-event evaluation, participants were contacted several months after the course to determine if and how teaching materials presented in the training session were used by the participants in their own teaching programmes. Finally, as with the summer schools, attracting participants from developing countries was most effective when full financing of travel was provided.

4.10 Involvement of organizations outside the project consortium

To provide a link between the NeWater project and the wider international IWRM community, a European and a global 'platform' were developed to promote dialogue and to connect with ongoing policy processes. Through platform activities, specific NeWater topics were matched with specific partners. In principle the external parties who engaged in these activities were to cover half of the total costs to demonstrate their interest and commitment. All activities had concrete outputs that could be disseminated. For example, the EU platform focused its work on a review of European IWRM research resulting in a book *The Adaptiveness of IWRM* (Timmerman et al, 2008). The Global Platform contributed to products like the CAIWA conference book, *Adaptive and Integrated Water Management* (Pahl-Wostl et al, 2008), and the Earthscan publication, *Climate Change Adaptation in the Water Sector* (Ludwig et al, 2009), as well as contributions to policy and economic studies.

The Global Platform entailed three activities: global events, collaboration and studies, and proposals and requests. With support from the Global Platform, NeWater partners organized a session at the World Water Forum 4 in Mexico at which they shared the experiences from the NeWater case studies with the World Water Forum stakeholders. Other events supported by the platform included the annual World Water Week in Stockholm, the CAIWA conference in Basel and the Final NeWater Conference in Seville in 2008.

With support from this platform, the project partners also formally collaborated with the Australian National University where comparative studies for the Rhine and the Murray Darling River Basin were undertaken leading to research initiatives, conference presentations and workshops in Australia. Collaborative research on the impact of global change on river basin management and the human role in the hydrological cycle was also initiated with the US.

Cooperative activities were established with the Global Water Partnership (sharing of IWRM concept and formal link with the GWP toolbox), the Global Water System Project (joint hosting of summer schools and development of the online curriculum), and The Coordinated Program on Water and Climate (collaboration with NeWater in the World Water Forum circuit and working papers)

The third part of the global platform was the facilitation of proposals and requests for upcoming initiatives. The programme launched 21 initiatives of which 19 were from developing countries for 11 separate events resulting in the further exchange of experiences and the dissemination of the NeWater vision to other knowledge centres in the world.

The most significant challenges of running these platforms were the streamlining of financial administration with the partners, and legal issues such as intellectual ownership. Overcoming these hurdles was time consuming but they did not reduce the effectiveness of the programme. The principle of co-financing – a useful tool for selecting serious partners – proved difficult for people from developing countries in valuing the time they spent (salaries) for the purposes of compensation.

In conclusion, the platform approach proved to be effective in supporting small initiatives to make ongoing AWM activities more effective, in bringing researchers and practitioners together to share experience and innovations, and in facilitating exchange and dialogue between NeWater and IWRM researchers and practitioners.

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5
The Elbe Case Study

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5.1 Background

The Elbe is an international river 1092km long. Its drainage basin is located mainly in Germany (about two-thirds), and the Czech Republic (about a third), and minor areas of the head waters are situated in Poland and Austria (see Figure 5.1). The drainage basin covers 148,268km² and supports a population of 25 million. The largest cities are Berlin, Hamburg and Prague.

There are three major water-related problems in the basin:

1 floods and their consequences for infrastructure and arable land;
2 vulnerability against water stress in dry periods and related problems for agriculture and water supply; and
3 pollution of surface water and groundwater.

In recent years, extreme hydrological events were observed in the region – a destructive flood in August 2002, and a severe drought only one year afterwards. Besides, it should be noted that the Elbe is a major contributor of nitrogen and phosphorus loads to the Northern Sea.

Water management in the basin is well developed and has the potential to operate Integrated Water Resources Management (IWRM) and adaptive management strategies. Transboundary cooperation exists at several levels, the highest being the International Commission for the Protection of the Elbe (ICPE) created in 1990. Since its creation the activities of the ICPE have been focused on several major topics:

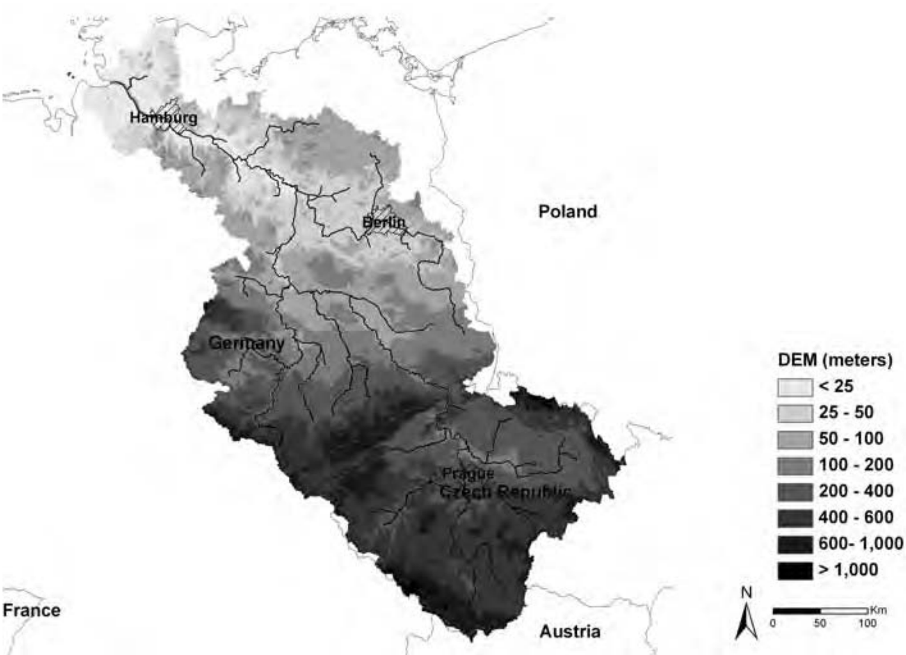

Figure 5.1 *The Elbe River basin*

- International monitoring programme,
- Decrease of the hazardous substances input to the Elbe river,
- Accidental water pollution,
- Flood protection, and
- Implementation of the Water Framework Directive (WFD).

5.2 Selected themes

Main themes addressed

To identify the major research issues to be addressed by the Elbe case study team, a 'Questionnaire on major water-related problems and research needs in the basin' was distributed to stakeholders in Germany and the Czech Republic. All major groups of stakeholders were involved in the action: policymakers, water managers, farmers, scientists, as well as representatives of water transport, spatial planning, NGOs and private households.

From 718 distributed questionnaires 33 per cent were completed and evaluated (Hesse et al, 2007). From these responses the following water-related problems were identified as a priority in the basin:

1 flood intensity;
2 water quality, diffuse pollution; and
3 summer droughts.

The following research needs were confirmed as a priority:

1 climate impact on water availability;
2 flood risk; and
3 water quality.

Based on the results, the following two major research issues were identified for the Elbe case study:

- How to incorporate adaptation to climate change into water management (with an emphasis on floods).
- How changes in land use and climate influence water quality, and how to integrate water quality and water quantity issues in water management.

How flood and drought-related problems are addressed in the basin

The two main elements of flood risk management in the basin are the reduction of flood risk and coping with floods. Preventative measures against flooding include the maintenance and updating of engineering structures (dams, storage reservoirs and polders), river basin planning to increase natural water retention, constructional measures, financial measures, and educational and awareness raising measures. Coping with flood disaster entails: aid for flood victims, averting disastrous impacts of flooding, and help in reconstruction.

The action plan for flood protection in the Elbe river basin was prepared by the ICPE and approved in October 2003. It was based on the evaluation of recent flood events, and mapping of the existing level of flood protection in the basin. The action plan included a series of measures in the drainage basin, and on the river itself, in addition to non-structural measures. These were:

- measures for increasing water retention capacity in the drainage basin,
- precaution measures in flood prone areas: their delineation, declaration and proper utilization,
- technical flood protection measures, and
- non-structural flood protection measures: flood warning, information and education.

Important results for all four types of measures were achieved since the Action Plan was created. The involvement of NGOs and relevant research projects at European and national levels contributed to the transparency of plans and the integration of the current state of knowledge into new developments.

The measures now used for water management, which are especially necessary in periods of droughts, are water saving technologies, water price mechanisms, and optimization of water resource use. Since 1990, water consumption in Germany has been reduced by almost 20 per cent (Rudolph and Block, 2001), with uneven distribution of this reduction between Western and Eastern

Germany. According to Kraemer and Piotrowski (1998), in Eastern Germany water consumption has decreased from 141l/day per capita in 1990 to 103l/day per capita in 1996 (26.9 per cent reduction), and to 93l/day per capita in 2000 (34 per cent reduction) (BGW-Wasserstatistik, 2001). The main reason was a notable increase in water prices. In future, other measures might be needed under drier climate such as land use change, the introduction of new crop varieties, the enforced use of water saving technologies, and the optimization of water resources demand.

How is the water quality problem addressed in the basin?

From 1960 to 1980 the waters of the Elbe and its tributaries were seriously polluted. The main reasons were inadequately treated municipal and industrial sewage, and diffuse pollution from intensive agriculture. After German unification, however, nutrient input into surface waters in Eastern Germany was significantly reduced. This was achieved in a number of ways:

- construction of new municipal sewage treatment plants (STPs),
- reconstruction of existing STPs,
- closure of many industrial enterprises,
- using phosphate-free washing agents,
- partial set-aside of arable land, and
- reduction in fertilizer application rates on arable land.

Reduced loads resulted in positive impacts on river water quality. A substantial decrease in the concentration of ammonium, phosphorus and heavy metals, in particular mercury, zinc, copper and cadmium, is observed in the Elbe. However, only a moderate reduction in nitrate nitrogen concentration was achieved (Krysanova et al, 2006). The explanation is that most nitrogen in the river originates from diffuse sources, mainly agricultural fields, which are more difficult to control than point sources. Moreover, the effect of improved agricultural practices (lower fertilization rates, set-aside of arable land, etc.) is usually delayed due to nutrient retention in groundwater and subsoil. Another factor to be considered is that even with reduced rates of fertilizer application, organic matter provides a permanent source of nutrients in soil.

The oxygen content in the Elbe from 1995–99 was, on average, 30 per cent higher than in the period 1981–85, leading to notable improvement in the conditions for fish breeding (Guhr et al, 2000). The improved water quality allowed the introduction of salmon and sea trout into the streams of Saxony and Brandenburg in 1998 as part of a special programme, ‘Elbe salmon 2000’. In 2002 for the first time since the 1980s salmon and sea trout returned to the river, an indication that the Elbe is in a regeneration phase.

To summarize, the emission of nutrients (N and P) from diffuse sources remains a problem in the Elbe basin. Among measures to reduce diffuse pollution, the most important are: reduction of fertilizer application rates, adjustment of fertilizer schedules to precisely meet crop requirements, and the improvement of the nutrient retention capacity of catchments (re-naturalization of landscapes, restoration of wetlands, etc.).

5.3 Research and tools applied in the Elbe case study

The Elbe case study applied and tested approaches and tools developed by NeWater and elsewhere, with a special emphasis on implementation of the EU WFD and IWRM principles.

The research was concentrated in three main areas:

1 conducting stakeholder surveys;
2 organizing stakeholder Workshops; and
3 applied research and existing tools enhancement.

Four stakeholder surveys were conducted in the basin for the evaluation of:

- major problems and research needs (total Elbe basin);
- information and research results needs (total Elbe basin);
- river basin management in relation to climate-related extreme events (the Ohre sub-basin); and
- adaptation strategies to climate change (total Elbe basin).

Four stakeholder Workshops were organized:

- Stakeholder Workshop in the Jizera catchment in October 2005;
- Workshop on perception of uncertainty in water management by stakeholders and researchers in Prague, May 2007;
- Workshop on optimization of land use in river basins to improve water quality (tools SWIM and Waterwise) in Erfurt, March 2008; and
- Simulation Game Workshop on operational flood management in Chomutov, Czech Republic, November 2008.

Applied research in the basin concentrated on climate and land use change impact assessment. Eco-hydrological modelling and scenario analysis was conducted for the whole Elbe basin and several meso-scale sub-basins.

Questionnaire surveys

The responses to the 'Questionnaire on major water-related problems and research needs in the basin' were used to identify most important water-related problems and research needs in the basin, and to compare the opinions of German and Czech stakeholders. The results of the Questionnaire are described in detail in Hesse et al (2007) and Martínková et al (2007a).

The second Questionnaire on 'Information and research results needed by stakeholders' focused on two specific issues: (a) how to better incorporate climate change into water management; and (b) how to better integrate water quality and water quantity issues in water management. The responses from water managers and experts were collected from Germany and the Czech Republic and analysed. The results of the Questionnaire are described in Martínková et al (2007b).

The evaluation of current water resource management was carried out using the Questionnaire on 'The state-of-the-art of river basin management in dealing with climate-related extreme events' (Huntjens et al, 2008). The questionnaire was distributed among experts in the Ohre River catchment (5,870 km^2), one of the large sub-basins of the Elbe located in North-West Bohemia. The research objective was an inventory of factors, considered to be important for effective water management in relation to climate-related extreme events. The evaluation identified issues that required improvement, such as cross-sectoral cooperation, dealing with transboundary conflicts, implementation of IWRM in education, and stakeholder participation.

A cross-comparison of climate change adaptation strategies across regions, including the Elbe, was performed in the NeWater project. The comparison focused on the following major issues: understanding climate change and its impacts; drivers and barriers involved in the development of the adaptation strategy; adaptation measures required, available and planned; and the status of adaptation strategy implementation. In total, 22 experts were involved in the evaluation of adaptation strategy in the Elbe basin. According to their responses, more precipitation in winter and less in summer, and higher frequency and intensity of floods and droughts are expected in the basin. Climate-related disasters and national and international policies were identified as the most important drivers for adaptation. The spatial and temporal uncertainties in projections of climate change impacts were identified as main barriers for adaptation. According to expert responses, the current water management measures, in practically all categories, belong to the 'existing and planned' class. However, the development of the adaptation strategy in the basin was evaluated as commenced but progressing rather slowly.

Stakeholder workshops

Two of four of the most important workshops organized by the Elbe case study team are shortly described below.

Workshop on Perception of Uncertainty

The Workshop on 'Perception of Uncertainty by Stakeholders and Researchers in Water Management' was held in Prague in May 2007. The objectives of the Workshop were:

- to inform stakeholders about state-of-the-art research concerning climate change, flood protection, water quality, and related uncertainties,
- to discuss the ways and strategies to cope with uncertainties in flood management and in water quality management, and
- to discuss the role of research in coping with uncertainty in water management.

The Workshop participants agreed that an integrated flood protection strategy including different types of measures is an absolute necessity in the Elbe basin. A combination of adaptative and preventive measures can be helpful for decreasing uncertainties in the strategy against harmful effects of floods under changing climatic conditions. Prevention is currently based mainly on structural or technical measures, but there needs to be an increase in the flexibility and efficiency of these water management systems through the introduction of non-structural approaches. Non-structural adaptive measures can be of two types: 1) preliminary measures such as the extention of floodplains, enhancement of infiltration and retardation of water, agriculture practices reducing runoff, and forecasting and warning systems; and 2) reactive measures including increased efficiency of water management in non-stationary conditions, efficient delivery of information and warning to populations at risk, timely evacuation of people and post-flood recovery.

The extension of floodplain areas is required in the basin, but it is often not easy or possible to achieve: better planning and control of funding is necessary. The uncertainties related to flood forecasts should be communicated to stakeholders and inhabitants who need to be made aware of the uncertainties involved, and not to believe exact numbers or precise forecasts. The suggestions relating to the implementation of the integrated flood protection strategy, concrete recommendations on how to reduce uncertainties related to flood management and measures to improve reliability of modelling results used for flood forecast and estimation of the design flood are reported (Deliverable 3.3.5).

Simulation Game Workshop

Decision making has to take place at varying time scales within an IWRM strategy. An extreme case is decision making for flood management, in situations in which the response times of the catchments are very short (e.g. hours). In this case, a quantitative precipitation forecast is necessary for the flood forecast to have a sufficient lead time. However, quantitative precipitation forecasts are extremely uncertain. During the flood, staff in the control room communicate with meteorologists and hydrologists to obtain predictions of precipitation and discharges that are as accurate as possible, and regional and local authorities who are responsible for response measures. Sometimes difficult decisions need to be taken in less than one hour.

The Simulation game on operational flood management was held in Chomutov, Czech Republic, 11–12 of November 2008 (see Figure 5.2). The game dealt with a system of four reservoirs facing a flood situation. These reservoirs were designed to protect Karlsbad, a well known spa town, from flooding. The purposes of the operational game were to demonstrate the uncertainties of using forecasts, and the difficult decisions which have to be made during the course of a flood. The main objective of the workshop was to enhance communication and social learning among water administrators (flood control room staff), decision makers, meteorologists and hydrologists.

Figure 5.2 *The 'simulation control centre' discusses the results*

The evaluation of the questionnaire demonstrated the Simulation game to be a very powerful tool for the enhancement of understanding, interaction and collaboration among water management authorities, water experts and local stakeholders.

Applied research in the basin

In the Elbe case study the ecohydrological river basin model SWIM (Soil and Water Integrated Model) (Krysanova et al, 1998) was used to assess the impacts of land use and climate change on water availability and quality. SWIM simulates hydrological processes, vegetation and nutrient cycles at the river basin scale by disaggregating the basins to sub-basins and hydrotopes. The model was applied to several meso-scale sub-basins of the Elbe: Rhin, Unstrut, Weiße Elster, Jizera and Malse-Rimov. In most cases the modelling was done in close collaboration with stakeholders interested in the assessment. A test of the Waterwise tool for optimization of land use and land management strategies was also conducted.

Application of the model SWIM to support WFD implementation

The Environmental Agency of Brandenburg (LUA) requested a modelling study for the Rhin catchment to support implementation of the WFD in Brandenburg in order to achieve the required 'good ecological status' by 2015.

The Rhin is a meso-scale catchment (1716km²) located in the Elbe drainage area. It is representative of the lowland part of the Elbe basin. The catchment is characterized by sandy forested areas in the north with many lakes along the course of the river, and very flat agricultural areas in the south. The Rhin river network is influenced by more than 300 small dams and weirs. Many irrigation and drainage ditches, pumping stations, water storage and transfer schemes and barrages influence the hydrological cycle, so that the natural discharge behaviour is heavily masked.

With respect to water quality, the river is polluted, although the upper reaches of the river network are less affected than the lower sections. Measures to improve water quality and to achieve 'good ecological status' and the 'good chemical status' required by the WFD are therefore necessary.

The analysis of time series and the modelling results have shown that the nitrate nitrogen load is strongly influenced by diffuse source pollution (mainly from agricultural fields), whereas the total load of phosphorus in the Rhin is affected mainly by emissions from point sources. The fraction of point borne loading is much higher for phosphorus than for nitrogen.

To find measures for nutrient load reduction in the Rhin and its tributaries, several scenarios of changing land use and land management were analysed (Hesse et al, 2008). The nitrogen load was more sensitive to changes in the fertilisation regime and crop type composition, whereas the load of phosphorus was most effectively reduced by decreasing point source emissions. Since no single scenario resulted in a substantial decrease of the nutrient load and the average concentration for both nitrogen and phosphorus, a combination of measures was tested. This led to a reduction of nitrogen and phosphorus loads and concentrations of up to 15 per cent (see Figure 5.3), which would enable the system to advance towards the 'good ecological status' required by the WFD.

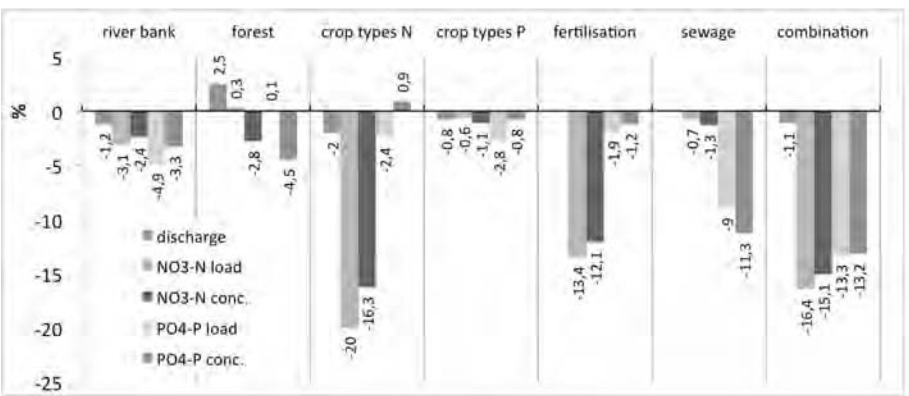

Figure 5.3 *Changes in water discharge, nutrient concentrations and loads according to land use/land management scenarios*

Testing the Waterwise tool for optimization of land use

Waterwise is a decision support tool for spatial land use planning and optimization of land use in relation to water quality and quantity (van Walsum et al, 2008). This tool was chosen as a part of a 'Train-the-Trainers' activity organized by NeWater to train the case study team in the use of the software, and ultimately to pass this knowledge on to local practitioners. Waterwise cannot be run as a stand-alone tool, it requires outputs of catchment-scale model(s) to obtain region-specific bio-physical, hydrological, water quality, and economic data.

The Waterwise tool was chosen for testing in one of the Elbe sub-basins. SWIM was used as the catchment model to provide necessary input data to Waterwise. Other information, including economic data and details of the nutrient abatement strategies employed, was collected separately. In the period from November 2007 to February 2008 a coupled SWIM-Waterwise simulation was performed for the Wipper catchment in Thuringia; the objective was to identify the optimum land use strategy needed to improve the quality of river water.

A prototype of the land use optimization for the Wipper was demonstrated at the Workshop in the Thuringian Ministry of Agriculture, Nature Protection and Environment (TMLNU) in Erfurt 27–28 of March 2008. It was confirmed that Waterwise is a useful decision support tool for planning spatial land and water use strategies. The impression of the Workshop participants was that the coupled application of Waterwise and SWIM for the WFD implementation could be useful and realistic under certain conditions. Though the usefulness of the tools and relevance for the real problems in the region were confirmed, the timing of the WFD-related stakeholder process in the region and further application of tools were found to be unfavourable. The main reason was that the plans and measures for the WFD implementation in Thuringia had just been compiled, and there was no justification to begin the process again. It was not possible to suggest a long-term strategy beyond 2008. Nevertheless, the experience of testing SWIM and Waterwise tools in the Wipper catchment has demonstrated that further applications of Waterwise in other catchments could be extremely useful.

5.4 Outlook and policy summary

Identified challenges and lessons learned

The main problems associated with water management in the Elbe basin are: floods and their consequences, vulnerability against water stress in dry periods, and water pollution. In general, water management in the basin is well developed and in a good position to adopt IWMR and adaptive management. The main challenges to integrated and adaptive water management in the Elbe basin were identified, in collaboration with stakeholders, as follows:

- better water management in relation to floods and droughts in view of climate change;

- improvement of water quality in the Elbe and its tributaries; and
- enhancement of the transboundary Czech-German dialogue on water management.

The challenges are easy to list, but very difficult to implement, especially in view of climate change and related uncertainties. The ability to cope with conflicts and to encourage awareness-raising would be enhanced, for instance, by better incorporation of IWRM and adaptive water management concepts into existing management rules and the education system. IWRM knowledge should be disseminated at special workshops for water managers, and by bringing new methods into common rules and software tools for water management. Integrated and adaptive water management concepts should become a basic part of water management education.

Our research within the framework of NeWater confirmed that the following steps would be useful for enhancing adaptive water management in the Elbe basin:

- development of a clear strategy for planning in light of climate change, and negotiations for a wider agreement between government authorities, non-governmental bodies and the public;
- establishment of clear indicators of the positive and negative effects, not only for water quality and quantity (they do exist), but also for environmental, economical and social aspects;
- extended usage of modelling tools and decision support systems in water management;
- enhanced support for the downscaling of EC rules, and knowledge dissemination at the local municipality level; and
- wider access of relevant information and data to the public.

An important conclusion from the stakeholder Workshop in Prague is that an integrated flood protection strategy with different types of measures is necessary in the basin. Concrete suggestions for implementation of the integrated flood protection strategy and reduction of uncertainties related to flood management collected at the Workshop, have been summarized within the NeWater project (Deliverable 3.3.5).

The evaluation of the questionnaire on ‘River basin management in dealing with climate-related extreme events’ for the Ohre basin made it possible to summarize the state-of-the-art river basin management for the Czech part of the Elbe, and to some extent for the whole Elbe basin, and to identify the issues in need of improvement. They are: cross-sectoral cooperation, dealing with transboundary conflicts, implementation of IWRM in education, and enhanced stakeholder participation.

Dynamic river basin modelling, which is driven by climate conditions and which takes into account water and nutrient processes as a function of vegetation, land use and human activities, can provide a very functional tool for creating a river basin management plan. These models can take account of possible changes that might confront the basin in future.

Modelling experiments can help us understand the river system behaviour better. For example, the model can be very useful for identifying fractions of point and diffuse sources at the outlet of a river system and the areas of highest diffuse pollution (hotspots). Knowing the fractions and hotspot areas, it is easier to identify useful measures for reducing nutrient loads in the river network and achieving 'good ecological status'.

Future water management decisions should be more adaptive, since we are living in a rapidly changing world. Model scenarios providing a range of different options for the future should be taken into account. They can be helpful for identifying reasonable measures to achieve better ecological status taking into account possible changes of land and water use, management practices and climate conditions.

The evaluation of the Simulation game on operational flood management has shown that it is a very powerful tool for enhancement of understanding, interaction and collaboration among the water management authorities, water experts and local stakeholders dealing with flood management.

How integrated and adaptive water management can help

Adapting water management to climate change requires adjustment in management practices, land use, technological development, diversification, changes in the economic structures of households and regions, and awareness raising.

However, the actual response strategies need to consider the adaptive capacity of the natural and social systems under consideration, including social and political drivers. Therefore, building and strengthening the adaptive capacity at the basin scale should be a central goal in view of climate change. The region-specific adaptation strategies should be developed by local water managers in discussion with the local population. This participative approach would allow site-specific expert knowledge to be incorporated into the planning process, and to ensure that the response strategies consider local social and political drivers.

Water management of extreme events is characterized by great complexity and inevitably involves considerable uncertainties. Therefore, WRM should be approached from a broad perspective following the IWRM concept and taking into consideration the interests of different related sectors, different spatial and temporal scales, and transboundary issues.

Moreover, projections of climate change and its impacts on the water sector suggest that the goal of water managers should be to increase adaptive capacity to better cope with uncertain future developments, rather than rely solely on finding optimal solutions. Therefore, strategies for coping with climatic hazards inevitably stress the need for integrated WRM in river basins, supplemented by adaptive management in conditions of uncertainty. Such an approach is especially needed in view of the expected climatic changes in the 21st century.

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6
The Guadiana Basin

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6.1 Background

The Guadiana is a transboundary basin whose water resources are shared by Spain and Portugal. The river rises in the Spanish province of Cuenca and flows 778km first in a westerly direction, then south into the Gulf of Cadiz near the Portuguese port of Vila Real de Santo António (Figure 6.1). It drains an area of 66,800km^2 of which 11,580km^2 (17 per cent) lies in Portugal. Within NeWater, work has concentrated on the Spanish side of the basin, although not exclusively.

Most of the research has focused in the Upper Guadiana Basin (UGB), above the El Vicario reservoir, that provides an example of conflict caused by the over-exploitation of water resources in a semi-arid region. Since the 1970s uncontrolled abstraction of groundwater to provide water for crop irrigation has lowered the water table in places by up to 50m, causing the main river channels to run dry and wetlands to become desiccated. The Tablas de Daimiel National Park, an internationally renowned wetland, is perhaps the most high profile victim of the desiccation process. The abstraction has also supported a booming agricultural economy with all the associated social benefits. The result has been conflict between farmers, local government, regulators and conservationists that legal action, subsidies and engineering solutions have to this date, failed to combat.

To find a solution to these environmental, economic and social problems, the Ministry of the Environment developed a Special Plan for the Upper Guadiana (*Plan Especial del Alto Guadiana* – PEAG). The plan, with a budget of €5500m, was approved by the Spanish Council of Ministers in January 2008.

Source: Guadiana Water Authority (2006)

Figure 6.1 *Map of the Guadiana river basin*

This plan devises a water consumption scenario that is compatible with a mid-term water table recovery (before the year 2027) and identifies water management tools to deal with the Upper Guadiana groundwater crisis. However, the plan does not appear to be in agreement with the principle of full cost recovery required by the EU Water Framework Directive (WFD), and there are many technical and political uncertainties that jeopardize its success.

6.2 Selected themes

Water scarcity

The Upper Guadiana Basin is one of Spain's driest areas. The agricultural sector, which uses 93 per cent of the total, dominates water use; by comparison urban water supply is limited to about 5 per cent and industrial use to 1 per cent (Guadiana Water Authority, 2006). Although agriculture accounts for a high percentage of water use it only contributes 8.4 per cent to Spain's Gross Value

Added (GVA) figure, whereas the industrial sector accounts for 2 per cent. This means that although agricultural water use is 93 times greater than that of industry, the GVA in euros is only four times higher.

The water scarcity problem has been made worse by the increased frequency and intensity of droughts, threatening the livelihood of many local farmers and the economy in general. This has not been a problem because in most cases the supply from groundwater has provided a buffer to the immediate impacts of drought (Hernández-Mora et al, 2003; Garrido et al, 2006). Until now the use of groundwater has continued to virtually negate the effects of the region's endemic drought problems, thus supporting irrigation-based social and economic welfare and acting as the main driver behind the region's prosperity. Uncontrolled intensive pumping by individual farmers has dramatically lowered water tables and has been responsible for considerable negative environmental impacts on groundwater-dependent wetlands, streams and rivers. Most wells in the UGB are currently illegal which makes it difficult to manage water resources in the area.

Recently, increased awareness of water scarcity has led to more thoughtful and sustainable water use. For instance high economic value, water-efficient crops such as olive trees and vines are replacing more water-intensive crops in terms of m^3 ha^{-1} like alfalfa, maize and sugar beet. Thus the Guadiana basin is slowly moving from a policy of 'more crops and jobs per drop' towards 'more cash and nature per drop'.

Irrigation

Since the 1980's the impact of endemic drought has been offset by the large-scale and uncontrolled abstraction of groundwater used to support an irrigation-based economy, providing prosperity in the region. Policy incentives to intensify agricultural production, low infrastructure costs, and high profitability, have encouraged individual farmers to invest in ground water irrigation systems (Varela-Ortega, 2007). As a direct result, between 1960 and 2003, the area under irrigation increased from 30,000 to 150,000 hectares (Guadiana Water Authority. 2005).[1] During that time groundwater abstraction consistently exceeded 500Mm^3 yr^{-1}, exceeding the estimated renewable resource of 230Mm^3 yr^{-1}; leading to unexpected and adverse environmental effects. From the 1970s to the 1990s intensive pumping caused the water table to drop by as much as 1m yr^{-1}, and led to the degradation of highly-valued wetland ecosystems including *Las Tablas de Daimiel* National Park, part of the UNESCO and Ramsar-listed *Mancha Humeda* Biosphere Reserve (de la Hera, 2003).

Extensive pollution of groundwater by nitrates through the application of nitrate-rich fertilizers has seriously affected the UGB. In order to comply with the Nitrates Directive a special programme (part of the Common Agricultural Cross-Compliance Policy) to combat the problem has been implemented. Its application has proved to be controversial since farmers maintain that compliance with the Directive leads to a considerable loss of income (Varela-Ortega et al, 2007b).

Since the late 1980s attempts have been made by river basin authorities to establish legal controls on water use. This has included yearly pumping restrictions without economic compensation (also named 'Water Abstraction Plans') and a ban for drilling new wells. The implementation of the 'Water Abstraction Plan' has created ongoing social unrest, hindering Spanish authorities in fully developing the water use limitation policy. Measures co-funded by the European Union (namely the Agri-Environmental Programs) have provided compensatory payments to encourage farmers to voluntarily reduce water use (Varela-Ortega, 2007a). While the latter policy has been more effective, neither measure has met their main objectives. Over 20,000 unauthorized boreholes still exist within the aquifer (Guadiana Water Authority, 2005), and the downward trend of groundwater levels has not been reversed (Varela-Ortega et al, 2008).

Livelihoods and ecosystem services

The EU WFD requires all water bodies to achieve a 'good' status in terms of both quantity and quality by 2015. The main issue in the UGB is how to achieve this whilst ensuring there are no adverse impacts on the social and economic well-being of the area. All stakeholders see this as a difficult task, particularly in view of the area's groundwater management difficulties (Guadiana Water Authority, 2006).

The close connection between ground and surface water in the UGB means that practically all the wetland ecosystems depend on groundwater discharge. To achieve good ecological status groundwater levels in the aquifers need to be raised to near natural levels. Considering this and the socio-economic implications of groundwater recovery, it is unlikely that full restoration of all wetlands can be achieved. The ecosystems located in the central and surrounding parts of the Mancha Occidental aquifer are practically irrecoverable and unless pumping is reduced to practically zero, a series of consecutive wet years follows. However, wetland ecosystems located in other areas of the basin are potentially easier to restore to good ecological status. These wetlands include:

- *Those located along the Cigüela river margins.* These wetland ecosystems were severely damaged by the water diversions made from the Tagus-Segura aqueduct to the Tablas de Daimiel National Park between 1988 and the present day and which are scheduled to continue. The Cigüela river-bed was made deeper and wider in order to facilitate an increased water flow. The volume of diversions from the Tagus-Segura aqueduct to the Tablas de Daimiel National Park were up to 30 million m^3 depending on the climatic conditions at the time. These wetlands face little demand on their resources because the Cigüela is brackish, and not attractive as an irrigation supply. Their recovery should restore the Cigüela river-bed to its natural state.
- *Those located upstream of Peñarroya Reservoir (Ruidera Lagoons).* The lagoons are fed by the Campo de Montiel groundwater body, which has not been adversely affected by pumping.

Conflict resolution and prevention

Water-related conflicts in the UGB are widespread and have created contention within the main interest groups: conservationists against irrigators; the central government against regional authorities; legal against illegal well owners; and farmers' collectives against each other. These disputes stem from the failure of existing institutional arrangements such as enforced water pumping restrictions and the compulsory creation of water associations. Confrontation has been exacerbated by the hostile relationship between the water authority and water users (Lopez-Gunn, 2003; Lopez-Gunn and Martinez-Cortina, 2006). Many farmers perceive high-level interventions as an attack on their rights to generate a profit, and as a result are unwilling to change their water use practices. In this context, the approval of the PEAG is perhaps the most ambitious and comprehensive attempt to settle water disputes in the region.

NeWater has brought together conflicting stakeholder groups and provided them with the opportunity to express their different views and opinions in an atmosphere of reliability and trust. This has facilitated the understanding and acceptance of the position of others and helped find acceptable solutions.

With regard to transboundary issues, the Guadiana Basin is included in the Albufeira Convention, which covers the protection and sustainable water use in Portuguese-Spanish hydrological basins. The relationship between Spain and Portugal in the framework of this Convention is generally constructive, albeit with rare discord or concern about river flows and water infrastructure developments (Wolf, 2005).

Information management and technical exchange/sharing knowledge

Although adaptive water management is essentially a scientific approach, it emphasises the need for successful public engagement and for an effective social learning process. Apart from recruiting representatives from the most relevant stakeholder groups, NeWater has also targeted a broad cross-section of individuals selected from a number of farmer collectives, since these groups are responsible for 95 per cent of the basin's water use. Primary and secondary educators have also been involved due to their potential 'ripple-effect' in society (Villarroya et al, 2008).

Between 2006 and 2008 Newater met with farmers and educators to help explain the hydrological setting of the Guadiana basin and in particular, the interaction between surface and groundwater bodies and the impact that intensive pumping has had on the wetlands. Meetings began with a background explanation followed by active debates during which the participants proposed practical measures to help implement adaptive water management at the ground level. Field trips were organized in conjunction with each meeting.

The main finding of the meetings was the widespread lack of knowledge about groundwater resources and the impact of over-abstraction on the local environment. Some progress has already been made in the education of the general public through direct contact with decision makers in the Education

Department of the Castilla-La Mancha Regional Government although this is a task beyond the four-year timescale of the NeWater project. These contacts have resulted in the distribution of 500 posters designed by the NeWater team to many state schools in the region. The inclusion of water education in the academic curricula is presently being discussed.

Stakeholder participation process

Conflict, data uncertainty, and concerns over the long-term sustainability of water resources are the hallmarks of the UGB. It requires the development of a long-term sustainable management strategy where every interested sector of the community is given the opportunity to participate in the decision-making process. A stakeholder participation process was established from the outset in which stakeholders were asked to identify the current types of management problems and uncertainties, and the types of tools required to meet them.

Stakeholders were representative of the main collectives responsible for water management at the basin scale,[2] and were selected based on the experience of the research team. The approach attempted to create environment to allow change towards adaptive water management, and to develop site-specific scenarios for the application of adaptive water management tools. A basic premise of the approach to these meetings was the neutrality of the Guadiana research team in order to generate an atmosphere of reliability and trust within which stakeholders felt free to openly share their views.

One of the products requested by stakeholders was developed by the Technical University of Madrid (UPM) and consisted of an agronomic-economic-hydrological framework for analysing policy scenarios and the cost-effectiveness of policy measures. The framework, which links water and agricultural policy, is used to examine the impact of adaptive policy options on socio-economic systems under different scenarios. This methodology is attractive as the selected scenarios are created using input from stakeholders.

The economic model is based on a constraint optimization approach that simulates farmer behaviour and predicts their response to changes in the natural system and adopted policies. Several agricultural and water policy scenarios (stakeholder-driven and policy-driven) have been simulated to assess their impact on different components of the system. Results showed that controlling illegal water mining is a necessary condition for aquifer recovery and should be combined with other actions. Water policies based on Water Abstraction Plan (WAP) quotas lead to important reductions in water consumption at a relatively low public cost, but a high private cost, creating social unrest and opposition from farmers (Varela-Ortega et al, 2007b). Modelling showed that the most cost-effective actions to achieve aquifer sustainability are those based on water pricing. This approach, however, causes income loss to small farms with a less flexible cropping pattern (vineyards) and could threaten their viability (Blanco et al, 2007). The purchase of water rights and the establishment of the water rights market are socially acceptable, but willingness to sell entitled rights varies across farm types and irrigators' attitudes, and is dependent on the offer price, the types of farm or agricultural systems, and other social factors (age of the farmer, etc.) (Varela-Ortega et al, 2008). Finally, agricultural policies can also promote water savings in some areas when full decoupled or cross-compliance measures are established and thereby contribute to water resource conservation and ecosystem protection as required by the WFD (Varela-Ortega et al, 2007b).

6.3 Groundwater modelling and management scenarios

The Guadiana Water Authority needs to ensure a complete recovery of the aquifer and its associated ecosystems as per WFD requirements. Controversies boil down to establishing the system limits and evaluating potential trade-offs between irrigation water demands and environmental flows. Consultation with Mancha Occidental stakeholders concluded that in this case these issues could be assessed by a numerical groundwater model (Martinez-Santos et al, 2008a).

NeWater has developed a methodology to couple hard-science numerical modelling approaches with the involvement of key water actors (Martinez-Santos et al, 2008b). The main factors controlling the resilience of the system and the drivers for change are identified, while the potential implications for aquifer sustainability are assessed. Full aquifer recovery seems unlikely, while reserves seem sufficient to support current pumping rates in the mid to long term.

Buffering capacity has also been evaluated. This includes the development of a preliminary MIKESHE model of the Upper Guadiana Basin.

6.4 WEAP model

The hydrology model WEAP (Water Evaluator and Planning System) has been specified, calibrated and validated for the Guadiana river basin (Varela et al, 2006). Model output includes monthly simulations of factors such as demand site requirement satisfaction, reservoir and groundwater storage, hydropower generation, evaporation, and transmission losses (SEI, 2008).

This innovative approach of coupling this model with an agro-economic model provides a useful tool for assessing water and agricultural policy-relevant scenarios in water stressed areas (Varela-Ortega et al, 2008).

Both models were run using policy scenarios generated by the scenario building sequence of the WEAP module, taking into account climate and water uncertainties (Varela-Ortega et al, 2007). The WEAP model is able to up-scale the results obtained from the farm-based economic model to the basin level and assess the impacts of the different policies on the aquifer's recharge, the overall availability of water resources and the unsatisfied demand in the basin (Varela-Ortega et al, 2007).

From the results we conclude that short-term water conservation policies implemented in the UGB can help reduce water consumption on farms, but will not be able to secure full recovery of groundwater levels in the Western La

Mancha aquifer. The desired target of aquifer recovery will be achieved when the newly approved measures for reducing water abstractions are fully enforced over the long term; these include measures such as buying water rights and closing unlicensed wells. Even then, recovery will be difficult to meet, during times of extended drought (Varela-Ortega et al, 2008).

6.5 The vulnerability analysis (CART analysis)

The implementation of water allocation limitations faces strong opposition from farmers due to the income loss it causes to them In order to support policy decisions and implementation, it is necessary to analyse farmers' vulnerability to this policy.

Farmers' vulnerability has been considered in economic terms. Input for the vulnerability analysis is obtained from the agro-economic model (Varela et al, 2006) developed by UPM. Two indicators of income loss are used to classify farms into four vulnerability classes: extreme, very high, high, and medium. The two indicators are: (1) the rate of income loss (per cent), and (2) the rate of actual farm income to minimum survival income (per cent), estimated from the official 2007 minimum inter-professional annual wage rate in Spain.

The approach developed by UPM in collaboration with SEI-Oxford highlights the most vulnerable farms. These are obtained using a decision tree tool called CART (Classification and Regression Trees, Salford Systems). The outcome is a classification tree of vulnerable farms, where the classification variables are vulnerability prediction variables. These represent:

1 structural characteristics (farm size, crop diversification, permanent crops and irrigated area);
2 technical characteristics (over abstraction of groundwater); and
3 institutional factors (impact of the degree of implementation of the water conservation policy).

Results show that the WAP provokes substantial farm income loss to all farms, but is higher on small non-diversified farms operating legally and complying with the licensed abstraction rates set by the WAP. Farms are more vulnerable to a reduced enforcement capacity, because illegal boreholes continue to abstract at higher rates placing legal irrigators at a disadvantage.

6.6 Bayesian Belief Networks

One objective of the NeWater project was to translate research outputs into tools for practitioners and end-users to help implement adaptive and integrated water resources management. One of the tools chosen was based on the application of Bayesian Belief Networks (BBNs) (Bromley, 2005; Henriksen et al, 2007). This aided water management decision making, stakeholder engagement, and identification of management potentials and constraints. A BBN is a decision support system based on Bayes' rule of probability. The nature of the technique enables identification of gaps in data or knowledge in the system, leading to an inability to meet some of the goals of the WFD.

Two BBNs have been developed for the UGB. One at a regional scale covering the entire UGB, the other at farm scale (Zorrilla et al, 2007). The regional network is designed to investigate hydrological, social and economic impacts of the PEAG at the scale of the Mancha Occidental Aquifer. In contrast, the farm scale network concentrates on the impact of the plan at single farm level. Results show that with the full implementation of the Special Plan, there is a 40–75 per cent chance of aquifer recovery before 2027 (deadline established by the WFD). However, full implementation of the plan will lead to a certain reduction of current agrarian economic production, which may be important for small vineyard farms.

6.7 Water Footprint

As the most arid country in the European Union, water use and management in Spain is a hot political and social topic. Knowledge of virtual water, defined as the volume of water used in the production of a commodity, good or service, and the water footprint (water volume used to produce the goods and services consumed by a person or community) together with an economic analysis, can contribute to improved adaptive management and allocation of water resources. Furthermore, this analysis could provide a multidisciplinary framework for achieving WFD objectives (Aldaya et al, 2008).

The present study deals with the economic and hydrological analysis of the virtual water and the water footprint of the Guadiana river basin, taking into account both green and blue (ground and surface) water (Aldaya and Llamas, in press). In the Guadiana basin the main water consuming sector is agriculture (about 95 per cent of total consumption). Within this sector, high virtual-water and low-economic value crops are widespread in the Upper and Middle Guadiana regions. The economic productivity of blue water ranges between 0.1–0.2 €/m^3 for low cost cereals and 1.5–4.5 €/m^3 for vegetables in the Upper and Middle Guadiana basin. In contrast, the value for vegetables can amount to 15 €/m^3 in the Lower Guadiana and TOP domain (group of three small river basins – Tinto, Odiel and Piedras – located near the Guadiana River mouth). Nevertheless, factors such as risk diversification, labour or other environmental, social, economic and agronomic reasons have to be taken into account in order to find a balance. The major environmental challenge to agriculture is the preservation of the environment without damaging the agricultural sector economy. The Guadiana basin has already moved in the direction of 'more crops and jobs per drop'. The aim now could be to move towards a policy of 'more cash and nature per drop', particularly in the Upper and Middle Guadiana basin.

6.7 The future

The ongoing water management problems in the Guadiana basin, particularly the upper Guadiana, mean that the goals set by the WFD are unlikely to be achieved within the required timescale.

The continued lack of transparency concerning land use and water rights in the Guadiana needs to be resolved and management policy requires full disclosure and a clear definition of these rights. In addition the recently approved Special Plan for the Upper Guadiana does not conform to the principle of full cost recovery specifically required by the EU WFD. Moreover the €5500m budget to implement the Plan is unlikely to be made available in the near future, meaning that any significant short-term progress is doubtful.

Since the emphasis of the WFD is to improve the ecological status of the environment, it is important to consider the long-term impact of water management practices in ecological terms. The prospects of achieving full recovery of groundwater levels and complete restoration of associated wetlands are extremely low mainly due to political and economic issues. Given the severity and complex nature of the problem it is possible that the Spanish Ministry for the Environment will request an extension of the deadline for achieving the environmental objective, or even an exception.

The detailed economic studies of the agricultural sector of the region undertaken by NeWater have provided an objective in-depth examination of the situation. We consider BBNs to be a particularly effective and easy technique to engage stakeholders and assist decision making under conditions of uncertainty. Application of the methodology to all Spanish basins should be encouraged in order to facilitate participation as required by the WFD. To encourage the application of BBNs a 'Train the Practitioners' workshop was organized to help disseminate the technique among Spanish practitioners.

Finally, we believe that the 'Water Footprint' analysis, combining hydrological and economic data, will prove to be a valuable aid to transfer from a policy of 'more crops and jobs per drop' towards 'more cash and nature per drop' and will ultimately benefit water governance in all industrialized semi-arid countries.

Notes

1 It is worth noting that no reliable figures for annual water abstraction from the aquifer exist; neither is there an estimate of the total surface area under irrigation, nor of the distribution of irrigated crops (Guadiana Water Authority 2006).

2 Stakeholders included: the Guadiana River Basin Authority (Confederación Hidrográfica del Guadiana), the regional agricultural authority (Consejería de Agricultura de Castilla-La Mancha), various farmer collectives, groundwater user associations and local and national environmental associations.

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7
Rhine River Basin

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7.1 Introduction

Basin description

The Rhine is 1300km long – 800km of which are navigable – and spreads over an area of 185,000km^2. The Rhine basin is shared by nine countries. Germany (55 per cent of basin area), Switzerland (18 per cent), France (13 per cent) and the Netherlands (6 per cent) share most of the basin (Wolf et al, 1999). The parts of the basin in Austria, Belgium, Italy, Liechtenstein and Luxembourg are very small. About 60 million people live in the basin. The average discharge at the mouth is 2200m^3 s^{-1}. The hydrology and flow distribution throughout the year are favourable for navigation, which explains why it represents one of the most important transport routes in Europe (Huisman et al, 2000). Apart from navigation the river is used as a water supply for domestic, agricultural and industrial purposes (including cooling water), for waste water disposal, hydropower generation, fisheries, and recreation.

Transboundary cooperation

There has been transboundary water management for a long time in the Rhine River basin. The first international agreements were signed in the 19th century, with the establishment of the Central Commission for Navigation on the Rhine (CCNR) and the Salmon Commission. The International Commission for the Protection of the Rhine (ICPR) was established in 1950 after pollution problems became noticeable and people realized that results could only be achieved through transboundary cooperation. Several flood events over the past decade drew attention to flood management and to transboundary cooperation for flood management. Thus, over time awareness has developed about the interdependence of riparian countries for achieving water management objectives (Raadgever, 2005).

Main water management issues in the Rhine basin

The Rhine River has a flow regime driven by rainfall and snowmelt. Peak discharges occur in winter, originating from precipitation in Germany and France (Silva et al, 2004). According to recent research on climate change, severe floods and droughts are expected to occur more often in the Rhine basin. Proceeding downstream, the problem of flood protection becomes more severe. Moreover, increased urbanization along the river banks has exacerbated the impact of flooding. The whole river faces the problem of pollution, mainly from non-point sources. Point source pollution is largely controlled by a combination of permits and charges to regulate polluted discharges (Raadgever, 2005). In general however, the Rhine countries have sufficient resources to counter most of their water problems. Also, trust has been built between the riparian countries through long-lasting cooperation in the ICPR and the EU (Raadgever et al, 2008a).

Three sub-cases

The NeWater effort in the Rhine case study was divided over three sub-cases: the Lower Rhine, the Kromme Rijn and the Wupper. The Lower Rhine case focused on transboundary flood management; the Kromme Rijn case largely dealt with water management planning; and the Wupper case looked at participatory water management planning. Further research dealt with questions about management style and uncertainties. This chapter describes the activities and outcomes from these sub-cases.

7.2 The Lower Rhine

The flood risk context

In this book 'The Lower Rhine' refers to the lower part of the Rhine River in Germany and the upper part in the Netherlands. Flooding is a serious threat along this densely populated stretch of the river. In North Rhine-Westphalia (NRW) and the Netherlands (NL) strong dikes have been constructed to protect the land from flooding. Apart from increasing the height of embankments, other types of measures to decrease flood risk – like creating more room for the river – are currently considered and put into practice. Both NRW and NL have established a set of flood management measures to be implemented by 2015 (Rijkswaterstaat, 1998).

Since 1997, a broad range of government actors from NRW and NL have exchanged knowledge and conducted joint research in the German-Dutch Working Group on Flood Management (WGFM). Currently, important focuses are the study of climate change consequences and spatial and socioeconomic change.

Participatory scenario study

A participatory scenario study was set up in the Lower Rhine case, initiated by the ACER and NeWater research projects in collaboration with the WGFM. Of particular importance was the need for good collaboration between researchers, policymakers, and other stakeholders from different countries (Germany and The Netherlands), and disciplines (e.g. water management, spatial planning, natural and social science). Over time some of the WGFM members limited their involvement due to time constraints and political reasons. This weakened the link between the process and formal policymaking but opened up possibilities for more intensive cooperation with other flood management stakeholders (Raadgever, submitted).

An overview of stakeholder perspectives was recorded to develop awareness among the stakeholders and to stimulate discussion. The researchers interviewed members of the WGFM and a few non-governmental stakeholders. Furthermore, a Q sorting questionnaire was administered among a broad range of flood management stakeholders in the Lower Rhine basin. Q methodology is intended to systematically elicit individual perspectives, and to group them into shared perspectives using quantitative factor analysis. The Q sorting identified a common basis of agreement and three distinct perspectives on future flood management (Raadgever et al, 2008b). Furthermore, repeating the Q sorting after the scenario study made it possible to evaluate whether the perspectives of the participants had changed.

The core of the participatory scenario study consisted of stakeholder workshops. Each workshop consisted of presentations from technical experts and others; working sessions in sub groups and plenary discussions. The workshops were facilitated by a consultancy firm specializing in participatory processes in water management. In between the workshops, the ACER project assessed the outcomes of different strategies under different scenarios. Preliminary results were fed back to the participants at the workshops.

After exploring the future more openly at workshop 1, a set of four scenarios from the literature were used in the remainder of the scenario study. The scenarios were based on two important aspects of uncertainties: values and governance (Berkhout et al, 2002). The 'values' dimension represents political and social priorities and the distribution of public and private responsibilities. The 'governance' dimension describes political and economic power relations and the spatial and structural orientation of decision making. Using scenarios from literature had the advantage that the scenarios were well grounded in science, and offered consistent data about many aspects of the future, such as economic growth and climate change; one disadvantage was that they were not specifically tailored to flood management and the stakeholders did not automatically understand or 'own' the scenarios (Raadgever and Becker, 2008). Therefore, at the workshops quite some time was spent on getting the participants acquainted with the scenarios and to tailor the scenarios to flood management in the Rhine basin.

The collaboration among stakeholders was generally good. Joint goals could be set and there was flexibility to adapt those goals. Everyone participated actively in the workshop discussions and there was a very positive atmosphere, which may have been due to the informal nature of the proceedings. The continuity of participation in the workshops was limited however, which may have been a result of participants giving priority to their daily work (and busy schedules) and transboundary politics.

Results

The participatory scenario study had several outcomes. Firstly, the study resulted in a set of four scenarios for future flood management in the Rhine basin, a strategy for each scenario, and a set of important indicators to evaluate these scenarios and strategies.

Secondly, good collaboration in the participatory scenario study improved relations between the stakeholders from different countries, organizations and disciplines. This may be useful for future transboundary and multidisciplinary collaboration in the Lower Rhine basin.

Thirdly, this study allowed for learning between different stakeholders. In evaluations carried out after each workshop the participants stated that they had learned about how people from other countries and disciplines think about flood management, and how to think in an open way about possible futures. Changes in the participants' perspectives on future flood management were measured through the Q sorting questionnaire before and after their participation in the workshops. Analysis revealed that although the perspectives of most participants changed significantly, mutual consensus increased only slightly, and learning from the research results was limited (Raadgever, submitted). The effect of the scenario study on decision making is not straightforward. As the scenario study was not linked directly to decision making, effects are expected to manifest in the long-term.

7.3 Kromme Rijn

Case study context

In the Kromme Rijn case, cooperation was established with Hoogheemraadschap De Stichtse Rijnlanden (HDSR), a Water board in the central Netherlands. The goal of the case study was to facilitate and analyse relevant stakeholder involvement processes in the Kromme Rijn area. The participation process focused on two overlapping projects: a European Water Framework Directive pilot for the water body 'Kromme Rijn' (WFD pilot), and a water management plan for the Kromme Rijn region.

The different actors' objectives and problem frames

Different actors and stakeholders brought a variety of objectives to the process. NeWater wanted to stimulate HDSR to permit an optimal level of participation and study the effect of that participation on water management. HDSR wanted to come up with a 'maximum ecological potential' for the Kromme Rijn, in compliance with the European Water Framework Directive and a water management plan for the (mainly agricultural) area 'Kromme Rijn', including a decision on water levels and an optimal ground and surface water regime. The objectives of the Province more or less coincided with those of HDSR. The Municipalities wanted to generate a strong link between their own plans and the interests of their inhabitants. Nature organizations in general wanted to maximize new natural environments while maintaining the benefits of those already in existence. The general farmers' associations (LTO) wanted to continue farming in an effective way, without having to pay too much for water management. The NFO, the fruit farmers' organization, a branch of LTO, also wanted this; however, the water use needs of fruit farmers are different from the other (dairy) farmers. Specifically, the fruit farmers need high water availability in spring for sprinkling to prevent young buds from frost damage. The challenge of the planning team was to reconcile all these different interests and objectives. Differences in interests and problem-framing were studied from audio recordings made during meetings (François et al, 2007).

Participatory methods and tools

The planning team, consisting of NeWater researchers and personnel of HDSR, did a stakeholder analysis at the start of the project based on two main criteria: interest in and influence on the process. On the basis of this stakeholder analysis, a division was made between a 'core group' consisting of representatives of the main water authorities, responsible for the project; an 'advisory group' consisting of the members of the core group and representatives of the main responsible user-organizations and interest groups; and a 'communication group/community' consisting of the members of the advisory group and other stakeholder groups, including the local community. This 'nested' approach was adopted and evaluated as part of the process. In a first workshop with the stakeholders of the core group and advisory groups, this structure was assessed and adapted (Lamers et al, in press).

Participation activities were divided into an excursion, core group meetings, advisory group workshops and public meetings (Lamers et al, in press). The excursion with the core group and the NeWater researchers was intended to help these participants become familiar with the area and each other, and to discuss the project's requirements and possibilities. During core group meetings the project boundaries were defined and the agenda and approach for the advisory group workshops were discussed. In advisory group workshops, participants were asked to either come up with ideas, or rank, comment and/or judge proposed ideas. All inhabitants of the area were invited to public meetings on four occasions, to be informed about planned activities and give their responses.

In the final phase of the water management plan project, a 'sub-area evening' was organized for landowners adjacent to ditches that needed widening as a solution for water shortage in spring.

HDSR published four newsletters for the wider public during the project, in which the process and the results were clearly outlined. Furthermore, HDSR placed all information related to the WFD pilot and the water management plan on their website, including workshop reports, research results, calculations, presentations and newsletters.

Results

The Kromme Rijn participatory process has resulted in a shared water management plan. Evaluation results show that in this particular context the nested approach worked very well in organising the participatory process in an adaptive way (Lamers et al, in press). This approach stimulated both horizontal and vertical communication by creating a safe environment, leading to an open atmosphere and generating trust. Furthermore, the evaluation has shown that a successful participatory process requires a reflective planning team with a capacity to adapt the process when necessary. Another important lesson was the necessity to ensure that the appropriate group of stakeholders is assembled around the table at all times during the process. Stakeholder analysis is needed not just in the design phase, but throughout the process. Finally, adaptive water management requires experienced process leaders with excellent communication skills, and this human resource may not necessarily be found within every organisation (Lamers et al, in press).

There are different framing processes: frame selling, frame filling and frame negotiation. They correspond with different levels of participation: informing, consulting, and active involvement. Awareness has risen about the necessity to reflect beforehand on the level of participation desired and to communicate to stakeholders at an early stage about the influence they may have (Francois et al, 2007).

Dynamics of the case study objectives in relation to involvement of stakeholders

Initially, HDSR considered the water management plan to be a routine project for which few problems were expected. At the end of 2006 however, the tensions between fruit farmers and other landowners became much more apparent, in part because hydraulic calculations showed that the water quantities necessary at peak times were much larger than expected and were going to be higher still with the present rate of development in the fruit sector.

HDSR staff became increasingly aware that the demands of the farmers lay beyond the original task of the water board, which was simply to maintain water supply at a level necessary to prevent damage from water surpluses. With the growing requirements of the fruit sector in particular, HDSR was on the way to becoming a water provider, an entirely different task requiring changes in both physical infrastructure and organization. When HDSR made its standpoint clear, this really boosted the awareness of the players involved and stimulated the different actors to participate at a higher level, resulting in a broadly supported water management plan. The plan, however, includes only limited solutions for the problems, based on the willingness of specific landowners to sell part of their land and it remains uncertain whether this approach will be sufficient for successful implementation.

7.4 Wupper

Case study context

The Wupper sub-case forms part of the Rhine case study within the NeWater project and was conducted in close cooperation with the ACER project. The goals of NeWater were to analyse Adaptive Management (AM) strategies, and support the implementation of AM in water management practice. Therefore, contacts formed with the main stakeholder, the Wupperverband, were very close and formalized in a co-operation treaty at the beginning of collaboration. The Wupperverband is the competent water association of the Wupper basin. Founded in 1930, it is a public corporation based on a special law and deals with water quality and quantity in the Wupper basin. Membership is obligatory for districts and municipalities, drinking water producers and industries in the basin. The members finance the work of the Wupperverband through membership fees and are represented in different bodies of the association.

The Wupper basin is a densely populated sub-basin of the Rhine, located in North Rhine-Westphalia (NRW), in Germany. To provide the population with drinking water many reservoirs have been constructed along the Wupper and its tributaries. These reservoirs shape the eco-morphological structure of the river and have modified the flow regime (MUNLV, 2005).

The major challenge facing water managers in the Wupper basin, where eco-morphological problems are of major importance, is the implementation of the European Water Framework Directive. The Dhünn basin, which is a tributary of the Wupper, currently does not qualify for 'good status' as defined by the WFD (MUNLV, 2005), although the water quality is reasonably good. This is because of the artificial water flows caused by the Dhünn dam and other barriers such as small weirs (ecological continuity) and canalized stretches of the river (eco-morphological quality). These problems affect fish population in the Dhünn (Möllenkamp et al, 2006).

Co-design and co-implementation of a participatory process in the Dhünn catchment

The major intervention in the Wupper sub-case study was the introduction of a participatory process in the Dhünn sub-basin. The aim of the exercise was to anticipate and prepare input for the formal WFD implementation process by involving all relevant stakeholders. The main goal of the process was to identify potential measures to improve the ecological status of the river and its tributaries.

The cooperation between the Wupperverband, NeWater and ACER scientists, and process consultants took place in three phases: a preparatory phase, a process phase consisting of a series of three workshops, and continuing evaluation. The Wupperverband was the formal convener of the process, which marks a mentionable change in the administrative attitude. The action allowed the Wupperverband to redefine its field of activity and to strengthen its position. The Wupperverband at the same time admittedly incorporated the risk of failure and of an unpredictable outcome. This risk could nevertheless to some extent be externalized to the design partners – science and consultancy. They, in cooperation with the Wupperverband, performed the stakeholder and issue analysis, set up the process boundaries and design, and gave scientific advice and consultancy on the design and implementation of workshops (Speil et al, 2008). Overall, the consultants moderated the process and the scientists evaluated it.

With a variety of measures such as changes in the operation of the dam outflow, technical changes at the dam or intervention along the course of the river it seemed possible to achieve good ecological status and to reintroduce an appropriate fish population. These measures however, would affect various water users and other stakeholders downstream of the dam, such as fisheries, agriculture and recreation. The participatory process discussed existing options and the development of new measures to improve ecological quality in the Dhünn. Various tools and methods were used, such as simple models for visualization purposes, expert interviews and questionnaires. During the workshop series various tools such as moderated discussions in break out groups and mapping of stakeholder perceptions were applied.

The rather informal setting of the participatory exercise allowed more freedom and experimental design than the formal participatory process that the current WFD implementation process is offering. At the same time, the WFD was the catalyst for the process and demonstrated an inherent necessity to change actual water management practices. The directive thus provided a positive context that allowed experimentation under pressure to attain a tangible thematic output.

The major achievement of the participatory exercise was a consensual agreement of all participants on a final document specifying possible measures in the basin (Seecon Deutschland GmbH et al, 2008). This document is considered to be an important input to the ongoing formal implementation of the WFD while the participatory process used in North Rhine Westphalia is a useful model and seen as a best practice example for WFD implementation. Apart from input to systematic design (Speil et al, 2008), the participatory exercise also offered the chance to analyse some of the major challenges considered to be barriers for participatory management. The research is described in detail in Möllenkamp (Möllenkamp et al, submitted).

7.5 Comparison between the Wupper and Kromme Rijn regimes

Management style analysis in the Wupper and Kromme Rijn regimes

The ability to adapt to new conditions under different institutional settings was investigated using a comparative management style analysis of the Wupperverband and HDSR (Möllenkamp et al, 2007). Historical development, institutional settings for membership, and the roles and decision making of these agencies were compared in the light of the role of emergent leadership, social learning, and both formal and informal forms of participation by stakeholders outside the regulatory system. Two simple models were developed representing the Wupper and Kromme Rijn regimes.

A balance is struck in adaptive water management institutions between taking legitimate and accountable decisions (addressing issues and stakes of all those involved) and the effectiveness with which these decisions are taken. With regard to effectiveness, the Wupperverband seems to be performing better in the current management situation. The leadership position of the managing director of the Wupperverband stimulates effective decision-making processes and determines the strategic direction of the water agency to a large extent. The democratic structure of HDSR, despite being an adaptive element, can hamper effective decision making due to an inability to find a compromise. On the other hand, HDSR proved to be more flexible in adapting to the changing needs of inhabitants and users in the region, and to changing management goals. However, the Wupperverband is able to engage additional stakeholder groups by opening up informally by means of workshops on water management questions, such as the Dhünn workshop series co-developed by NeWater/ACER. In the long run, the transmission of social capital and institutional learning is easier between groups that share responsibility than between two leading persons in case of a management shift. Combinations of different institutional elements thus influence the capacity of both water agencies to adapt to changing conditions in an effective and legitimate way. Stronger centralized decision making may be more effective in taking decisions while more influence from stakeholders can ensure a more flexible approach.

Dealing with uncertainties in water management practice – Wupper and Kromme Rijn cases

A second comparative study was performed in the Wupper and Kromme Rijn basins, analysing uncertainties. The study was to evaluate the way in which uncertainties are framed by practitioners in water management, how they deal with them, and how this might be improved.

A series of workshops and interviews were undertaken in each sub-case study with representatives from regional entities responsible for water management, i.e. water agencies, public administration, and municipalities. The study showed that uncertainties are already recognized and integrated in the work of practitioners. However, in the two case studies uncertainty, for the most part, is not approached in a structured way but rather dealt with by experience or intuition. The research showed that in order to develop more systematic and structured approaches it is important to make the framing of an uncertainty explicit and to identify possible framing differences, particularly in situations where several actors are involved. A cross-checking list using parameters of framing was developed by Isendahl et al (submitted) as a tool for systematically identifying improvement options when dealing with uncertainty situations. The list does not require specialized scientific knowledge or assessment and is designed to be easily applicable for practitioners in water management.

The research in the two case studies once again emphasizes that not all uncertainty can be overcome completely. It follows that because not all uncertainties can be solved or solved fully, then ultimately dealing with uncertainties is a matter of choices and priorities, which in the search for certainty are often neglected.

7.6 Conclusions

As shown in this chapter, AWM can improve water management through participation, the use of scenarios and modelling. The most important tool employed to improve participation in the three Rhine cases was the workshop. From the NeWater experience it is clear that a set process is critical for successful participation and it needs to be implemented with care. Setting up a participatory process, particularly for the first time, can be considered a risk for the organizer. Cooperation with researchers and consultants can help since this offers an opportunity to share both the burden and the blame should something go wrong.

Building trust is an important – though time-consuming – activity in the participatory process. The ‘core’ team of initiators should be confident about the organizers’ objectives and skills. Preparatory steps in the organization and design of the different events are important elements in the building of trust and should be considered to be an important joint task. The nested design approach used in the Kromme Rijn case is also a useful means to build trust.

A rather informal approach can also be helpful in building the trust needed and to further the exchange of ideas. However, at a certain point, the process must feed into the formal process to influence policy making. This, however, does not always happen. The transboundary setting in the Lower Rhine case was probably considered too sensitive to open up formal decision making to a participatory process that could not be controlled by the governments involved. In the Wupper case on the other hand, the experience was such that the outcomes of the process were adopted as input into the formal process.

Participatory processes have led to changes in the participants’ perspectives on the issues at stake. The exchange provided the opportunity to learn from technical expert knowledge as well as from other stakeholders and supported social learning between the participants. Comparisons between two of the cases showed that strong leadership that can influence and promote decision making, is an important part of the process. Strong leadership can however reduce the flexibility of decision making.

Uncertainty can be a factor that interferes in the process as it is generally viewed as a negative factor. Explicitly framing the uncertainty can help to overcome this barrier. Having to deal with uncertainties, and to explicitly define them and make them clear to all the actors contributes to better and more considered decision making, since a wide range of management options have to be evaluated. The use of scenarios then makes it possible to explore a range of potential futures in which political interests are less prominent.

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8
Tisza River Basin

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8.1 Background

Introducing the catchment

Transboundary water management is a major global concern. In Europe, this concern has dramatically increased since catastrophic transboundary floods in the Tisza River Basin (TRB) this past decade, contrasting with water scarcity in dry periods which has led to dust storms and fires. The populations in the region's floodplains live with a considerable degree of uncertainty and vulnerability. Another problem is that the Tisza is a transboundary basin on the border of the EU. Thus, national and regional water management strategies vary for different parts of the river. This is why the Tisza was selected as a NeWater case study.

Physical features

Near the geographical centre of Europe, the Tisza drains an area of 157,218km^2. The TRB has a population of 14.4 million and covers parts of Ukraine, Slovakia, Hungary, Romania, Serbia and Montenegro. On its route from the Ukrainian Carpathian Mountains to the confluence with the Danube in Serbia the Tisza flows mainly through Hungary's Great Pannonia plain. The topography of the TRB is characterized by high, narrow chains of mountains surrounding expansive, flat lowlands (Jolankai and Pataki, 2005). The mountains cause serious flooding when rainwater flows quickly down the slopes and accumulates in lowland areas (Burnod-Requia, 2004). At 966km and an average discharge of 794m^{3}s^{-1} the Tisza is the Danube's longest and second largest tributary. Most discharge is generated directly from rainfall but there is a contribution from both snowmelt and subsurface soil water. The Tisza can be subdivided into three main sectors: the mountainous Upper Tisza in Ukraine, including the headwater section upstream of the Ukrainian-Hungarian border; the Middle Tisza in Hungary receiving larger tributaries from the Slovakian, Ukrainian and Romanian Carpathian Mountains, and some rivers draining Transylvania and the Lower Tisza downstream of the Hungarian-Serbian border.

Water regime

The TRB climate can be described as moderately continental. Annual precipitation reflects terrain elevation: in the high Carpathians it can exceed 1700mm, while in the Great Hungarian Plains precipitation is frequently less than 500mm. There are however, deviations from this trend. Due to the prevailing north-westerly wind, the north-western slopes are more exposed to precipitation as moist air masses are forced to rise. Conversely the south-eastern slopes receive much less precipitation than their elevations might imply. Due to these conditions the rivers and streams responsible for the generation of discharge are situated mainly in the Carpathians (Slovakia, Ukraine and Romania).

8.2 Major problems

Along with water quality, a primary challenge to the Upper Tisza is the increasing frequency and severity of floods (see Table 8.1). There are a number of anthropogenic factors (climate change apart) that increase flood risk in the basin (Jolonkai and Pataki, 2005). Among the most important are: (1) reduced water storage capacity caused by (a) river regulation, affecting wetlands and riparian zones; (b) deforestation and degradation of vegetation; (c) urbanization and an increase in impermeable surfaces; and: (2) human activities in flood-prone areas (Haase and Bohn, 2007). In the Carpathians, flood events in the last decade severely damaged low income regions that have limited government budgets. This made people and ecosystems extremely vulnerable.

Table 8.1 *Key water challenges*

Country	*Key issues*
Ukraine	Flood management, Reforestation in the Carpathians, Water quality, Reduction of contamination, Industrial development, Job diversification
Hungary	Flood management, International Cooperation, Good Agricultural Practice, WFD Implementation
Romania	Flood management, TRB management with ICPDR , Water supply and Sewage treatment, Water quality, Ecological reconstruction
Slovakia	Flood management, Water supply, Biodiversity, Agricultural potential
Serbia-Montenegro	Flood management, Water supply, Water quality, Biodiversity, Navigation

Monitoring systems serve administrative objectives rather than technical requirements; consequently, local municipalities risk mismanaging the complex flooding issue, since it is not clearly linked to local decision makers' priorities. The participatory approach described here explores local strategies for successful adaptation using people's perceptions, beliefs, local knowledge and networking resources (Haase and Bohn, 2007). The frequency of extreme floods in the Tisza basin has increased from once every 18 years (1877–1933) to once every 3–4 years (1934–1964), and to almost once every other year over the last decade. In the lowland part of the basin, there is a downward trend in annual precipitation (Jolonkai and Pataki, 2005). In the Carpathians, precipitation will increase by up to 30 per cent by 2050 (Krysanova et al, 2008).

WRM development in the catchment

The institutional settings of Ukraine and Hungary possess a common socialist past from which they both inherit problems with administrative hierarchy and economic weakness. In Hungary, NGOs are working on nature-adapted floodplain management. They have a vision to give more space to the river, to involve local farmers in floodplain management and revitalize historic drainage structures such as the fok channel-system. Analysis during the NeWater project has shed light on factors that hinder management.

In both countries, studies indicated that the most striking barrier to more adaptive transboundary water management is an absence of governance and social norms. In the Ukraine there is also a lack of legal frameworks and strong hierarchies, and institutional planning is in its infancy. Budget limitations are an additional constraint.

Nonetheless, local experts and stakeholders from both countries came together, shared ideas and attitudes, and identified priorities for transition. Priority issues for water management include lack of data and public access to information. The latter served as a catalyst in the formulation of common goals, since this problem exists on both sides of the border.

In the past, Hungary and Ukraine shared a common policy of using traditional measures to cope with floods. In Hungary there was extensive hydro-engineering construction in the 19th century to limit inundation and increase flood safety. The floodplain was drastically reduced by the construction of dikes, levees and bank-protecting structures. The Tisza was shortened by about 400km and deepened to facilitate transport. Currently, some 500,000 people live on land reclaimed from the floodplains. Rising flood levels have been countered by increasing the crowning levels of the dikes and enforcing flood protection structures. Similarly, in the upper Tisza the flood defense system consists of dikes (707km), embankments, and 260km of bank-protecting structures.

Measures for drought protection are almost non-existent. This protection scheme was successful until the record-breaking floods of 2001 and 2005 which caused enormous damage following breaches in several dikes. As a result, alternative solutions such as the use of small emergency reservoirs and polders, and integrated land use management within the floodplain are now gaining more attention in both countries (Horvath et al, 2001).

Nevertheless, the new Hungarian Vásárhelyi water management plan (2004) aims to ensure flood protection almost exclusively through the construction of six new emergency reservoirs, leaving other options for the future. Public awareness and collaboration with NGOs, who criticized this exclusively-technical strategy, helped to broaden the aims of the plan, which now include solutions like agro-ecological farming practices, eco-tourism and nature conservation (Burnod-Requia, 2004). People learned that public awareness can improve water management; there are similar strategies for the Ukrainian part of the basin. Several international agreements help foster and strengthen collaboration for flood protection.

Tools applied in NeWater

A participatory flood management analysis was conducted to identify ways to reduce flood risk by enhancing local capacities. Eliciting existing knowledge and jointly learning about existing decision-making procedures supported the introduction of stakeholder participation (Kuptsova et al, in revision). In the following sections two participatory methods applied in the Tisza river basin are described:

1 conceptual and cognitive modelling (CCM) together with Group Model Building (GMB), which investigates system understanding of flood risk and uncertainties about the generation of floods; and
2 a knowledge elicitation game on decision-making behaviour applied to uncertainties and soft risk prevention in flood risk management.

CCM and GMB

The major purpose of participatory modelling was to engage stakeholders in the process of developing schemes on flood preparedness by eliciting their mental models. There are many barriers to the implementation of effective flood risk management in the region. GMB was used to investigate these barriers and see if a joint analysis of stakeholders' mental models might shed light on their nature and open a floor for discussing alternative options. The study attempted to identify niches for Adaptive Management. Developing land use mosaics can enable a transition from conventional intensive and flood-protected land management regimes to one more resilient to floods and droughts. After some initial resistance by the water managers the process proved to be very successful.

Methodological design

The GMB process started with a problem identified by a group of expert stakeholders together with NeWater and Ukrainian scientists: flood preparedness and coping with climate change impacts. The scientists chose to apply the GMB approach to the problem of flood risk management. Workshops involving NeWater and Ukrainian scientists, water board members and local stakeholders used cognitive maps to conceptualize and assess local flood vulnerability (see Table 8.2). During the workshops, round table discussions and break out groups were employed. Each workshop began with a brainstorming session to review results for the benefit of permanent group members and as an introduction for newcomers. Break out groups discussed flood risk and preparedness in communities, identified basic components (variables, relationships) and (after variable grouping) the initial mental model structures. The models were then discussed jointly and developed into a combined conceptual model.

Table 8.2 *Methodological design*

Prior involvement of participants	To a larger extent. Some of them are strongly involved in another NeWater activity (KnETs).
Initiation of process	NeWater European scientists and Hungarian expert and scientific partners
Representativeness of stakeholders	Local water management board representatives with different roles in water management: water quality, monitoring, flood prediction and public relations. National member from the Hydromet service. Department head from the Ministry of Environment. NGOs representing independent agents
Design of process (CCM; GMB)	Introduction by NeWater scientists, 2–3 breakout groups on definition of topics. CCM: individual cognitive mapping by each participant within the breakout group; GMB: joint construction of GM by all participants; each participant contributed major factors from her/his CM. Summary/Iteration: Emergence of mental models, loops, concepts, stock-flow approach
Duration of process	At each location CCM and GMB took place in separate sessions during a two-day workshop
Goals/Framing	Identify factors that are crucial for improving current flood risk management practices, particularly soft measures; roles of actors in the implementation process
Link to ongoing policy process	GMB in accordance with ongoing budget revision and re-allocation after flood in 2001. Planning process of technical flood protection measures (reservoirs, dams). Flood study in an international research project

Results

The conceptual causal models that emerged from the GMB process focused on the following flood management components:

1 flood exposure;
2 flood damage;
3 short-term and event-related coping capacity;
4 long-term oriented adaptive capacity; and
5 overall community welfare and the welfare of single households.

Although mutually linked, the first three components reflect hazard mitigation management, whereas the other two feed a long-term view into the causal models which are expected to influence coping with floods.

In the group model building exercise stakeholders identified improved information access and 'local information' management as well as education on floods as important 'soft' or non-technical measures for improving flood management in their region.

The stakeholders' mental models informed the development of conceptual and simulation models to assess local flood risks. These models integrate state-of-the-art scientific knowledge on flood risk mitigation with local knowledge provided by the group model building process and experiences from other river basins. They can be used to compare the costs, effectiveness and benefits of soft measures with technical approaches to flood prevention (Haase and Bohn 2007). Both CCM and GMB supported the elicitation of local knowledge about the river basin system and management. The scientific modelling process structured this knowledge and integrated it with scientific knowledge. The resulting tool can be used for scenario analysis to assess the feasibility and impact of suggested courses of action.

Table 8.3 *Analysis of the GMB process*

Topics	Improving flood risk management including coping with extreme flood events, identifying local municipalities' adaptive capacities, introducing soft flood mitigation and adaptation measures
Spatial scale	Upstream Ukrainian part of the Tisza river basin (Zacarpathian part) characterized by high water flow travel times and frequent flooding
Acceptance and uptake	Low to medium at beginning, then high
Generation of novel ideas	List of soft flood mitigation and adaptation measures Identification of new actors in flood management and flood preparedness
Added value in view of stakeholders	Very useful joint brainstorming and identification of different 'ways of thinking' with people that know each other for a long time, more integrated perspective on deficits and potentials of flood risk management, measures to address adaptive capacities
Added value for scientists	New insights about the system and flood risk management and actual management processes; creation of mutual understanding and trust in scientific models from the stakeholders' side
Focus of the resulting models	Flood risk management (from the beginning) but then biased in (short-term) mitigation and (long-term) adaptation
Comprehensiveness	Comprehensive model but not complete
Degree of integration	Integrative in terms of geo-components, disciplines and hierarchies (of management)
Implementation/realization	Realization as CM (visualization of variables – stocks and flows – relationships and polarity) and quantitative model using empirical evidence/initial values

In the Ukrainian section of the basin in particular participation in policy making is relatively uncommon and has not been built into the policy process. Stakeholders thus have little experience of participation. The initial response of stakeholders to this exercise was skeptical. However, over time the opportunity to communicate with other stakeholders from different hierarchical levels, and to learn about their perceptions of the system, was more and more appreciated. The process facilitated joint identification and agreement on causal relationships within the system and the integration of technical and soft measures to address flood risks. The method helped reduce communication barriers and encouraged stakeholders to reflect on the views of other participants and upon the consequences of management proposals (Haase et al, submitted).

Participatory scenario games: Knowledge Elicitation Tools

The need to understand the multiple stresses which interact to form complex vulnerabilities, such as those observed in the Tisza basin, has led to the design of Knowledge Elicitation Tools (KnETs). Through interviews these tools provide a way to formalize local socio-environmental knowledge, while exploring future scenarios. KnETs depart from the classical empirical approach for qualitative social science research by adopting a flexible and interactive interview technique resulting in an iterative 'game' (Downing et al, 2005, Bharwani, 2006, Bharwani et al, 2008). However, this does not replace the exploratory, open-ended and often less structured phase of social science research.

The Tisza game

In the case of the Tisza, the stressors include climate (low–high precipitation), personal awareness of risk (awareness of flood risk areas or of the flood action plan) and economic factors (existence of state funds, personal capital or compensation potential). As we are interested in community and household preparedness strategies, which can provide protection in the absence of additional assistance from government, adaptation options are also included. Such options might include relocating away from vulnerable areas, paying for insurance, education on floods, involving the Church, reliance on social networks, or simply following the flood action plan and restocking First Aid resources. These actions represent the adaptive capacity of the community which can ultimately lead to a different decision pathway. These combinations of variables are used to produce a scenario, which is explored using the computer-aided interactive 'game', to isolate the specific variables required for the decision-making process to proceed under different conditions (Bharwani, 2006; Kuptsova et al, in revision; Figures 3 and 4).

The purpose of the KnETs game is to assess whether local village council heads (VCH: the target stakeholder group with whom the game is played) from various upland and lowland farming communities would decide to help their communities 'prepare' or 'not to prepare' for a potential flood situation (their decision/goal). VCHs are responsible for decision making in the case of flooding, which is why they are a significant target group for the knowledge sharing and learning process. Exploring their decision pathways and the adaptive capacity of the group to deal with differing scenarios is important. A comparison between the VCHs say they would do what they have actually done in the past, and what they currently do, provides insights about where interventions would be most valuable and where capacity is currently lacking. The type of adaptation strategies selected would be both short- and long-term strategies to help better cope with a given scenario and to potentially reduce future vulnerability. Strategies might include switching to soft risk adaptation paths, such as:

1 providing insurance mechanisms;
2 improving social networks;
3 construction of floodplain management plans;
4 improving the early warning system and technical support;
5 education on soft floodplain management;
6 flood education at school;
7 involving the church;
8 improving information networks; and
9 reforestation and evacuation of vulnerable populations.

These are all important options that need to be explored in hypothetical scenarios. People may indicate that they would opt for alternative adaptive management techniques if they had the capacity to do so, which may lead to a different management solution altogether (see Figures 8.1 and 8.2).

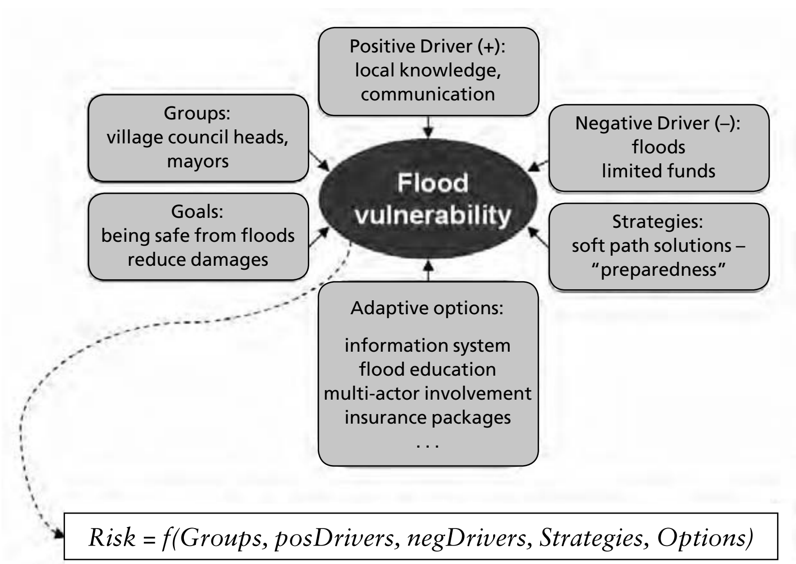

Figure 8.1 *Variables which affect decisions*

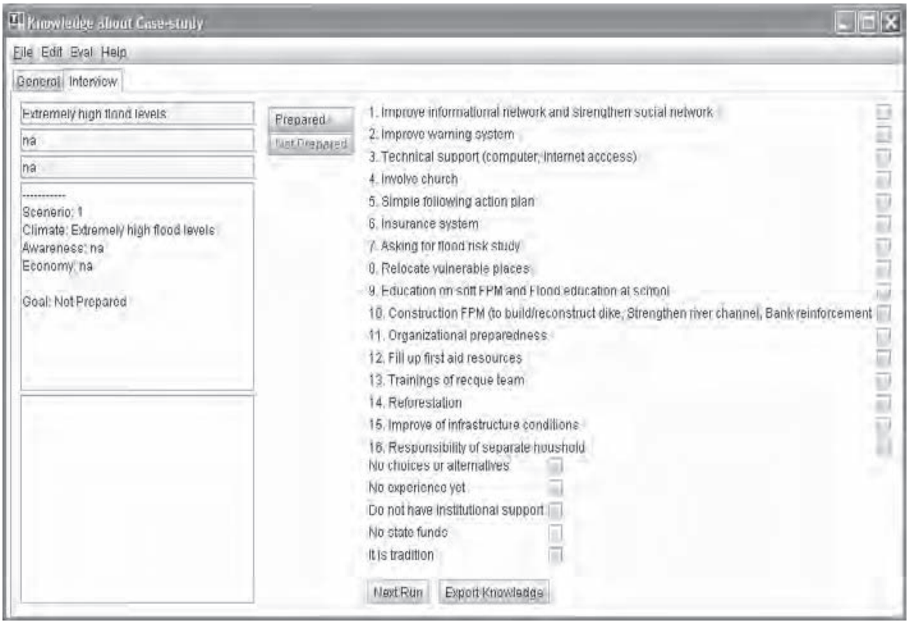

Figure 8.2 *Game designed for VCHs*

Fieldwork

Between March and June 2008, the Ukrainian team designed the KnETs game by conducting interviews with VCHs, reviewing secondary literature, and studying local press and planning documents. A local stakeholder analysis was conducted and first contacts were made with the stakeholders. From July to September 2008 the field study game was refined, using input from the interviews. The game was translated into Ukrainian and transferred to cards since most of the VCH have only limited computer access. From October to November 2007 ten VCH interviews were conducted (in Ukrainian). After a general introduction to the theme, various computer-generated scenarios were presented using cards. This allowed responses to strategies and motivations for decision making to be electronically recorded and then filtered through a rule induction algorithm (Kuptsova et al, in revision). In order to obtain adequate, comparable results, the profile of the respondents in the chosen sample, in our case the experienced local VCH, remained the same during all three phases of the KnETs gaming process: the game itself, verification, and validation (Kuptsova et al, in revision).

KnETs uses Weka – an open source software tool to support data mining – to produce decision trees based on stakeholder judgements about a single goal. Weka identifies relationships within large datasets by building decision trees and implements exception based filtering: it learns by forming entailment rules and by actively seeking instances that do not follow the rule. It then uses these exceptions to enhance its representation of the data set.

Creation process of behavioural rules of decision making

The rule induction algorithm was used to create decision trees which were then reorganized by researchers on the basis of different criteria, such as 'enabling' and 'maximizing' conditions, based on the researcher's own knowledge of the domain. The first number next to each rule represents the number of stakeholder responses that support the rule (success), while the second number represents the number of times the response does not correspond with the rule (failure). The next stage in the KnETs process is to try and improve the re-ordered decision trees with further input from the informants. This aggregates our decision trees with monotonic decision paths to a generalized production system with potentially dynamic outcomes at each node. The verification phase was carried out with the same VCH (the 'training' group) to correct any inaccuracies – such as missing conditions, incorrect branches or decision nodes – and to access new and potentially tacit knowledge that was driving the decision to 'prepare' or 'not to prepare' for floods. Once the rules were verified with the original stakeholder group, our aim was to identify another sample of stakeholders with a similar profile (a 'testing group') who were not involved in the initial phase, to validate the rules and establish how well they predicted the decision-making processes of the VCH group as a whole. Therefore, five new VCHs were interviewed. In each new village a short introduction about the research was given. Some scenarios were then proposed based on the decision trees from the previous game and their responses were incorporated into the game as new nodes where appropriate (see Figure 8.3).

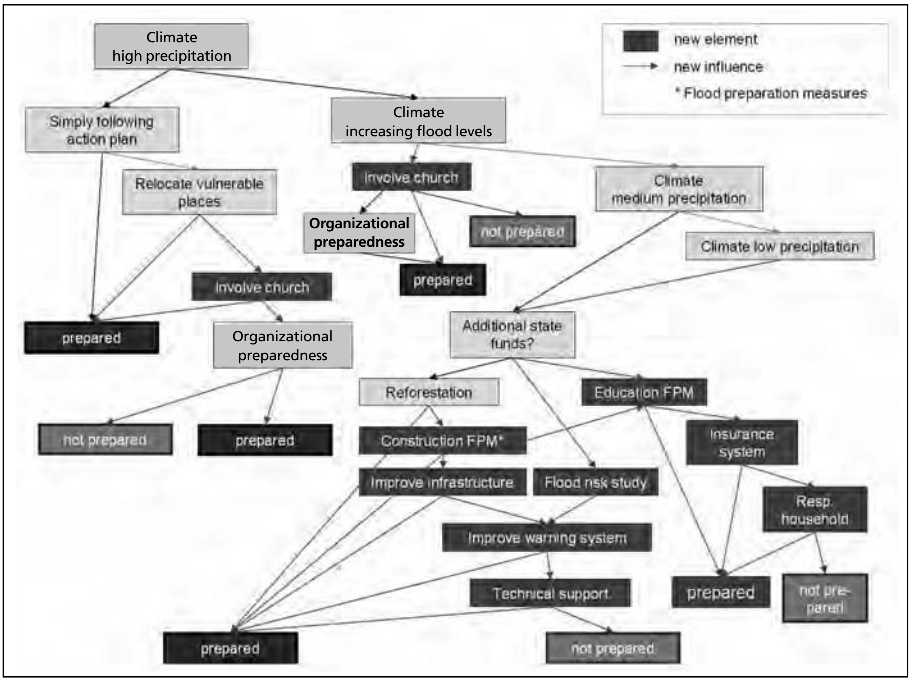

Figure 8.3 *Decision-making rules from the KnETs game*

Our analysis of flood risk management and flood preparedness measures indicates that long-term adaptation can only be planned when risk is low (medium or low precipitation periods) and when funding is available. However, when funding is not available, in both low- and high-risk periods, adaptation planning is not undertaken and responses are simply short-term coping strategies or highly dependent on individual households and social responsibility or on the Church. This implies that above all else, government support is critical for long-term adaptation. That is, long-term planning is not neglected because of a lack of knowledge of adaptation strategies, but rather due to a lack of finance.

We gained new knowledge about potentials and barriers for the implementation of soft flood risk prevention by using KnETs instead of straightforward interviews because of the following reasons:

1 The approach explores the role of local knowledge – knowledge that is voiced and knowledge that is actually used may be different. This may be due to the tacit nature of this knowledge, which can also cause communication problems in the community.
2 In the Tisza case, the strategies that emerged (stage 2 – game design) following conversations with VCHs (stage 1), represented measures previously unknown to the researcher.
3 The method allowed specific drivers to be investigated, which made it possible for particular strategies to be selected by VCHs. The research was interesting and important for the VCHs because their understanding of what should be done for flood preparedness in their villages became more structured and explicit.
4 A practical outcome from this research is that it may allow newly elected VHCs who have little experience in flood protection to become quickly familiar with the necessary information in the domain. This is particularly valuable where experienced VCHs may not realize that certain knowledge does need to be articulated, or where they may find it difficult to describe their knowledge.
5 Finally, in contrast to cognitive mapping techniques, which take more time and a lot of explanation, KnETs let us rapidly access, represent, verify and validate local knowledge (both tacit and explicit). Furthermore, as both techniques were piloted in the Tisza basin, the results complement each other very well (Kuptsova et al, in revision).

8.3 Lessons learnt and the future

An analysis of bio-physical, environmental and socio-economic conditions is a prerequisite for any participative action such as a GMB process. It helps all participants to understand the questions to be analysed. It is crucial that the stakeholders develop a sense of ownership of the results. Participants' strong willingness to contribute to the process was because the original ideas were their own, and thus they related to the process quite easily. To simply reinforce what has been experienced by many researchers, time as well as interactions, plays an important role within the group. A Group Model for a larger group take more time to be developed, but holds the intrinsic value of being a ‘common model’, compared to more easily compiled face-to-face interviews, where the scientist is the ‘combining’ element. The impact of the project team and prior participation activities on the focus of GMB is considerable. GMB appears to work surprisingly well in post-socialist countries, where participation and freedom of opinion were banned for a long time.

The application of the KnETs methodology revealed the salient criteria and thresholds of decision making by municipal representatives concerning ‘soft’ mitigation decision pathways in flood risk management. The resulting production rules shed light on what knowledge is used for decision making, and how different criteria are prioritized in these choices. Interventions, be they related to water management or vulnerability reduction, generally must take into account socio-cultural context – relevant perceptions in order to understand what drives adaptive and non-adaptive options, changes in behaviour and what initiates learning; this can be described as the capacity of stakeholders to adapt. Where gaps in these decision-making structures exist may be exactly where development interventions may be most valuable. In this case, government funding, which is specifically targeted toward long-term adaptation planning, such as an early warning system, technological support and improved insurance mechanisms would resonate most strongly with the needs expressed by those whose responsibility it is to prepare communities for flood events (Kuptsova et al, in revision).

8.4 How can AWM help and what tools are still needed?

The GMB process encouraged integrative thinking about the way that stakeholders shape and perceive problems, and the nature of their own role in WRM. New ideas on potentials and barriers in IWRM have been generated using a participative method that triggers stakeholders to give their opinion through an open but positively ‘competitive’ atmosphere and thereby to contribute to a final model. In doing so, existing bottlenecks in the water management process have been cleared through a system-way of thinking. The rate of adoption of models created as ‘own’ models, is much higher than that created by an expert team. Ultimately the GMB process helps to elicit and later integrate scientific with local stakeholder knowledge. Although this does not prove that better measures ultimately emerge from the process, it is a prerequisite for creating them.

What is most striking is that adaptation planning is not neglected due to a lack of knowledge of adaptation strategies, but rather to a lack of institutional and financial capacity to undertake these options to their maximum benefit. Ideally these needs could be addressed together and draw on the current strengths of the community. For example, the use of social networks, the

Church and innovative information communication technologies (ICTs) could be drawn together to design a community-based early warning flood system. As these conclusions are derived from participatory, grounded, bottom-up research methods, where both scenarios and responses were stakeholder-defined, one anticipates that interventions at this level have the potential to be most effective.

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9
The Amudarya River Basin

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9.1 Background

The Amudarya River flows for 2540km from the Pamir Mountains through the Turan lowlands to the Aral Sea (see Figure 9.1). Its runoff of approximately 79km^3 is generated by glacier and snowmelt in the high mountain areas of Tajikistan, Afghanistan and Kyrgyzstan. Most water resources are used for irrigated cotton and wheat production in the semi-arid downstream areas of Uzbekistan and Turkmenistan. Water is a strategic and vital resource for the region's economies with agriculture accounting for approximately 30 per cent of national GDPs. Hence, water management is largely governed by the priorities of agricultural production. This increasingly leads to conflicts with the needs of other users such as hydropower generation and the fisheries in the floodplains of the river delta.

The major problems in the river basin today are:

1 insufficient water supply in low water years which severely affects agricultural production, drinking water provision and the provision of wetland ecosystem services;
2 wide-spread soil salinization; and
3 massive degradation of the deltaic wetlands which provide a substantial part of local communities' livelihood.

These problems are aggravated by the ongoing process of socio-economic transition which has introduced a range of institutional, economic and social reforms in land and water sectors.

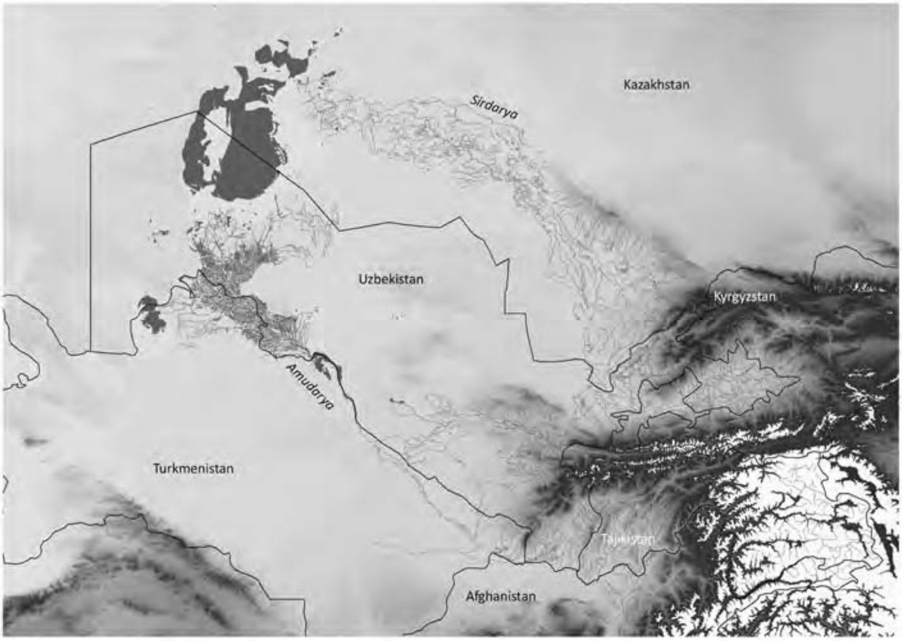


Figure 9.1 *The Amudarya river basin in Central Asia*

9.2 Selected Themes addressed in the Amudarya Case Study

The research, stakeholder activities and tool development in the Amudarya case study were focused around major research needs identified by stakeholders from Uzbekistan in a participatory assessment at the beginning of the project. Research, methods and tools range in scale from the river-basin to the local area; in this study emphasis has been placed on the delta area of Uzbekistan.

Adaptive management to better cope with extreme events

In Central Asia extreme climatic events include extended droughts and floods, which occur on a regular and possibly increasing, basis. The last severe drought in 2000–2001 caused significant crop losses and shortages in drinking water, particularly in the lower reaches of the river. In Uzbekistan the impacts of these naturally occurring extreme events are often exacerbated by insufficient water management. These problems include:

- Unclear decision-making mandates of new water institutions such as the Irrigation System Authorities (UISs) at the district level and Water User Associations (WUAs) at the local level.
- Interference from representatives of old (mainly agricultural) institutions in the activities of those more recently established. For example, provincial governors interfere with inter-district water distribution decisions, which are the responsibility of the UISs.

- Water managers and farmers with insufficient or outdated knowledge of water, and an uncertain water supply, which leads to the overuse of water resources, exacerbating water deficits in water scarce years

In the past, droughts and floods were managed with civil engineering and technical solutions, such as the construction of dams, water distribution systems and monitoring networks. The degradation of those systems combined with recent extreme events and human-induced water scarcity has placed pressure on the water management system to adapt by changing practices and policies. We have focused our research on current water sector reforms, i.e. Uzbek's water management transition to applying the hydrographic principle and the response of stakeholders to environmental threats, such as water deficit. An institutional analysis was carried out based on interviews, group discussions and participatory observation. The following measures to cope with drought and to enhance the preparedness for extreme events were given priority by local stakeholders:

- improvement of water management laws;
- observation of water quotas within Uzbekistan and among the Central Asian countries;
- enhancement of the authority of water practitioners and equal status for water and agricultural management;
- introduction of water saving measures (economic, legal and technical), increase in water use efficiency, change in cropping patterns; and
- capacity building for water practitioners and water users.

Information production and management at the local and transboundary scales

Within the last 15–20 years, and particularly since the breakdown of the Soviet Union, the extensive monitoring network that used to provide data for managing the region's massive irrigation system has fallen apart due to lack of finances, the priorities of the newly independent states, and organizational problems. NeWater addressed this very pressing issue by developing novel approaches for information production and management at local and transboundary scales.

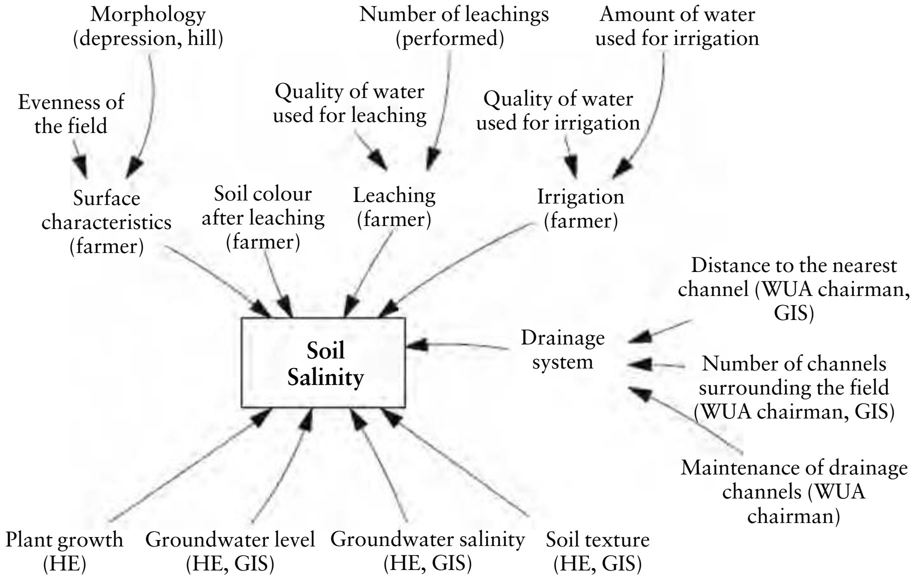
A local participatory system to improve soil salinity monitoring

Soil salinity is a major factor determining the amount of water required for leaching which accounts for up to 40 per cent of the water used. Monitoring soil salinity is thus a crucial aspect of reducing agricultural water consumption. The current governmental system consists of a network of soil sampling stations spaced at intervals of approximately 50ha. According to the opinions of several local experts (i.e. people who manage the monitoring system, water managers, and chiefs of the WUAs) the resolution is too low to provide reliable information at the local scale. However, extending the network is not possible because of the cost of modern environmental monitoring equipment. To improve soil salinity measurements agronomists carry out a preliminary assessment. They identify adjacent fields with homogenous soil salinization based on similar plant growth characteristics, take a soil sample in each area and assign the salinity value to each field inside this area. The result is a refined map of soil salinity at the local scale; however, it still has major deficiencies.

The method is ambiguous because it relies on plant growth alone, which is influenced by a series of variables, such as seed quality, agricultural management practices, and climatic conditions. The objective of our research was to develop an affordable locally-based participatory monitoring strategy to improve existing soil salinity assessment methods. To achieve this several aspects proved to be crucial. Firstly, to guarantee the long-term involvement of the local population in monitoring activities the procedure needed to be kept as simple and locally appropriate as possible and to be incorporated in the members' daily activities. To this end we worked with experienced farmers to describe traditional methods used by local community members to assess the soil salinity. Based on those interviews we identified the farmers' mental models of soil salinization. Secondly, locally-based monitoring has to be acceptable to decision makers. To ensure the sustainability of the monitoring programme and the usability of the information for decision making, efforts were made to build the monitoring system around existing traditional institutions and other management structures. The main aim of the adopted approach is not to substitute existing monitoring practices, but to integrate 'new' and structured information provided by local farmers into the existing procedure. Thirdly, locally-based monitoring information has to be reliable. To complement and test the assessment made by farmers, a conceptual model was developed based on the knowledge of local scientists and experts. It was used for defining the integrated monitoring system, in which the soil salinity value is assessed by combining farmer and expert opinions (see Figure 9.2 for a combined mental model based on local and expert knowledge). Based on this model a simple methodology to assess soil salinization was developed and incorporated into the Advanced Monitoring and Information System (AMIS – see p 152). More information about the topic is provided by Giordano et al (2008).

Institutional and technical provisions to create trust as a basis for transboundary information exchange

Major constraints on information management at the transboundary scale are the lack of a sound legal basis for information exchange and technical problems related to data collection and processing. Moreover, it is not clear if the existing information presents a suitable basis for decision making and for the operational tasks of water management at the transboundary scale. Decisions should be backed by validated data, and collected in a procedure agreed upon by all riparian users. If available information is not accurate it is difficult to create an atmosphere of trust and openness among the representatives of the different governments involved in transboundary negotiations. Currently, in the



Source: Liersch and Giordano (2008)

Figure 9.2 *Combined cognitive models for soil salinity assessment. HE = Hydromeliorative Expedition, GIS = Geographic Information System, WUA = Water User Association*

Amudarya basin there is no clear basis for the exchange of information at the transboundary scale. Information is only exchanged between a select number of institutions in the riparian countries and this is of varying and often insufficient quality. The reduction in the number of hydro-meteorological monitoring stations since the independence of the Central Asian states is critical. Information exchange on water quality occurs only at the national level. Information exchange at regional levels is limited to water quantity and organized by hydrometeorologists on the basis of bilateral contracts.

Information management and exchange at the transboundary level is an effective way to establish and strengthen trust among riparian states in the basin as well as an important pre-requisite for fostering adaptive water management practices. The Amudarya basin is subject to a number of challenges in this regard, which need to be addressed in order to initiate a transition in water management practices at the transboundary scale. An important step would be the creation of institutional structures that serve as custodians for the data collected at the transboundary scale and an information hub. Institutions geared for basin-wide water management are in place; however, they are not necessarily widely accepted. In the meantime, a semi-formal epistemic network of scientists from different riparian countries serves as a proxy for managing information at the transboundary level.

Under the umbrella of a trust-based and trust-building institutional system, the following issues need to be addressed. With regard to technical provisions in the field of information exchange, measurement points should be evenly distributed across the basin. Data and methods should be comparable, reliable, complete, and provided in a timely manner. In addition, data and information should be transparent and accessible to the parties involved. Attention should also be given to the terminology of methods and results, which ideally would be the same for the whole basin. So far none of these points has been fully implemented. The issue of data quality in particular (e.g. reliability, comparability and timeliness) has been intensively discussed and identified as one of the most pressing challenges in the Amudarya Basin. Many projects that address data collection and data management exist, but the co-ordination of these is insufficient.

In terms of the types of data to be collected, at the transboundary scale the following are of particular relevance:

1 Meteorological parameters, especially if factors such as climate change need to be considered in future water management planning, and
2 Water quality information such as chemical analyses, and in particular pollutants.

An early warning system for floods and droughts is a major requirement, especially in the context of water reservoir infrastructure security and dam safety, but also for agricultural planning.

Integrating Environmental Flows into Water Management

The deltaic ecosystems of the Amudarya have been severely impacted by changes in the hydrological regime and massive water extraction for irrigated agriculture. The most visible consequences are the shrinking of the Aral Sea and the loss of its fisheries in the 1980s, which was a major income source for the local population in the river delta. Today, people rely on the wetlands and lakes in the delta to provide fish, reeds, game for hunting, construction wood, and pasture. However, the provision of these ecosystem goods and services is strongly affected by an unstable and highly variable water flow regime. In low water years the lakes do not receive any inflow, which severely affects their biochemical regime and biological productivity. In the drought years 2000/2001, for example, more than 80 per cent of the deltaic lakes dried out, which led to a complete loss of the fish population. However, re-population in subsequent high water years is relatively rapid, provided that the spring floods with their abundant load of larvae and young fish reach the deltaic lakes.

Today's water management does not consider the needs of the deltaic and instream ecosystems and the often conflicting tradeoffs between different water users. Instead it allocates resources according to the needs of irrigated agriculture, leaving only the leftovers for downstream ecosystems. Apart from the problem of water scarcity, often the spatio-temporal timing of water distribution is not adequate.

An environmental flow is the flow required to maintain the integrity of a river's ecosystems and the services they provide in the face of competing water uses. Integrating environmental flows into water management in the Amudarya would enhance the provision of wetland goods, and the adaptive capacity of the social-ecological systems in the delta to low water years (Schlüter et al, 2009). We integrated our assessment of environmental flows into an ongoing government project for the restoration of deltaic lakes. As a first step, indicators for the state of lake ecosystems were identified and, given the implementation of the proposed measures, an assessment of the vulnerability of the deltaic lakes to low water years was conducted. It showed that the central lakes are most vulnerable to low water events and remain vulnerable even when the proposed measures are implemented. Thus additional measures are needed to guarantee the required water flows. Initial model-based investigations into the impact of temporal water flows on fish population viability give some indications on how environmental flows need to be made operational, i.e. a severe decrease in water flows to the lakes for short periods during parts of the reproductive period is better for fish population productivity than a medium decrease over the entire season (Drees, 2008).

Social aspects of water management

Equity of resource distribution and integration of perspectives from all water users

The priority given to agriculture in water management in Uzbekistan has largely ignored the issue of 'equity' amongst various water users, and this may have contributed to the deteriorating living conditions for many, despite steady economy growth overall (CER and UNDP, 2005). The issue of equity and the integration of perspectives from *all* water users into an institutional learning process are important for the resolution of complex environmental problems. Since the principles of IWRM entail a holistic approach and the recognition of all water uses by all water users, it is well suited to address the issue of equity. AWM can take this further by emphasizing a process of active social learning that essentially relies on broad-based stakeholder participation, and includes local communities with valuable experience in coping and adapting to complex environmental problems.

Research was initiated on the basis of stakeholder consultations in Uzbekistan which highlighted a number of areas needing further investigation. These included: livelihood activities and strategies; institutions guiding decision making about livelihood options; gender relations within the family and the community; vulnerabilities related to provisioning of water and ecosystem services; and the resulting threats to health. The entry point of the research was to understand the adaptive capacity of water users in the context of irregular and uncertain water availability with a view to promoting an equitable and sustainable path for the increase of human well-being and ecological sustainability. Particular attention was paid to understanding access to livelihood resources and institutions for low income farmers and fishermen, women, homestead producers, downstream households and other seemingly disadvantaged groups. The principles of participatory research were followed as far as possible and an iterative dialogue process in the form of public meetings, focus groups and dialogue sessions with local experts was conducted. The process was complemented by a series of household interviews in all communities.

The main findings include the need for:

- improving cross-scale linkages for water allocation at various levels, for example, among upstream and downstream users, between agriculture and lake fisheries;
- increasing water use diversity and moving away from the current focus on irrigation. In particular, prioritizing the provision of water to homestead producers, pasture, and open access ecosystems from which fodder, fuel and construction materials are harvested; emphasis should also be placed on the supply of good quality drinking water;
- extending the scope of formal social networks (e.g. Water User Associations (WUAs) and fishing organizations) to include all water users, and, recognizing the roles of informal social groups in the representation of locally embedded interests; and
- integrating all forms of knowledge about ecological changes and their interactions with human action and using it to adapt to emerging local needs, e.g. developing crop varieties to suit water scarcity and saline soils, improving irrigation and water saving techniques, forecasting and monitoring to better cope with and anticipate uncertainties.

Social Capital and the performance of newly established Water User Associations

In conjunction with recent land reforms, Uzbekistan undertook an institutional restructuring of water management organizations. This included a transition from administrative to hydrographic principles of water resources management, which delegated farm water management rights and duties to the level of WUAs. WUAs were established in a top-down fashion within a very short time scale, without the participation of farmers, and with varying degrees of success and acceptance. Recently several studies about the role of social factors for the functioning and efficiency of WUAs were carried out. For example, a study by Washington State University and the Tashkent Institute of Irrigation and Melioration showed that WUAs with greater social capital have higher crop yields and decreased water needs (Weber et al, 2006). Furthermore it was pointed out that the WUA as a new institution is as yet not fully understood by its farmer members. There is limited knowledge about the objectives and functioning of the organization and the role of farmers as the main stakeholders.

Within the framework of the Amudarya case study we have shown that under changing economic conditions and ongoing institutional change the importance of social factors in water resources management grows significantly. The new study which involved both WUA members as well as representatives of water authorities shows that WUA members now participate more actively in decisions affecting water resources distribution, in the election of officers and the contribution of fees which stabilizes the income of the Associations. The importance of different social and technical factors in water resources management was assessed and several indices for each of the WUAs studied were developed. Analysis of the survey results allows us to conclude that the provision of technical facilities and equipment alone cannot guarantee a high level of efficiency for water resources management and agricultural development in a WUA. For efficient water management and a functioning WUA the following aspects are crucial:

- the awareness of farmers of WUA infrastructure;
- active participation of WUA members in decision-making processes. The WUAs with high Participation and Awareness (PA) and also Egalitarian Decision-Making Indexes (EDMI) were characterized by better water resources management efficiency (water supply and water availability); and
- the level of social capital. WUAs with a higher score for social capital levels were characterized by better water supply conditions.

9.3 Tools developed and applied in the Amudarya case study

Participative methods to support stakeholder participation

In the Amudarya case considerable emphasis was placed on the involvement of relevant stakeholders at all levels in the identification of priority research issues, the analysis of the current regime, and the identification of potential measures for a transition towards one that is a more adaptive. Over the course of four years about 25 workshops were held involving stakeholders at the transboundary, national, regional and local levels, at which specific as well as integrative questions about AWM were addressed. A variety of participatory methods such as focus group discussion, the nominal group technique, the strategic choice approach, cognitive mapping, group model building and role playing games were applied. When working in smaller groups interactive methods created an open and creative atmosphere that encouraged stakeholders to participate actively in the discussions. They helped to overcome the formal and hierarchical setting that is common to the region. Participants acknowledged the opportunity for open discourse and interaction with other stakeholders, thus indicating that the application of the methods supported a dialogue among stakeholders of different levels or backgrounds as well as local and European scientists.

While those methods new to the participants – such as group model building or role playing games – were initially greeted with scepticism, they were eventually accepted as useful and interesting means to engage stakeholders. Naturally, some methods were more difficult to apply in the given setting than others. This was partly because a high degree of familiarity with the existing management regime is needed for some methods, e.g. for a role-playing game. But success also depends on the relationships among stakeholders and overcoming language problems. Language barriers can be more easily overcome when discussing individual written contributions than, for example, in a lively role-playing session.

Adaptive Monitoring and Information System

The Adaptive Monitoring and Information System (AMIS) developed for the Amudarya provides a methodology to support current monitoring practices by integrating local knowledge into a scientific assessment approach. Thus, it helps to partly overcome problems related to data gaps without increasing monitoring costs. Moreover, the system supports the long-term monitoring of ecological conditions which is needed to detect environmental trends and changes.

The AMIS is a software tool that provides a selection of methods to deal with spatial and temporal data. It was extended specifically to meet the requirements of soil salinity and wetland monitoring based on local knowledge as described above. The system consists of various software components:

1 the GIS SAGA (http://sourceforge.net/projects/saga-gis/);
2 the object-relational database management system PostgreSQL (www.postgresql.org);
3 a GIS-database interface; and
4 a graphical user interface.

In order to ensure sustainability from a technical point of view, only freely available and open source software was used.

We introduced GIS technology into the proposed new soil salinity monitoring approach to provide data at the local and regional scale in digital format. The soil salinity data collected by farmers once a year is assigned to each digitized agricultural field via a user dialogue in AMIS. For each field the degree of salinization is computed using fuzzy logic to combine the different inputs. The GIS component acts here as user interface to enter and to visualize data. Data entry takes place via sliders for qualitative information, such as the soil color or the evenness of the field, and drop down menus for discrete information, such as the number of leaching cycles. The terminology used to describe the values of the slide bars are the terms used by the local community.

During development of the methodology with scientists, local people, and decision makers, our intention was to design a practical tool that would 'survive' the lifetime of the NeWater project. The interest of stakeholders and their willingness to contribute was high, which we attribute to the fact that the tool addresses an issue that is highly relevant to farmers and decision makers and to our efforts to involve all relevant stakeholders which gave them a sense of ownership. Stakeholders especially appreciated our approach of developing a methodology that:

1 fits into the existing system, rather than substituting established methods;
2 integrates and elicits knowledge from alternative sources (local knowledge from farmers); and
3 is sustainable from a financial point of view.

Tools for integrated water allocation planning and assessment

AWM calls for an integrated approach to water and land use that is informed by an assessment of the current state of the river basin as well as potential impacts of environmental or management changes. To achieve fair, transparent and thereby durable AWM among conflicting stakeholder interests, policy choices need to be supported by the best available knowledge and a common and accepted knowledge base. AWM also emphasizes the need to adapt to and cope with the uncertainties of climate and global change by constantly revising current policies based on newly available information and knowledge. Support from modelling tools to explore the effects of future changes can contribute to better, adaptive IWRM, particularly in a river basin such as the Amudarya, with its highly complex water management system and high natural variability.

WEAP – Amudarya – Water Evaluation and Planning System

A water allocation and planning model was developed using WEAP (www.weap21.org) to support the operational and strategic planning of water allocation carried out at regional and national scales. It has been linked to the official national runoff database of Uzbekistan and to a tool that uses available past and actual information to predict water availability for the upcoming vegetation season. The development was carried out in close cooperation with staff from the Uzbek Ministry of Agriculture and Water Resources to adapt it to their needs for water allocation planning. The system was translated into Russian for use by the staff of the Ministry and the River Basin Authority. To meet the need for improved education and awareness of future water managers we also designed a study course of integrated water resources management using tools such as WEAP for the Tashkent Institute of Irrigation and Melioration that can be used to educate future water managers.

MODFLOW-SIMGRO Amudarya – a regional water quantity and quality modelling tool for AWM

The MODFLOW-SIMGRO modelling tool fills a gap between large scale optimization models such as WEAP (see above) and field scale modelling studies. MODFLOW-SIMGRO is detailed in its description of the hydrological system, but at the same time covers the whole river delta (see Figure 9.3). It not only focuses on water quantity, but also on quality. This is particularly relevant as the assessment of the impact of climate change is still very much focused on water quantity in the form of precipitation, snowmelt and runoff change and related events like floods and droughts. However, it has become increasingly clear that it is also important to take into account the effects on water quality, certainly in the case of the Amudarya region where salinity problems are severe.

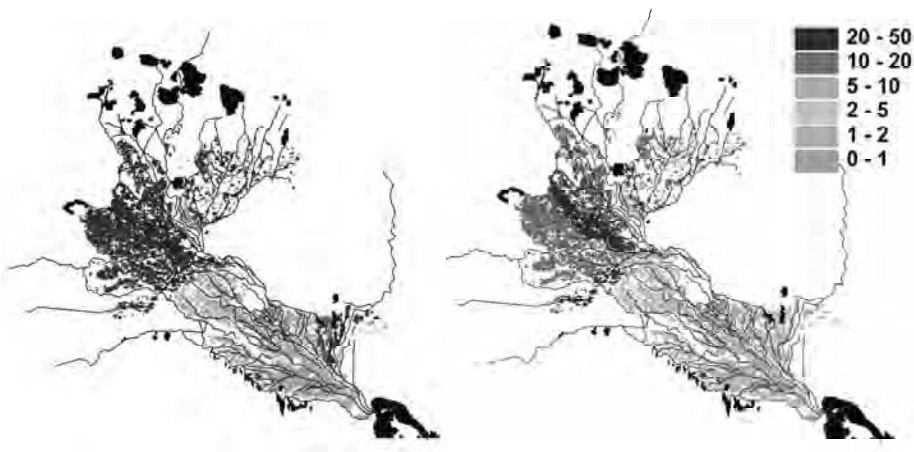


Figure 9.3 MODFLOW-SIMGRO *Amudarya model output for the whole Amudarya delta*

THE MODFLOW-SIMGRO modelling tool targets scientists and regional water managers who need to assess the effects of climate change and management options on a regional scale. It takes the processes that occur at field scale to a higher level and shows the interaction and effects on a regional scale. It indicates which areas are most affected by, for example, water shortage or salinization and by its level of detail identifies the main processes behind these effects. One of the advantages of the tool is that despite its regional nature, output can be made at a more detailed level. Discharges, water shortages and concentrations of collector drains are properties that regional water managers can relate to. Using ten-day output in the form of water balances and water quality maps, short animations were created which highlighted dynamic changes within a year.

The development of an integrated modelling tool takes time and constant feedback. The stakeholder workshops in the NeWater project provided good opportunities to assess the usefulness of the current tool and collect recommendations on directions for future development. Inevitably, one recommendation was to increase detail, changing the resolution from one km^2 to one hectare, since farmers' decisions are related to this field scale. Although this will not be possible given the required computational time, improvement of input data will still make it possible for more accurate predictions at the current scale.

9.4 The future

The future of the basin depends to a large extent on the development paths and structural changes taken by the riverine countries in the coming years, both at a national as well as transboundary level. To address the problems of water scarcity and environmental degradation and to facilitate adaptation to climate change, major changes are needed in agricultural and water management policies towards a diversification of the economy and water use, and for improvements in horizontal and vertical cooperation. There is a need for education and awareness raising, development of capacity and support for the development of institutions and legal frameworks for all aspects of water management, as well as tools to support communication, trust building and negotiation across all scales.

Adaptive integrated water resources management can help to improve the current situation and prepare for the challenges of climate change through:

- Recognizing a diversity of water uses and integrating their needs.
- Promoting the participation of all water users.
- Providing tools to assess the impact of uncertainties and management measures.
- Supporting learning from past experiences, e.g. the severe drought in 2000/2001.
- Enhancing cooperation across administrative levels, e.g. by strengthening smaller scale governance units.
- Improving monitoring by integrating different knowledge sources, e.g. measurements by specialized agencies with assessment by users.
- Adapting an environmental flows approach by incorporating water needs for ecosystems into water allocation planning.

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10
Nile River Basin

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10.1 Background

Nile basin description

The Nile is the world's longest river at 6700km and one of the world's greatest natural assets. It is a transboundary river shared by ten African countries: Burundi, the Democratic Republic of Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania and Uganda. The Nile River originates from two distinct geographical zones, the basins of the White and Blue Niles and drains an estimated 3.1 million km^2 covering 10 per cent of Africa's landmass. It is estimated that 60 million people live in the basin while 300 million (40 per cent of Africa's population) live in the riparian countries.

The Blue Nile originates in the Ethiopia highlands, as do the other major tributaries, the Atbara and the Sobat. Its flow is subject to extreme fluctuations due to the seasonal rains in the Ethiopian highlands. Between the months of July and September, flow increases due to heavy rains, but the Blue Nile may run empty during dry seasons or droughts. The source of the White Nile is in the Great Lakes Region. It is also ephemerally fed by the Bahr-el-Ghazal water system to the north and east of the Nile-Congo Rivers divide. Its catchment includes the riparian states of Tanzania, Rwanda, Burundi, Uganda, DR Congo, Kenya and Sudan. Its flow is tempered by the natural perennial storage of the Great Lakes, of which Lake Victoria is the most important. Consequently, it is characterized by a relatively steady flow pattern. Although the annual water input in the equatorial region is estimated at 400 billion m^3, the annual measured flow at the Uganda-Sudanese border varies between 20 and 22 billion m^3

because of the lakes' storage. In southern Sudan, the White Nile meanders through the Sudd where over 50 per cent of its flow is lost to evapotranspiration.

The White and Blue Niles converge in Khartoum, Sudan, and flow north to the Mediterranean Sea. The Nile River has an annual flow of 84 billion m^3 as measured at Aswan, in Southern Egypt. Of this, 85 per cent is from the Blue Nile, the Atbara and the Sobat, while 15 per cent originates from the Great Lakes region. The bulk of the Nile waters are used in the downstream states of Sudan and Egypt. The water resources support various sectors, which include agriculture, fisheries, water supply, energy production and ecosystem services.

The major determinant of the Nile basin water balance is the agricultural sector. Agriculture accounts for at least 80 per cent of all water consumption. The Nile has provided the basis for agricultural development in Egypt and Sudan since the start of agriculture, about 7000 years ago, and for political reasons, the East African nations have adopted a policy of self-sufficiency for food supplies.

Only a fraction of the rain falling on the watershed is channelled through the river to its downstream part and to the sea. A large part is lost through seepage, evapotranspiration and over-bank flows to the swampy lands that fringe the basin in many parts in its equatorial stretch. Large quantities of water are lost in both the Bahr el Ghazal and the Sobat basins. The present-day river regime does not carry more than 150 billion m^3 of water beyond Atbara each year. Variations in rainfall cause considerable variations in discharges and lake levels, which is the case for the White Nile River system. The average annual inflow at Aswan during the period 1940–1995 was 84.7 billion m^3. This represents a runoff/rainfall ratio of 0.055 implying that only 6 per cent of the total estimated rainfall over the Nile Basin is arriving at Aswan.

Major problems and challenges

Population growth and widespread poverty are key drivers in socio-economic development, which adds to the pressure on water resources caused by climate change and climate variability. Effects also include ecological consequences like reduction in stream flows, and degradation of riparian habitats. In the upstream countries of the Nile Equatorial Lake region as well as in Eastern Nile countries like Ethiopia, forests are cut down and wetlands are drained. Soils are eroded, resulting in reduced crop yields and non-sustainable livelihoods. Groundwater recharge is reduced and levels lowered, river flows become flashier and downstream flood and drought impacts are more severe. Other stresses include high sediment loads, water quality changes, seawater intrusion and waterweed infestation. Especially in Egypt and Sudan, the aspirations of the population and economies are intricately linked with water.

The Nile crosses international political boundaries and involves many decision makers. This, coupled with climatic variability, the spatial and temporal distribution of water resources and the complex social, political, and economic situation creates challenges to sustainable development and is a potential source of conflict. The present conflicts focus on water allocation, which is a source of debate and litigation rather than a forum for cooperation. Sharing the Nile waters gives rise to debate among users with conflicting demands and management preferences. The control of river flows has long been a source of tension and dispute and an issue of sovereignty, strategic necessity, and territorial integrity. Such tensions in the Nile basin are obstacles to development and constrain the regional political economy and divert resources from economic development.

There is a great potential for conflicts over water use, which is why achieving an integrated regional development of water resources on a sustainable basis is a critical condition for the socioeconomic development of the Nile countries. To date, efforts to promote a water agreement between all Nile Basin countries have failed to materialize due to several factors. One of the most pronounced is the lack of a clear basin-wide water resources development strategy due to the absence of a reliable tool for accurately evaluating different Nile water development options and projects. Hilhorst et al (2008) argue that the hydro-political dialogue in the Nile Basin is a zero-sum game that needs to be widened to include other potential cooperation activities between the Nile countries. Tools to provide transparency to such opportunities are crucial for supporting the hydro-political debate.

IWRM development in the Nile basin

The Nile's transboundary nature touches international political boundaries and involves many decision makers and creates challenges to sustainable development. The present focus on water allocation, however, is a source of debate and conflict rather than a forum for cooperation and a constraint of the regional political economy and exclusion of resources from economic development. A broader approach is needed. In 1999, the Nile riparian states created the Nile Basin Initiative (NBI). This historic initiative includes all Nile riparian countries and provides a basin-wide framework for cooperation. It pursues shared vision development through the equitable utilization of their common Nile water resource. The focus is on sharing benefits of the Nile, rather than sharing the resource itself.

Most of the basin countries are constrained by weak human and institutional capacity for integrated water management. This affects not only the management of international waters but also the water management within each country as well; there is little integration among various water use sectors, and water quantity and quality are often managed separately, as are surface water and groundwater. Most problems associated with water management in the Nile basin are of a transboundary nature and need a regional perspective for the identification of solutions, especially as water stress in the basin is likely to intensify. The challenge lies in creating cooperation and economic development mechanisms that effectively defuse the emerging conflicts and subsequently help authorities to manage the water resources in ways that reduce the water stress.

The policy framework in the Nile basin is characterized by poor policies and/or an inability to translate policy frameworks into action. Of particular concern is the absence of property rights and other policies that would provide an incentive for efficient water use, which are critical in promoting individual investments in resource conservation. Policy reforms have affected the economies of most of the Nile basin, and hence reduced the level of economic development and investments in water management. Public involvement in policy formulation – particularly in water policy – has been limited. Most stakeholders are not aware of the water policy and how it affects them. Most countries lack policies that promote water conservation at the user level.

10.2 Selected themes in the NeWater project

A basin wide approach was used to address management and governance issues. Given the basin size and complex river system, the appropriate decision level for policies that affect the functioning of the entire Nile river system is the highest rather than the local level. The focus of interventions for the Nile basin under the adaptive management framework should be to promote an integrated, system-wide perspective, where various inter-relationships of water uses can be considered. The complexity of the water requirements coupled with a continued increase in the demand for water in the Nile basin, call for urgent, systematic, sustained and concerted actions at the basin scale. This also calls for adaptive measures and implementation of the principles of IWRM to ensure sustainability of the water resources. In a basin-wide context, interrelated issues on quantity and quality of surface water and groundwater, and the extraction, use and disposal of water resources should be comprehensively analysed.

Based on the discussions with the NBI stakeholders, the following issues were identified as important for the NeWater research:

- Integration of the important sectors within the Nile Basin (agriculture, hydropower and environment) with water management.
- Sharing the benefits of water management and projects instead of just sharing water resources.
- Linking water management and spatial planning with an emphasis on the transboundary context.
- Investigating the tension between water allocation and the environment (water quality and ecological flows).
- Providing access to data and insights into the future climate change and climate variability expected in the Nile Basin.
- Ensuring the link with capacity building and training needs for water professionals in the Nile Basin.

10.3 Tools applied in NeWater

Water quality and ecosystem services

Lake Victoria is the natural reservoir on the Equatorial Plateau, and receives the discharges from a large number of (relatively) small rivers. Population pressure and poverty in the region (Rwanda, Burundi, Tanzania, Uganda and Kenya) has resulted in deforestation, the draining of wetlands, unprecedented soil erosion and the discharge of untreated wastewater into the rivers. Euthrophication of Lake Victoria has resulted in water hyacinth invasions and the loss of biodiversity. Changed hydrological behaviour causes disruptions in hydropower generation and difficulties in lake transport (shipping).

Table 10.1 *Priority environmental threats by country*

Country	*Environmental threats*
Burundi	Deforestation, soil erosion, degradation of river banks and lakeshores, mining, wildlife hunting
DR Congo	River and lake pollution, deforestation, soil erosion, wildlife hunting
Egypt	Water and air pollution, filling of wetlands, desertification, water logging and soil salinity, sanitation, river bank degradation
Ethiopia	Deforestation, overgrazing, soil erosion, desertification, sanitation, loss of biodiversity (including agro-biodiversity), floods, droughts
Kenya	River and lake pollution (point and non-point source), deforestation, desertification, soil erosion, sedimentation, loss of wetlands, euthrophication and water weeds
Rwanda	Deforestation, soil erosion, degradation of river banks and lakeshores, desertification, wildlife hunting, overgrazing
Sudan	Soil erosion, desertification, pollution of water supplies, wildlife hunting, floods, droughts, sanitation, deforestation
Tanzania	Deforestation, soil degradation, desertification, river and lake pollution, poaching and shortage of potable water
Uganda	Draining of wetlands, deforestation, soil erosion, encroachment into marginal lakeshore and riverine ecosystems, point and non point-source pollution

(Asfaw, 2005)

Although the major concern within the Nile basin is about water quantity, water quality problems are widespread as well. An important process affecting water quality in the Lake Victoria region and the Nile as a whole is erosion. Erosion is largely controlled by the hydrological pathways and as such climate change can increase the effects of existing drivers like deforestation. Integrated assessment methods can give valuable insights and indicate the most vulnerable areas.

A framework for creating an erosion risk map based on freely available data was developed and a prototype erosion risk map was created. The erosion risk map indicates the areas which contribute most to erosion and where erosion control measures are most likely to have the greatest effect. The erosion-risk mapping applied in this study is based on a two-step approach. Firstly, runoff is determined. A simple, but process-based, hydrological model was used for this purpose using available data. In this way, the pathways of the sediment's transporting agent – the water – could be quantified. Secondly, the

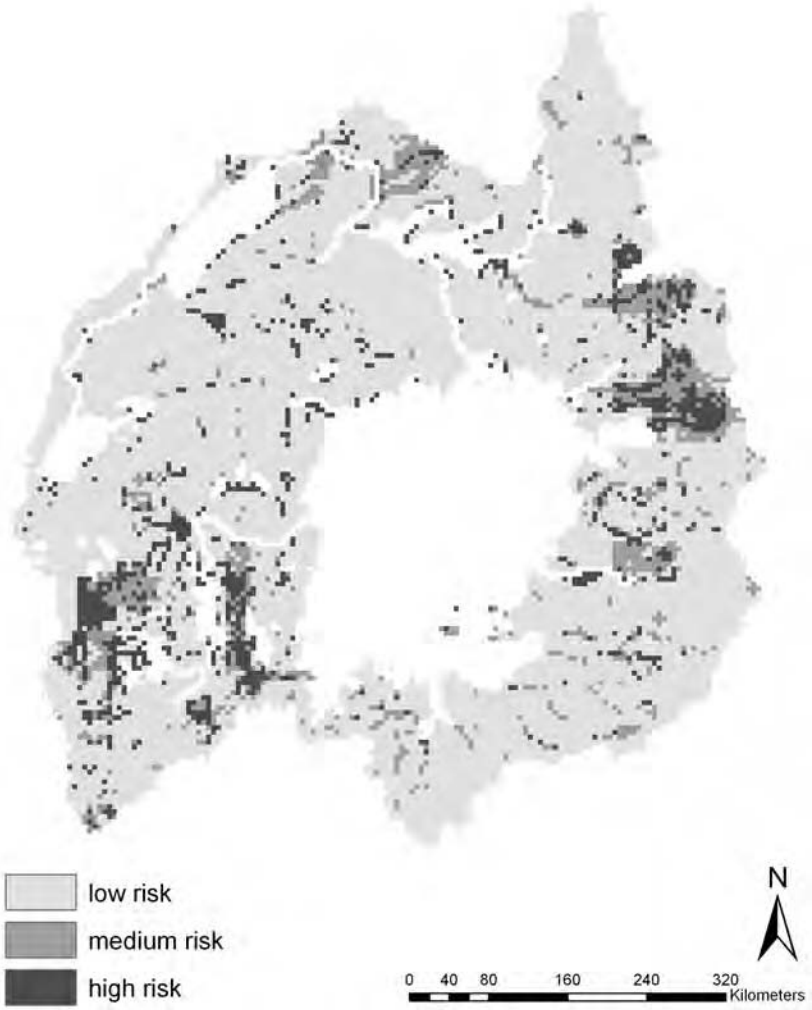

Figure 10.2 *Erosion risk map for the Lake Victoria region*

vulnerability of the soil was assessed using several parameters like land cover, slope length and steepness and soil properties. This information is then combined in a GIS with the hydrological information to derive the erosion risk.

The erosion risk map indicates regions with high, medium and low soil erosion risk. The hilly areas in Rwanda and parts of Burundi are very susceptible to erosion. Also parts of Uganda and western Kenya have a high risk of erosion. In large areas the map indicates a relatively low risk for erosion.

The NeWater research indicates the information needed to set up this quick analysis method, its possibilities and limitations. In order to improve on the method, higher resolution of input data is the highest priority. Data availability is decreasing in the Nile region. More data on runoff are available for the 1970s than for the last decades. For better understanding and adaptive management capacity it is of the upmost importance that information gathering is improved and that data is made easily available. Only then will an adaptive learning cycle be most effective.

Spatial planning

The NeWater project has specifically focused on the interaction between adaptive water management, land use and spatial planning, the spatial adaptation. This spatial adaptation includes local, specific options like finding space for flood mitigation or decisions on the location of buildings. But in a broader sense it also relates to the way land is used, which crops are planted or, for example, how trees can prevent soil erosion and help to preserve or restore river base flows.

Land use patterns and changes are most often based on many individual decisions made by farmers and local land owners. However, both now and in the past, land use is planned and changed also on a larger scale by introducing irrigation for example. The Nile region is an interesting case study for examining how land use change is perceived as an adaptation option at different levels. In the past, water resources have been adequate to meet existing and emerging demands from the various economic sectors in the Nile Basin countries. Population pressure, the use of marginal lands in upstream countries and the expansion of irrigated areas in the downstream countries have gradually increased tensions between the Nile riparian countries. Water is a primary strategic resource in many facets of the complex economic, social and culturally diverse situation in the Nile Basin. Each Nile country expects benefits from the control and management of the Nile water.

To identify and prioritize adaptation needs, the National Adaptation Programmes of Action (NAPAs) of various Nile countries were compared.[1] These programmes draw on existing information and community-level input to identify adaptation projects required now in order to enable these countries to cope with the immediate impacts of climate change. A quick scan reveals that many proposed adaptation measures consist of small scale local water and land use management improvements. These relate mostly to the use of drought resistant crops, water harvesting and erosion control measures. Another measure given high priority in many countries is reforestation or, on a smaller scale, the planting of crops on farmlands or homesteads.

Erosion control and reforestation not only help communities to adapt to drought but can also have an important affect on preventing floods during periods of heavy rainfall. The different climate scenarios show that impacts in the Nile basin vary. Especially in the Great Lakes area there is a high probability of a strong increase in rainfall. Erosion control measures are seen as essential in these upstream countries. In addition, especially in Sudan, the construction of larger scale infrastructure to control the river flow is proposed. In Burundi, small scale hydropower is promoted. In many countries early forecasting systems are mentioned.

Table 10.2 *Overview of priorities in adaptation options (iiiiii = high priority)*

	Spatial			*Hydrological*		*Other*		
	Rangeland conser-vation	*Land use change or preservation*	*Water and land management options*	*Controlling rivers, forecasting*	*Hydro-power*	*Health*	*Financial*	*Training, other livelihoods*
Burundi		iii	iiiii	ii	i			iii
Rwanda		i	iii	i				ii
Sudan	ii	iii	iiiii	ii		iiii		iii
Ethiopia	ii	iii	ii	ii		i	i	iii
Tanzania		iii	iiiii					iiiiiiii
Uganda			iiiii	ii		i		iiiiiiiiiii
Eritrea	ii	i	ii					

Waterwise

To facilitate investigations into a system as complex as the Nile Basin and to structure the process of trans-disciplinary stakeholder consultation, the analyses are done with Waterwise (Van Walsum et al, 2008), which is an integrated model linking hydrology, economy and ecology. Measures of future land use, hydropower, nature and water management can be evaluated in close interaction with stakeholders. It provides an integrated modelling platform for exploring a range of strategies and innovative ideas with respect to the socio-economic development in the context of the Nile basin. The results can be understood in conventional economic terms and also in terms of their effects on ecosystem services and human welfare. Results are not only visible for the Nile Basin as a whole, but also for the different riparian countries to support discussions and negotiations about acceptable solutions for spatial planning and water management.

The Nile Basin application of Waterwise was constructed around a simplified hydrological model. One hundred and twenty sub-basins of the Nile were integrated; at a more detailed level there are 1371 so-called hydrotopes, which in turn are comprised of 3 million 1 km^2 pixels. All the major rivers are included as well as the main lakes and reservoirs. The land use was derived from a FAO classification and each country's current and potential agricultural production was assessed. The main hydropower stations are included.

Important options within the Nile basin, as identified among others in the NAPAs, are the large scale introduction of local watershed improvement. The Waterwise model makes it possible to choose several options like irrigation from local groundwater or regional surface water reservoirs and to increase infiltration capacity. These options have initial investment and continuous maintenance costs. The model can also convert land use and will do so if the increased yields are higher than conversion and maintenance costs. In addition large scale options like new irrigation projects, new hydropower dams or the final construction of the Jonglei canal are also included in the model.

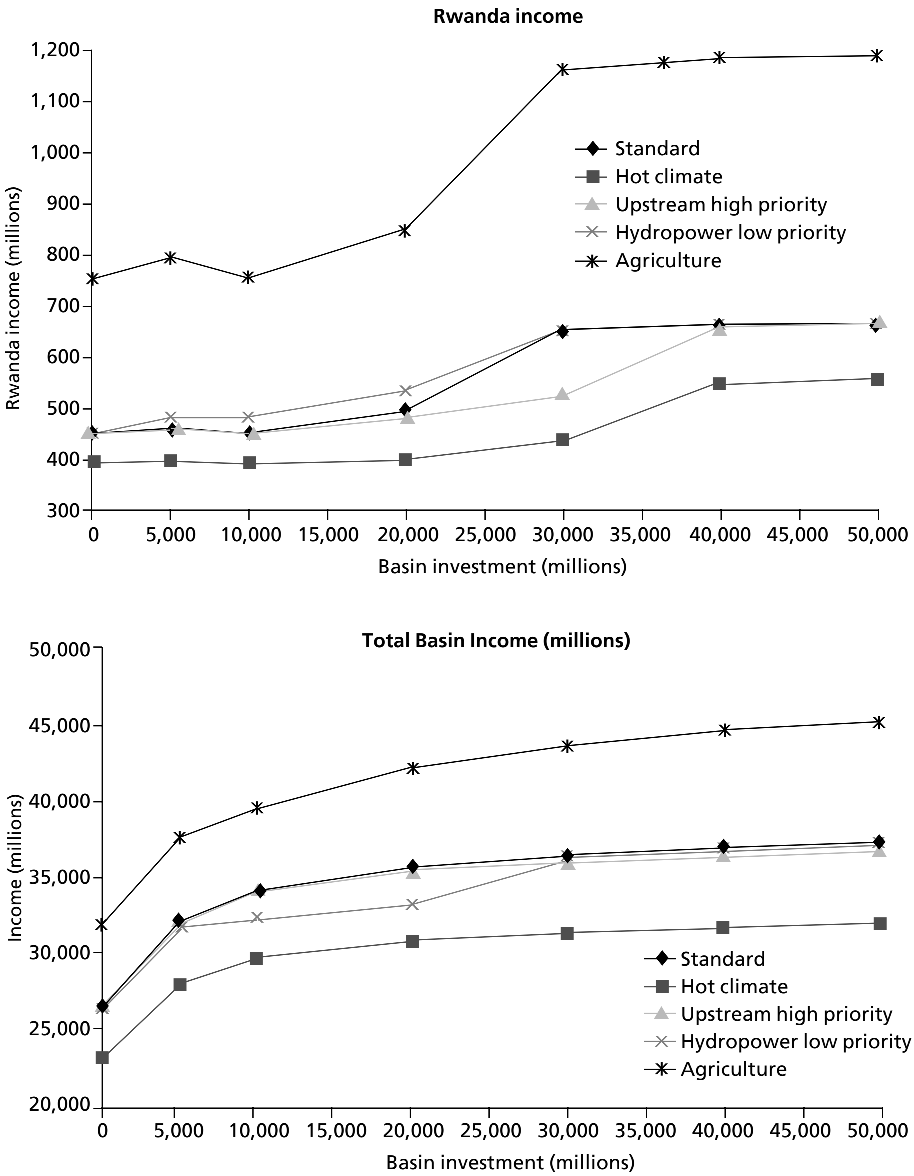

Figure 10.3 *Evolution of income for Rwanda and for the Nile Basin as a result of investment level and different priorities*

Finally the model was adapted to reflect the NeWater philosophy, where adaptation has to take place in an uncertain future. With WaterWise, solutions can be sought within the context of a specific climate or by taking into account multiple climate possibilities. This highlights the options that are robust in different circumstances and can show the extra costs of decisions compared to decisions based on the current or a single climate scenario.

Different investments lead to different priorities within the basin. Hydropower needs high investments but also brings instant yields. The model shows that in certain countries there is still space for extending agricultural lands. Watershed improvement is effective mainly in combination with the intensification of agriculture.

Climate change

NeWater in cooperation with CPWC analysed IPCC scenarios for the Nile which indicate that the uncertainties are huge. The projections for rainfall changes during the rainy season for the Blue Nile range between –15 per cent and +15 per cent in 2050 for the scenarios and CGMs considered. The Blue Nile is specifically important as the main water source for the downstream countries Sudan and Egypt. The projections for the White Nile are more consistent as to the direction of change in rainfall, but the degree of uncertainty is greater: from almost no change in precipitation to an increase of about 50 per cent in 2050.

Inflow into Lake Nasser, the main water resources for Egypt (40 per cent of the basin population) could double this century, but could also be reduced by 75 per cent. This is an extreme variability in river flow, which affects irrigated agriculture, the hydro-electricity and its users, industry, and town dwellers along the rivers.

Training

Dissemination and training are of vital importance, since they are needed to raise awareness and build capacities to undertake IWRM approaches. In a NELSAP workshop in September 2008 aspects of CC and CV and participatory processes were discussed and integrated into development plans and management across economic, social and environmental sectors.

To strengthen the NBI staff capacities three tools for adaptive water management were selected for a 'train the trainers' workshop in Cairo in 2008:

- The Multiple Actor Behaviour Simulation method to show participants how to behave and interact in situations with multiple actors, ambiguous issues and diverging frames on natural resources management.
- Waterwise to introduce land and water use strategies and discuss them with participants in response to user wishes on conflicting claims for land and water.
- A search conference process to identify the relevance of well-functioning institutions in water management and to formulate the need for change in measures, tasks, responsibilities and structure.

The interest of the (mainly NBI) participants at the Cairo workshop was equally divided among the tools. The Multiple Actor Behaviour Simulation was most successful in quality and relevance. Participants were able to apply what they learned and recognized that interaction and negotiation processes were as important as the content of water management strategies. Participants appreciated the search conferencing approach for discovering the importance of understanding existing institutions at different levels along with their complex relations before introducing change in water management institutions. Waterwise was demonstrated as a prototype of a Nile simulation. The participants recognized the importance of Waterwise for the integrated assessment of water management in the Nile basin and accepted the invitation to formulate further criteria and relevant goal functions for the issues they deal with under Nile Basin conditions.

Stakeholder approaches

Working with the NBI as a stakeholder means working in a formal environment that must accommodate national preferences and obstacles and plan according to an international agenda. Through this collaboration, the team organized and actively participated in seven major stakeholder workshops:

- The NBI kick-off workshop (October 2005) in Entebbe to define the research agenda for the NeWater Nile programme and to incorporate climate change and climate variability into the existing Nile Basin Programme.
- The Water Scarcity Workshop (March 2007) in Cairo to identify strategies for Egypt to deal with future water scarcity due to population growth and uncertainties in climate change.
- The NBI stakeholder meeting (April 2007) in Entebbe to update and reconfirm the Newater Nile research programme.
- The NBI training workshop (February 2008) in Cairo to test the application of the first prototype of Waterwise for the Nile Basin.
- The Climate Change Research Scoping workshop (June 2008) in Nairobi.
- The NBI workshop (September 2008) in Kigali on the integration of social development issues and climate change in NBI investment projects.
- The NBI workshop (February 2009) in Addis Ababa on the application of Waterwise in the Nile Basin.

10.4 Future of the Nile Basin

Population growth and widespread poverty are key problems to be solved in the Nile Basin countries. Only through socio-economic development can the pressures on the water resources aggravated by future climate change and climate variability be reduced. The international dialogue on water sharing as implemented by the Nile Basin Initiative needs to be widened to include economic cooperation in the region. Discussions about sharing contested water resources frame the problem differently then a discussion focused on sharing the potential benefits of using water resources in a better way.

The NBI is advocating sharing the benefits and has been able to reduce tensions between the Nile riparian countries. At the technical level there is a growing awareness that transboundary cooperation needs to be widened and guided away from a water sharing discourse. At the political level, however, the NBI recommendations have not yet been acknowledged and accepted.

The Nile Basin countries are mainly rural economies with limited economic activities other than agriculture. Agriculture itself is mainly subsistence in nature in many countries, with limited links to local markets. Production levels are far below potential which offers opportunities for the future. Water, climate change and climate variability are important determinant factors for future (agricultural) development. Market development and diversification of national economies, however, are absolutely necessary if people are to benefit from these opportunities.

Large investments are needed in the Nile Basin to guarantee a better (economic) future. Many of these investments (hydropower, small scale water buffering through watershed improvement, increased agricultural productivity through better farm management) are endangered by the huge uncertainty in the climate change forecasts for the Nile Basin. The uncertainty in the future climate conditions urgently needs to be reduced by better (regional) climate models. Investment decisions need to be screened with consideration for the uncertainty in climate change predictions (climate proofing).

Notes

1 The NAPAs are created under the coordination of the UNFCCC for the 39 least developed countries in the world. Egypt and Kenia are not included.

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11
The Orange River Basin

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11.1 Background

Rising 3300m above sea level in the steep Maloti Mountains of eastern Lesotho, and flowing for some 2300km though an increasingly arid landscape until it reaches the Atlantic Ocean, the Orange River (or the Senqu, as it is known in Lesotho) is one of the largest river basins in the world. In South Africa itself, the Vaal River is considered to be the most important tributary, providing crucial water resources to the urban industrialized conglomeration of Johannesburg and Pretoria.

Each of the basin states has a different legal regime, with varying management capacities and frameworks for water resource management. As a result of this complexity, the basin has an advanced hydropolitical regime, characterized by major international and national water transfers and huge water infrastructure. These supply water to industries, farms, forestry concessions and municipalities, both inside and outside the basin, and these groups represent the main beneficiaries of an effective implementation of Integrated Water Resources Management (IWRM).

Historically, ineffective and inequitable water management has given rise to the most obvious and pervasive problem in the Orange-Senqu basin: widespread poverty and economic hardship. In South Africa, the Department of Water Affairs and Forestry (DWAF) has put in place a policy to redress the balance of water distribution, whereby attempts are made to ensure that '*historically disadvantaged groups*' are given priority in allocations, along with the environment, which is identified as a priority user through the '*environmental reserve*', now implemented through the National Water Act (DWAF, 1998).

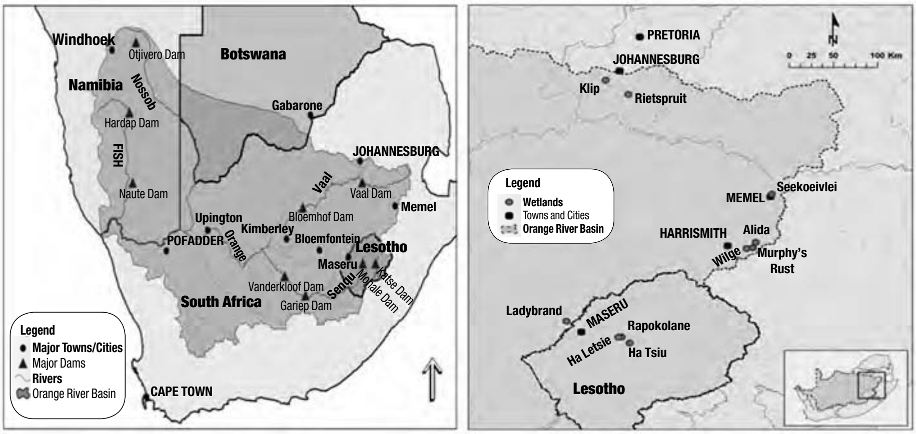


Figure 11.1 *The Orange River Basin in Southern Africa, and wetland study sites in the upper basin*

Commercial farming and industrial activities dominate the economy in South Africa, but in both Botswana and Namibia mining is important, but other economic activities are more limited, and water scarcity remains a problem. In Lesotho, rapid industrialization within the textile industry (a heavy water user) has brought about some major water quality problems, with little effective regulation taking place. Water quality is also a major problem in the South African part of the basin, along with widespread wetland degradation. To address these problems, there is still much to be learned about how *effective implementation* will be achieved, in the context of this complex situation, and if the promotion of *Adaptive Water Resource Management* will facilitate a more flexible approach to how needs can be met in across the region.

11.2 Addressing issues of concern

Irrigation, mining, industry, power generation and domestic consumption are all major uses of water from the Orange-Senqu system, and the complexity of these adverse pressures have resulted in a number of problems to be addressed. These include:

- ***Highly variable levels of human well-being*** – The population of the basin comprises a diverse mix of cultural and ethnic backgrounds, a multitude of languages, and wide-ranging socio-economic status. High rates of unemployment, low rural literacy, and high levels of HIV-AIDS all have significant consequences for livelihood options in the basin.
- ***High levels of rainfall variability*** – Serious issues of rainfall variability have been addressed in the basin through the development of a highly complex system of transfers and storage, and future water demands are likely to be met through transfers into the Orange from other river basins. In spite of

this development, infrastructure to deliver water to local populations is lacking in many rural areas, and many households cannot afford to pay for water.

- ***Problems of water sharing*** – The Orange-Senqu basin carries one of the most regulated rivers in the whole of Sub-Saharan Africa, encompassing as it does the huge Lesotho Highlands Water Project, under which arrangement South Africa pays Lesotho (the upstream riparian country), for water storage. To date, Namibia and Botswana have had few benefits from the river, both also contributing little to its flow.
- ***Regional economic security*** – Recent water shortages have brought about failures in power generation schemes, particularly in South Africa, giving rise to further development of the basin through Phase 3 of the Lesotho Highlands Scheme.
- ***Threats to water quality from mineral extraction of globally important resources*** – Mining makes a massive contribution to the economies of the region and creates employment for thousands of people, As in other places, this creates significant environmental impacts, particularly on ground and surface water resources.

11.3 The institutional context in the Orange basin

There is much diversity in the kinds of institutions which play a role in water management in the Orange-Senqu basin. These range from local traditional customary practices to international agreements and institutions. Historical legacy and biophysical conditions have both played an important role in shaping conditions in the basin today. In an attempt to regularize the way the basin is managed, an international river basin commission ORASECOM, has been established, and institutional reform and policy development have been achieved in various levels of governance. However, ORASECOM is an advisory body to the riparian Governments, with no basin management or regulatory functions, and a more integrated basin approach to managing the resource is yet to be achieved. During the NeWater project, water management officials of all four riparian countries as well as independent scientists, representatives of NGOs and donor organizations, and representatives from ORASECOM itself, were consulted regarding their views on institutional development in the basin.

11.4 Tools and approaches applied in the Orange-Senqu case study

To investigate basin conditions and to promote the adoption of Adaptive Water Resources Management, a number of diverse approaches have been used in this case study. These have been grouped under two over-arching themes: ecosystem goods and services, and scenarios of future change. In addition, two cross-cutting issues of institutional analysis and capacity building have also been addressed. These are summarized in Table 11.1, with some details provided below.

Table 11.1 *Themes and tools applied in the Orange-Senqu case study*

Over-arching themes	
1 Ecosystem goods and services	*2 Scenarios of future change*
Livelihood assessment and vulnerability analysis	Hydrological modelling from sub-catchment to basin scale
Ecological assessment of wetlands	Hydro climatic scenario analysis
Valuation of wetland ecosystem goods and services	Water vulnerability analysis
Water chemistry analysis	
Environmental water allocations	
Cross-cutting issues	
Multi-level Institutional analysis	Capacity building

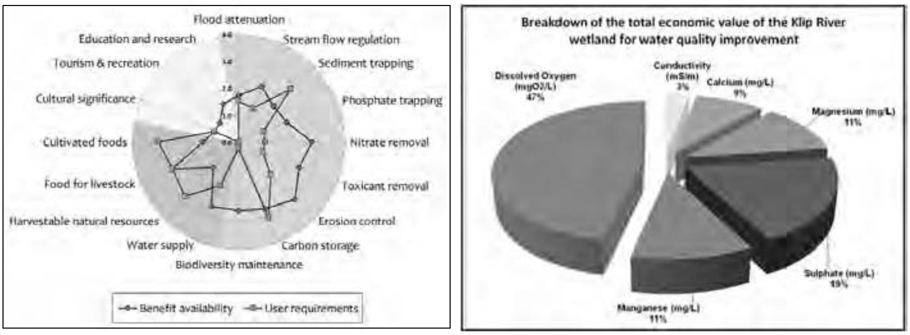
11.5 Theme 1: A focus on ecosystem goods and services

Wetlands play important provisioning, regulating, aesthetic, recreational and even spiritual roles for people in all four countries in the Orange-Senqu basin. Increasing attention has been placed on this issue, and in line with this, and on the basis of consultative responses from a range of stakeholders, much of the work in the NeWater Orange case study has been focused on wetland ecosystems, and the benefits they deliver in the basin. As a result, ten specific wetland sites were identified in the area of the upper basin, to provide an insight into different wetland types and their various functions and values (see Figure 11.1).

The role played by wetlands in the hydrological cycle of the basin is recognized as important, but still remains to be fully quantified. To address this knowledge gap, it was first important to build an understanding of the catchment and wetland characteristics in order to assess the current integrity of each wetland system. This was based on WET-Health (Macfarlane et al, 2008), a technique specifically designed to establish the current state of wetland hydrology, geomorphology and vegetation, reflecting the overall wetland condition. This was then followed by a qualitative assessment of the goods and services supplied by each case study wetland using a modified version of WET-Ecoservices (Kotze et al, 2008). This relied on field visits and interaction with local stakeholders, to determine current levels of benefit availability and user requirements for wetland benefits.

Results of the ten case study assessments carried out in the Orange-Senqu basin have highlighted the high variability in wetland benefits from different wetland types, and in some places, certain benefits are highly sought after, while others have very little importance to local users.

An illustration of how this approach identifies key functions is shown in Figure 11.2, which also provides an example of the economic value of water quality improvements associated with wetland functionality. This has been calculated on the basis of replacement costs.



Source: (left) Macfarlane, D.M. and A. Teixiera-Leite (2008). (right) Bonjean and Sullivan, 2008

Figure 11.2 *An output from the WET-Ecoservices tool describing a valley bottom wetland in the Lesotho Highlands, and an illustration of the costs associated with water quality improvements in a wetland system in Gauteng*

Water quality analysis

There has been much written on the ability of wetlands to improve water quality (Mitsch and Gosselink, 2000), and the work described here has been carried out to test this hypothesis in the Southern African context. In order to assess the functionality of a wetland system to improve water quality, comprehensive analysis of the water chemistry of the Klip River in Gauteng was carried out. Using data collected from Rand Water and other sources, detailed analysis was made of the differences in water chemistry recorded at monitoring points at the input and output points of the wetland system. These results are summarized in Table 11.2 which indicates that some pollutants are significantly improving, while others are significantly deteriorating.

For those determinants that are deteriorating, it is possible that this could be either input sources of pollution between the two monitoring points, or the release of pollutants from sediments, as has been suggested in earlier work on the same wetland (McCarthy et al, 2007). In addition to the specific improvements shown in Table 11.2, it is also possible to estimate the contribution that these improvements are making to achieve the standards set in the Target Water

Table 11.2 *Significant differences between the upstream input and downstream output sites of the Klip River wetland*

Determinants that show a significant overall improvement ($p<0.10$, two-tailed) between the upstream input (K6) and downstream output (K21) of the Klip wetland for the period July 2006–July 2007	Electrical conductivity, calcium, magnesium, manganese, sulphate, dissolved oxygen
Determinants that show a significant overall deterioration ($p<0.10$, two-tailed) between the upstream input (K6) and downstream output (K21) sites of the Klip wetland for July 2006 to July 2007	Aluminium, boron, bromine, chlorine, iron, potassium, sodium, nitrate, phosphate, nickel

Quality Range (TWQR) set by DWAF guidelines. These guidelines relate to water quality requirements for both aquatic ecosystems and for domestic use, and the contribution made by the Klip wetland to reaching this target range has been calculated to be 57.9 per cent for the TWQR for ecosystems, and 78.1 per cent of the TWQR for human use. This is a significant contribution, and it can be clearly seen that this improvement of water quality as a result of effective wetland functionality has an important economic implications for the water industry.

Valuation of wetland ecosystem goods and services

In an attempt to value this water quality improvement functionality, the value of goods and services from different wetland types have been investigated, and attempts have been made to value these on the basis of use values. Various valuation approaches including replacement cost, market pricing and imputed values have been used. No attempt has been made to assess either the *option* or *intrinsic* values of these wetlands, and it is important to note that these values all represent partial values and the Total Economic Value of each of these wetland systems is in fact significantly higher than the simple use values shown here. Nevertheless, through the evaluation of a selection of different use values, it is possible to demonstrate the significant economic importance which can be associated with wetland benefits. In the case of valuation of wetland benefits for livelihood support, this has been done on the basis of replacement cost approaches in terms of fodder values, fuel costs etc., and on market prices, for example in terms of costs of roof thatching, handicraft production from wetland resources, and water provision. Valuation of the benefits of wetlands to tourism and economic development has been calculated on the basis of the Seekoeivlei wetland which is an important site for bird watching and wildlife photography. These recreational benefits have been assessed on the basis of tourism expenditures and associated multipliers, calculated from accommodation occupancy rates and travel costs, gathered through interviews and surveys in the small town of Memel in South Africa. The value of wetland benefits to commercial agriculture have been assessed on the basis of grazing values, calculated from data gathered from farm surveys from three wetland sites in the Free State. These are based on the market price of cattle and the replacement cost of fodder. In the case of the water quality improvement, this has been valued on the basis of what it would cost (i.e. the opportunity cost) to remove those determinants that have been shown statistically to have improved, using currently available technologies. Figure 11.2 shows a summary of how these costs are attributed to the different determinants improved by the wetland.

This replacement cost approach has been based on the identification of those technologies which perform the function of removing those specific chemicals, and an assessment of the part of the fixed and variable costs of that technology which can be ascribed to the removal of those specific chemicals. In this case, these costs are based on two technologies: the SPARRO plant, and the Sidestream Elevated Pool Aeration (SEPA).

A summary of the calculated values of these various wetland functions is provided in Table 11.3. The values shown here are only partial values, serving to illustrate the importance of wetlands from an anthropogenic perspective. There are other non-anthropocentric values relating to existence values which are only linked to human systems through international conservation efforts such as the Convention on Biodiversity and the Ramsar Convention. In the context of adaptive water management, providing insights into wetland values can help decision makers to better manage the resources more sustainably. Specifically in the context of the Orange-Senqu basin, this information will be relevant to those in the Lesotho Highlands Development Authority, or in ORASECOM, who may wish to use this information to justify more active support for a system of payment for ecosystem services.

Table 11.3 *Selected example values of wetland benefits in the Orange-Senqu basin*

Wetland	*Selected key benefits from this example*	*Valuation method used*	*Estimated benefit value per hectare (2008 prices)*
Ha Tsiu	Domestic water supply	Replacement cost method	R1437
Ha Letsie	Livelihood support, multiple benefits	Market pricing, replacement cost method	R1577
Rapokolane	Harvestable natural resources	Market pricing, replacement cost method	R310
Alida	Haybale production	Market pricing	R1758
Wilge	Commercial grazing	Replacement cost method	R1387
Murphy's Rust	Livestock watering	Replacement cost method	R151
Seekoeivlei	Tourism income	Market pricing, occupancy rates, travel costs	R1289
Klip*	Water purification	Replacement cost method	R1534

Note: Rand & Maloti (Lesotho currency) are equivalent in value so for simplicity, all values are shown here in South African Rand. * Values for the Klip water purification process are given in 2006 prices.

Source: Sullivan et al, 2008

The results of this wetland valuation work have been produced in a booklet entitled '*Keeping the Benefits Growing and Flowing*'. This has been distributed through key institutional and academic networks, and another less technical one is being produced for distribution in Sesuthu, the local language of Lesotho, targeted specifically to the remote communities of the Lesotho Highlands where much misunderstanding of wetlands was found to exist.

Environmental water allocations

Countries in the Orange-Senqu basin, in particular Lesotho and South Africa, have been at the forefront of world developments in recognition of the value of environmental water allocations that are needed to sustain the flow of benefits from rivers. Lesotho probably leads the world in having implemented the longest running and biggest project to implement environmental flows (called Instream Flow Requirements in Lesotho), while South Africa has been at the forefront of the assessment of these needs. Yet, after a decade of work in this area, it has become clear that there is a growing resistance to fulfilling these ideals in certain sectors of water management. NeWater has contributed to an investigation of the causes of this, concluding that management style has prevented the adaptability that is essential for effective implementation of environmental flows. Recommendations have been made on how adaptive management could greatly improve the success managing the ongoing flow of benefits from rivers.

11.6 Theme 2 Investigating alternative possible futures through scenarios

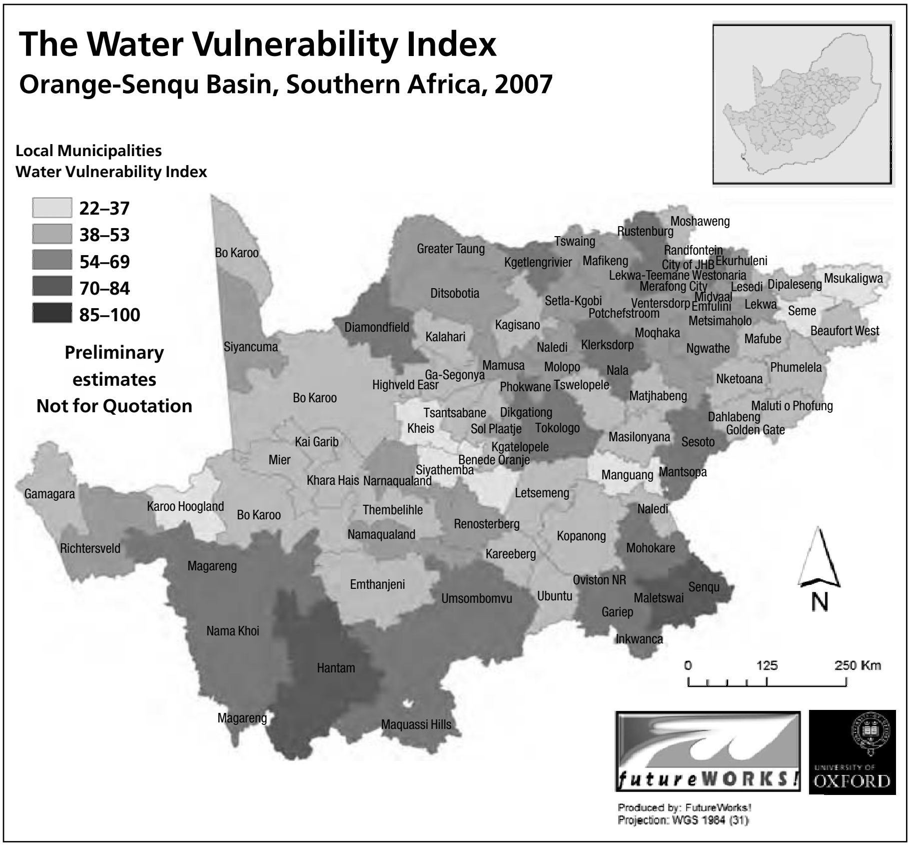
The Orange-Senqu basin has already been the subject of a scenario generation exercise carried out for the Millennium Ecosystem Assessment (Bohensky et al, 2004). To build on this, and the input from stakeholders, the NeWater team has promoted hydrological modelling, to provide information on the *water resource* itself in the basin, the actual *quantity of water* and the *assurance of supply*. This work has been initiated by the NeWater team in collaboration with the University of KwaZulu-Natal in South Africa, and it has resulted in a modelled assessment of the likely climate related changes to water resources and hydrological hazards within the Orange basin. The potential changes in flow regimes under intermediate (2046–2065) and distant future (2081–2100) scenarios were modelled using the ACRU daily time step model (Schulze, 2002), and the output compared with that from the present climate for the 1443 hydrologically interlinked sub-quaternary (quinary) catchments into which the Orange basin had been subdelineated. On this basis, the modelling predicts the future likely flows within each of the quinary catchments, both for the individual sub-catchment and for accumulated flows, thereby illustrating the possible implications of climate change on water resources in the basin. The model generated outputs relating to low and high flows and extreme events used in hydrological design, sediment yields and seasonal shifts in high flows. The results suggest that climate change is likely to have the effect of reducing water resource availability in the Western side of the basin, while in the East, more water is projected to become available.

Another initiative to provide insight into possible futures has been provided in the NeWater project by the development of the Water Vulnerability Index (WVI). This involved a comprehensive study of the water vulnerability profile of communities living in the basin, assessed at the municipal scale. Being the unit of local governance, this can have powerful influence over water management issues.

The WVI

The further development of indicators and indices has been one of the topics tackled in various ways in the NeWater project, but in the Orange basin, work has been carried out to develop a novel approach to explore the factors which give rise to human vulnerability in the water domain. The work carried out under the NeWater project has taken this composite index development work further, by building a spatially distributed database from which these index values can be calculated, at the resolution of individual municipalities (Sullivan, et al, 2009). The WVI is designed to be of use to water managers at various levels, and presently provides coverage of the whole of the South African part of the basin, at the municipal scale, as illustrated in Figure 11.3.

By combining the outputs of the *hydro-climatic modelling* with the rapid appraisal approach of the WVI, it will be possible to indicate those water users most likely to be vulnerable under different scenarios. This will provide the information needed to allow stakeholders and decision makers to become more adaptive in their water management and water use behaviour.



Source: Sullivan et al., 2009

Figure 11.3 *Water Vulnerability Index Scores, South Africa, 2008*

Vulnerabilities in the Lesotho Highlands

Another aspect of vulnerability has been investigated through local scale research carried out in Lesotho, focusing on the vulnerability of local livelihoods, and their relationship to wetland resources and ecosystem services. The dominant livelihood activities in the region are cattle and sheep rearing, crop farming, vegetable cultivation, off-farm labour and handicraft production. Following a series of focus group discussions in some of the highland communities around the Mohale dam, a number of issues were revealed to be undermining these local livelihoods (Bharwani et al, 2007). These include heavier snow and hail storms damaging crops, degraded grazing land, reduction in fuel wood sources, more frequent floods and droughts, loss of natural materials for building and craft making, and additional pressure on grasses as alternative fuel sources. The impacts of HIV-Aids, lack of agricultural land, and encroachment of surface runoff and groundwater upwelling into fields, coupled with the lack of local employment opportunities which is pervasive across the region, are also reducing local resilience. In the area of the Mohale Dam, some developments such as the construction of an all weather road and a health post have been completed, but local people point out that in spite of improved access to public transport, there remains poor access to markets for crafts and agricultural produce, and health facilities have not been conveniently located. This disconnect between local needs and new infrastructure has not encouraged the evolution of a strong and resilient community. Failure to recognize the multiple attributes of vulnerability, and the heterogeneous groups at risk, or to capitalize on local knowledge and traditional adaptation strategies have not helped strengthen these communities or their links with the water authorities, and more work needs to be done to rectify this situation.

Investigating social networks and local ecological knowledge for adaption to environmental change in the Lesotho highlands.

One of the research questions in Lesotho is a study on the role of local knowledge systems and the social network in the Lesotho highlands in understanding resilience of local livelihoods and use of ecosystem services. Using a network mapping exercise, nodes of local ecological knowledge are identified, and the flow of knowledge to and from these nodes are traced. These are then assessed for their relevance to a number of features identified in resilience literature as critical for adaptive management, e.g. social memory, redundancy, heterogeneity, adaptive capacity, and trust. On this basis, a restructuring of the social networks and knowledge flow for improved governance practices has been proposed to cope with current environmental challenges.

Initial findings show that in the two study villages, i.e. Ha Tsiu and Ha Rapokolane, people live in a closely knit community and a strong link is noted between individuals and local organizations, the most important among them being the Chief and his informal group of advisors consisting of village elders. The recently established village development council is yet to take root, however, a number of committees operate that undertake various local initiatives and provide services to the community. Linkages to outside groups and to government bodies at higher levels seem to be weak. Villagers are well aware of the strong environmental feedbacks to their own actions, and, although there exists a remarkable experience-based understanding, there is a clear need to develop skills and inter-disciplinary knowledge on adaptation and resilience building. Further, cross-scale linkages need to be activated, creating alternative livelihood activities to enhance income and well being and reduce pressure on local ecosystems.

Group Model Building in South Africa

In the Upper Vaal catchment in South Africa, individual cognitive mapping amongst stakeholders and Group Model Building (GMB) by scientists have been used for knowledge elicitation on drivers and barriers for the implementation of IWRM plans. Scientists were interested in obtaining a stakeholder-driven account of the current water management issues in the Upper Vaal, while at the same time allowing stakeholders to reflect on issues themselves. This was done by scientists working directly with stakeholders to develop individual cognitive maps of key problems, and these were then brought together to develop a group model to provide a synthesis of linkages giving a holistic overview of water management issues in the upper Vaal. As a result of this deliberative process, several first order factors influencing the implementation of IWRM plans were identified. Second order factors were then identified, specifically detailing transparency in the exchange of information and the overcoming of administrative disparities

How have these issues of concern been addressed in the past?

Water resource management in the basin has in the past been reactive in nature and has been dominated by the needs for economic development with a short time-horizon. So, for example, while the South African National Water Act is a remarkable piece of legislation that should provide for holistic management of water resources, including all of the tenets of IWRM and Adaptive Management, in practice, short-term objectives are dominating the decision-making process, leading to severe degradation of the system as a whole. It is only in recent years that the wetlands in the basin have emerged as an ecosystem under threat, yet they provide a hydrological and economic contribution that the basin cannot afford to lose. The wetlands of the rural Lesotho Highlands for example are major components of the hydrological system, but these have been subject to excessive degradation caused by a number of factors which are still poorly understood. In the past in South Africa, wetlands were often drained for agriculture, but in recent years, there has been some reversal of this trend, and protection of wetlands in South Africa has become an important part of natural resource management. The Working for Wetlands programme of the South African SANBI (South African National Biodiversity Institute) has become a highly successful initiative, and there are indications that the Lesotho Highlands

Development Authority (LHDA) may be interested in developing a similar strategy to address poverty alleviation and environmental improvement in that part of the basin.

While the concept of IWRM is supported by all countries in the basin and by the overarching SADC community, in practice water management remains dominated by water service issues. In the Orange River Basin however, there is some discrepancy between the written stated intentions for the basin and actual practice. For example, while DWAF in South Africa is charged with the protection of water quality, they are powerless to manage this, as the ideology of 'cooperative governance' – which prevents sister government departments from sanctioning each other – has resulted in local municipalities grossly abusing the water quality of the Orange/Vaal system.

The need for more effective water management, and challenges for its implementation

Possibly the most significant IWRM issue that has come up again and again during the consultation with stakeholders in the Orange Basin, is the lack of implementation of what is at times good policy and certainly good intention. By providing a more detailed insight into various aspects of the situation in the basin, the NeWater project can contribute to the development of water management at all levels, including those responsibilities assigned to the evolving river basin commission, ORASECOM.

The greatest problem preventing AWM is the prevailing style of governance and management in many areas, which is driven by pre-determined budgets and a strong objectives-based approach, where management may be slow to adapt. This severely constrains innovation and the ability to respond to changing circumstances. It is hoped that some of the outputs from this project (e.g. insights into wetland functionality, or the results from the water vulnerability assessment at the municipal scale) will help to provide information to support a more adaptive approach.

11.7 Conclusion

In addition to being a vast mineral reserve with globally important mining activities, the Orange-Senqu basin houses one of the most industrially developed parts of Africa, around Johannesburg. Supporting a range of commercial and subsistence farmers, it is home for some 19 million people. Both the individual and combined effects of these diverse pressures on the freshwater system of the basin are giving cause for concern. Faced with the uncertainties associated with the human condition, and the condition of the very earth system itself, water managers have to prepare for all eventualities. This means that the way problems are evaluated must change, and the way actions are decided must become more inclusive. These dimensions of flexibility are indeed important pillars of the principles of sustainability, and are the cornerstone of the more adaptive approach to water management that the NeWater project is aiming to promote. Three specific actions that can be taken in this direction are:

- to focus on the management of water quality as well as quantity in water resource planning;
- to ensure that direct discharges to rivers are licensed, and managed properly on the basis of their assimilative capacities; and
- to implement essential monitoring to ensure compliance with policies and regulations.

To this end, the NeWater project has generated a selection of specific outputs targeted towards awareness raising. These have included dissemination materials on the importance of wetlands, insights into mechanisms of more inclusive water conservation and management, and estimations of the impact of climate change on water availability across the basin. While there is abundant evidence to show that the waters of the Orange-Senqu basin are being grossly polluted, and great inequity still exits in their utilization, there is still inertia in the management response. The challenge now is to identify and loosen the knots that restrict management actions, to address these diverse and challenging problems, and perhaps a more adaptive approach will be the key to promoting more equitable and sustainable use of water resources across the basin in the future.

Acknowledgements

We would like to thank many people for supporting the work in the Orange-Senqu basin. These would include the many stakeholders who took part in the extensive consultation process at the start of the work, and the many others who enabled field work to be done and investigations to be made. In Lesotho, these included the communities of Ha Letsie, Ha Tsiu and Ha Rapokolane, and in South Africa, numerous farmers and land owners and other businesses helped to provide an understanding of prevailing conditions. In particular, Rand Water provided detailed datasets for water quality analysis, while numerous other institutions including the Water Departments of the four riparian states and the Basin Commission (ORASECOM) all provided useful insights. Details of the work done in the case study can be found in the NeWater Final Technical Report on the Orange Basin Case Study (Sullivan and Dickens, 2009).

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12
Summary and outlook

H.J. Henriksen, J. Mysiak, C.A. Sullivan, J. Bromley and C. Pahl-Wostl

12.1 What is adaptive management and why does it matter?

Adaptive management favours management practices that are sufficiently robust and flexible to cope with the uncertainties and inevitable surprises that are endemic in natural resource planning. In NeWater, adaptive management has been portrayed as a '*systematic process for improving management policies and practices by learning from the outcomes of implemented management strategies*' (Pahl-Wostl, 2007).

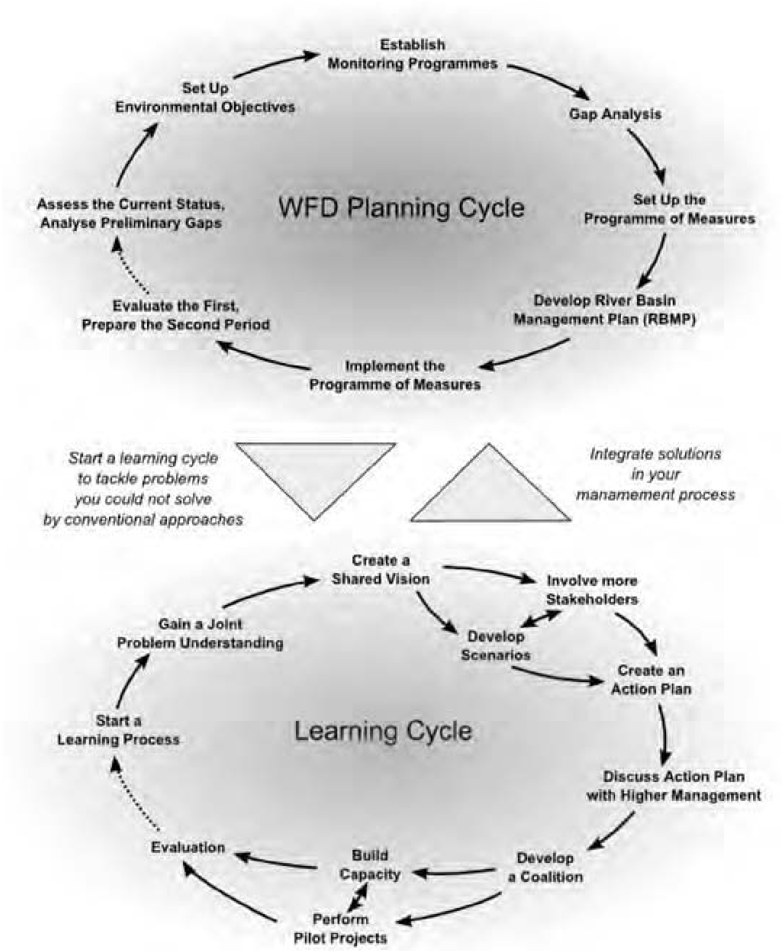
Adaptive water management (AWM) draws on the principles which have proved effective and are embodied in the design of the integrated water resource management (IWRM), namely broad stakeholders' and public participation, cross-sectoral analysis and policy integration, polycentric and decentralized governance, focus on multiple scales and transboundary efforts to manage natural resources. The focus on complexity and commitment to uncertainty is true to the AWM school of thought.

Yet, adaptive management it is not a panacea for all water management problems, and neither is it a one-size-fits-all solution. It is best suited for situations where uncertainty cannot be minimized in the short-term or where the implementation of policies cannot be delayed until more and better knowledge is available.

AWM and climate adaptation

Adaptive management should not be confused with climate adaptation, which is defined in the latest IPCC report as an 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities' (IPCC, 2007). Examples of climate adaptation are coastal dikes and water gates which hold back the rising sea levels, introduction of drought-resistant crop varieties in areas where precipitation will decline, or efforts to boost resilience of ecosystems and communities to extreme meteorological events.

Adaptive management is the more important as climate change introduces an additional factor of uncertainty into environmental policy making. It is no longer possible to rely on past experiences to determine future strategies and actions. Embracing the adaptive management principles and paying due attention to uncertainty will ensure that adaptation strategies are effective and robust under different future conditions.



Source: Wise RTD portal, www.wise-rtd.info

Figure 12.1 *The double loop learning cycle with regular planning and learning cycles*

AWM and NeWater project

The NeWater project has focused on the understanding of the changes needed to make water management regimes more adaptive and integrated. The project has produced a number of outputs and short-term outcomes, described in detail see Chapters 2, 3, 5–11 and in particular, the Management and Transition Framework (MTF, see Section 3.8, p67). The MTF is a tool for researchers and practitioners that supports a thoughtful analysis of structure and dynamics of water management regimes. It helps to identify priorities, structure problems and assess solutions to these problems. It can be explained as a 'double-loop learning cycle', one which combines regular planning activities (e.g. the sequence of planning steps according to the Water Framework Directive) with a learning cycle. As shown in Figure 12.1, the MTF encourages system thinking and process management. The 'double loop' comprises a regular planning cycle (upper cycle in the Figure 12.1), and an adaptive learning cycle (lower cycle), aiming to instigate learning experiments.

The key to AWM is social learning (see Section 1.5, p.11) and collective (community) management of water resources (Maurel et al, 2007; Pahl-Wostl et al, 2008). Social learning is portrayed as group learning processes (Armitage et al, 2007) with three depths: (i) single loop learning is '*identification of alternative strategies and actions*', (ii) double loop learning/reframing means '*challenging existing worldviews and underlying values*' and (iii) triple loop learning/transforming refers to '*directing attention to the norms and protocols upon which single- and double-loop learning are predicated or governed*' (Armitage et al, 2008).

Please note that the reason behind starting a learning cycle is the recognition that the available evidence is inconclusive, and thus the policy response is a matter of public dialogue and deliberation.

12.2 How AWM can contribute to implementation of water policies

What is the minimum level of environmental flow which the river ecosystem can endure without being seriously damaged during the low water stages in summer? How much water should be released from the reservoirs before major rainfall events and will that amount of water not be missed in the dry period thereafter? Will the levees stand the high river stages? How to best manage groundwater water bodies when in many places limited information is available?

These are just a few examples of situations in which persistent uncertainty characterizes policy options. Choices have to be made which may lead to loss of life, substantial material damages or degradation of invaluable ecosystems.

AWM and the Water Framework Directive

The systematic, forward-looking planning process of the Water Framework Directive (WFD) and the periodic revision of the river district management plans can provide 'a powerful adaptive management tool' (EEA 2007, p27).

Indeed, the WFD has been used as an example for other sectors and initiatives addressing global environmental changes.

However, the scale of the challenges is high and the forward-thinking provisions of the WFD may not be exploited as the Member States struggle with the tight implementation of time schedules and labour through the novel policy instruments. The need to adopt more flexible and adaptive management strategies has received major attention with the increased awareness for the impacts of climate change.

Climate change may alter biological, chemical, hydrological and quantitative parameters which determine the ecological status or which underpin the reference conditions against which the ecological status is assessed (EEA, 2007). If these changes are not taken into account, then a good ecological status will not be met and reference conditions relying on historical analogy will provide no benchmarks for measuring efficiency and effectiveness of implemented measures. The Article 5(2) of the Directive thus foresees a periodic update of reference conditions and the instalment of a monitoring system which is able to detect relevant changes and apposite revision of management plans.

The WFD allows for a number of exemptions such as the extension of deadlines, less stringent objectives, and in well justified situations, quality status deterioration as a result of natural or human cause. These exemptions allow policy makers to weigh in uncertainties (including those associated with future climate impacts), technical feasibility, costs and benefits, i.e. policy factors beyond scientific rationalization. However, the use of these adjustments will need to be justified – more specifically, the decision-making process will have to be well informed, transparent and inclusive and less burdensome alternatives should be explored first (CIS, 2007; WD, 2008).

The repetitive WFD planning cycle (six years) allows for a continuous review of management decisions and adjustments of policy decisions, if needed. AWM can provide guidance for 'doing things better', e.g. by reducing water consumption or improving irrigation efficiency. But AWM can also help to find how to 'doing better things ', e.g. to adjust crops to future rain patter.

Can AWM be used to address climate change incorporated in the Floods Directive?

Floods are natural phenomena which cannot be prevented (EC, 2007) but whose adverse impacts can be reduced, sometimes significantly so. The Directive on the Assessment and Management of Flood Risks (hereafter Flood Risk Directive, FRD) has addressed these risks. AWM is instrumental in increasing social and economic resilience of communities in flood-prone areas. Although the practical meaning of resilience and other definitions[1] have yet to be translated into measurable and enforceable terms, the systems' ability to withstand the hazard, to learn how to protect themselves and to re-organize, so as to continue, are pivotal to up-to-date flood management.

The Flood Risk Directive builds on and specifies in more detail some provisions of the WFD. The purpose is to establish a framework for the assessment and management of flood risks, reduction of adverse consequences on human health, the environment, cultural heritage and economic activity in the European Community. Effective management of flood risks requires a proper implementation of a chain of activities, which includes both technical-engineering and social aspects to be integrated and to complement each other. Flood resilience ties in with the community's awareness of risk and its preparation in the event of flooding.

The Directive obliges the Member States to assess flood risks and to produce maps of areas subject to floods of different intensities. The risk assessment is to inform adequate and coordinated management measures to protect assets and humans in flood-prone areas. In this context, AWM has much to offer in terms of system thinking, for example by providing room for the river and including a reflection on the need for reframing and even the transformation of infrastructure conditions, rules, etc. Still, a major challenge is to ensure that the Flood Directive is closely integrated with the WFD. AWM offers the opportunity to introduce adaptive flood management, one of which is primarily based on the understanding of vulnerability and resilience.

12.3 Lessons learned and practical suggestions

In Chapter 3 (pp 17–34) we described the lessons learned from the NeWater case studies. Here, we extend these lessons into suggestions (if not recommendations) and take-away messages on what needs to be done to put the AWM principles in place.

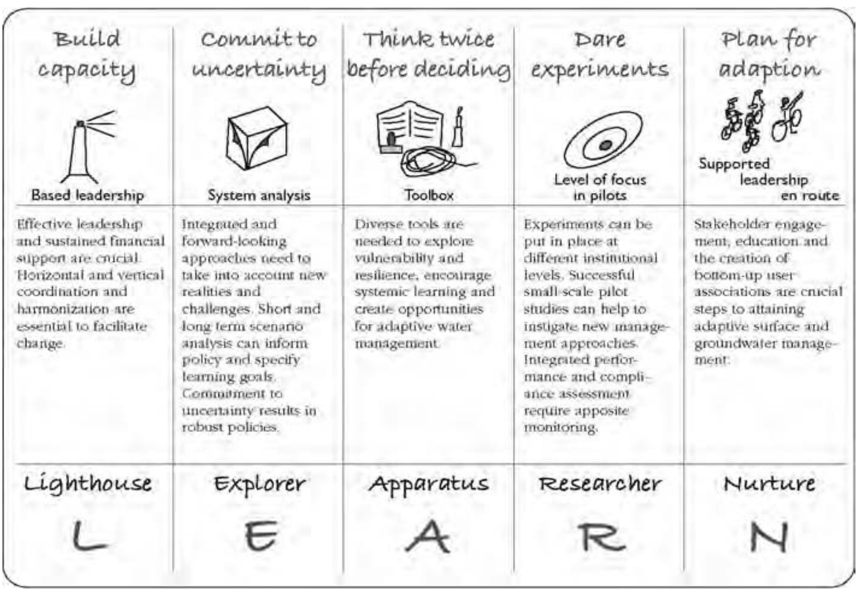


Figure 12.2 *Metaphors and lessons learning from piloting AWM in NeWater case studies*

Recommendation 1 Enabling environment and capacity building

It is unrealistic to expect that the implementation of the AWM principles will be smooth and straightforward. One might rather expect to meet similar obstacles to those identified in the efforts to put IWRM in place.

The experimental character of the adaptive policies will require regulatory flexibility, or more specifically the discretion to tighten or relax the rules and policy provisions to fit local circumstances. The exemptions granted by the WFD provide this type of flexibility, at least in theory. The wider discretion of the water authorities however will need to be balanced by greater public oversight, in order to ensure that the flexibility does not taint the lack of response and so that uncertainty is not used as an excuse to deter action (Doremus, 2001).

Secondly, engaging in learning experiments and meaningful public dialogue will require time and financial commitments. Unless sufficient resources are devoted to capacity building and public engagement exercises, it will be difficult to implement AWM.

As shown in Chapter 4, training and capacity-building play important roles in realizing an AWM: capacity to fully exploit the given mandate, build skills (know how), and deploy resources. In NeWater, a demand-oriented training, train-the-trainer, broker and train-the-practitioners concepts worked well, as did demonstration projects. Similar principles could become a basis for broader training programmes, targeted to different administrative levels and public interest groups. The ability to create social learning, propel trust and ensure ownership to ideas and processes is paramount to AWM. The Guadiana case study (see Chapter 6) demonstrates how different perceptions of the issues at stake can obstruct consensus. Social learning exercises conducted by the case study team which engaged various stakeholder groups helped to dispel disagreements on the facts (what is or will be) and understand the values in question (what ought to be). They also helped the participants to better appreciate the positions of others, crystallize shared beliefs and achieve a collective understanding of the water issues faced.

Recommendation 2 Commit to uncertainty

Commitment to uncertainty means that uncertainty is addressed openly in a transparent and accountable manner. The first and least controversial step in doing so is to acknowledge the major uncertainties and their implications on policy. Concealing uncertainty for whatever reason is not reconcilable with scientific norms or with principles of good governance. The second step on the ladder of difficulty is to describe the uncertainty in quantitative or qualitative terms, and explain their origin, causes and magnitude, in a way which is accessible to various stakeholders without scientific training. It is important to describe what is known together with what is unknown; a lopsided focus on uncertainty alone can occasionally mask the substantial body of available knowledge (Rosenberg, 2007).

The third step is to decide what course of action is the most reconcilable with our knowledge and expectations with what the future might bring. These choices manifest values held and are a matter of public debate and conciliation. One of the possible responses to uncertainty is to decide not to take any action until more and better knowledge is collected. There are however, two aspects to bear in mind: firstly, postponing decisions is often associated with costs which may outweigh the benefits of dispelled doubts; and secondly, improved knowledge does not necessarily mean uncertainty will be reduced. A proactive take on uncertainty is possible by hedging against adverse future outcomes, or by deploying a range of complementary policy measures. Adaptive management handles uncertainty, for example, by creating flexible and robust solutions that are able to adapt to unknown, unexpected or changing conditions. The type of solutions sought are those which can work in a range of future conditions, or ones which can be successively adjusted and corrected as new knowledge is gained.

In the Guadiana case study (see Chapter 6), the Bayesian Belief Networks (BBN) helped stakeholders to retain control over the conceptual design of the model used for policy assessment, while at the same time uncertainty was represented in a way that made it easier for non-experts to understand its meaning and implications.

Recommendation 3 Think twice before deciding

Even a well-designed and intentioned policy can trigger unintended consequences or be cancelled out by unforeseeable events. A recent example is the biofuel policies now blamed for high food prices and increased tropical deforestation (see Note 1 below).

Under AWM it is essential to examine the potential corollaries and ancillary effects of policy choices. Many techniques are available for this end: foresight pursuits ranging from prediction to pragmatic speculation, scrutiny of out-of-sight feedbacks, deliberative exercises, etc.

From the outset, the possible adverse consequences and surprises can be matched with corrective mechanisms. Where this is not practical, policy response can be split into a series of sequential commitments, implemented incrementally and reversed when the setbacks become evident, as in the case of the EU biofuel policy.

Group model building (see Section 3.2, p 39), vulnerability assessments (see Section 3.5, p 53), Management and Transition Framework (Section 3.8, p 67) and other tools described in this book and elsewhere facilitate a thoughtful policy analysis and systemic learning targeted at vulnerability, adaptive capacity, resilience, and other key aspects of AWM and the transition processes.

Recommendation 4 Dare experiments

The policy experiments are learning-by/while-doing exercises. They may take different forms such as pilot projects, community-based management and stewardship, conditional permits, voluntary commitments, public communication campaign, etc. All of them need to be based on well-defined and implementable learning objectives, and clear and measurable outcomes. However, once concluded, a post-audit review should address all impacts, including those for which the experiments were not initially designed.

The experiments, by definition, may fail to deliver the expected results. This needs to be taken into account when setting up the experiment; where failure may harm the resources beyond repair, the experiments are not the best methods to pursue. The experiments should therefore be planned so as to encourage sustained participation of various actors, and to instigate a spirit of collaboration, ownership and trust. As the experiments will demand substantial resources and time, it is important to share the insights and knowledge gained from the experiments.

On the other hand, experience and practice, even if scattered with a few errors, are necessary to make an expert.

Recommendation 5 Plan for adaptation

Planning for adaptation means to identify the conditions under which the policy has to be revised in advance – i.e. reversed, adjusted, strengthened or complemented by additional measures. This revision can be scheduled – for example, the WFD planning cycles are to be renewed every six years, or initiated after the agreed performance indicators have reached a critical value (e.g. when it becomes clear that the good ecological status cannot be achieved, or will deteriorate, in the current planning period).

Enforcement and compliance monitoring systems, which are essential under any accountable management approach, are even more important under the AWM. The indicators of short-, medium- and long-term performance of adaptive policies are instrumental for policy monitoring, and transparency and accountability to the respective authorities. To design the useful indicators and monitoring systems is not an easy task, it is important to ensure that the monitoring does not turn into disproportional administrative burdens. Section 3.4 (p47) addresses the various approaches and issues encountered when designing indicators and monitoring systems for the AWM.

AWM requires larger investments into the monitoring of hydrological characteristics of the basin, measuring the links between climate, land use, groundwater and surface water systems and wetlands, and assessing the performance of economic, social and environmental indicators. In order to properly design, evaluate and adjust these types of monitoring programmes, the integration of modelling that allows a proper evaluation of the status of interacting groundwater and surface water systems is needed.

Notes

1 Alternative definitions of resilience exist. The IPCC Fourth Assessment Report (IPPC, 2007) understands resilience as 'the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of

functioning, the capacity for self-organization, and the capacity to adapt to stress and change'. The earlier IPCC report (Houghton et al, 2001) instead described resilience as 'ability of a system to return to a pre-disturbed state without incurring any lasting fundamental change. Resilient resource systems recover to some normal range of operation after a perturbation'. Yet another definition is provided by Arrow (1995), one of the most cited papers in resilience field: '[resilience is] measure of the magnitude that can be absorbed before a system centred on one locally stable equilibrium flips to another'.

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