# Adaptive Water Management: Strengthening Laws and Institutions to Cope with Uncertainty

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## Introduction

We live in a complex world full of uncertainty. This is particularly true of hydrological systems and the myriad other factors affecting water management. The nonlinear nature of the hydrologic cycle is well documented (Gleick, 1987; Lewin, 1992; Nonlinear Processes in Geophysics, 2006; Ruhl, 1997). As the debate on climate change and climate change models illustrates, it can be notoriously difficult to develop models that accurately reflect the hydrologic cycle and the factors that affect it, even when phalanxes of the world's leading scientists and computer modellers focus their attention on the task (IPCC, 2007a).

Demands on water are increasing and evolving (Varis, 2006; Gleick, 2000). Many countries have burgeoning population growth, and most are experiencing changing population dynamics as vast numbers of people move to urban centres, often clustered along coastal areas. Moreover, an overriding emphasis on economic development – and the accompanying changes in commercial and industrial demands on water that this implies – contributes to the shifting demands in water needs (Varis, 2006; Gleick, 2000). The laws, policies and institutions in place for managing water resources, however, often reflect historic uses and needs and employ outdated management approaches (Biswas, 2006; MacKay et al. 2003; Pahl-Wostl et al. 2005).

As available water resources become overdrawn and stressed, water quality problems are becoming more acute. With less water flowing, the effects of sewage, urban runoff, industrial chemicals and wastes, and agricultural fertilisers and pesticides are felt more acutely: dilution is no longer a reliable solution to pollution. While political attention from time to time focuses on the reduced quantities of available water (and the concomitant struggles over water allocation), rarely does this attention focus as keenly on water quality. Yet, it is likely that many countries will face water quality problems long before water quantity becomes a significant issue (Biswas, 2006).

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These challenges are not new. For years, development planners and water managers have modelled and planned for population and economic changes in the water sector, as well as other sectors (energy, transportation, etc.). Politicians, managers and the public have become increasingly aware of – and often tried to account for – environmental considerations over the last few decades. Despite this, the laws, policies and institutions governing water and other environmental media have generally failed to keep pace with increasing demands. The Millennium Ecosystem Assessment found that approximately 60% of the ecosystem services upon which people around the world depend have been degraded or unsustainably used (MA, 2005). Over a billion people throughout the world continue to lack access to safe water sources, and 2.6 billion live without access to improved sanitation services (WHO/UNICEF, 2006).

Enter climate change. Climate change dramatically complicates the existing complexity and uncertainty that planners and managers have faced over the years. Climate change and climate variability render the entire situation more uncertain and difficult to manage. Better planning and management can enhance resilience to uncertainties in water quality and availability (this is sometimes referred to as "anticipatory adaptation") (Burton et al. 2006; Hansen et al. 2003). However, there is a growing consensus that climate change will entail significant variations in the amount and timing of precipitation, changes that are potentially dramatic or even catastrophic (Adger et al. 2007; Alley et al. 2007; IPCC, 2007a,b; Kabat and van Schaik, 2003; Arvai et al. 2006; USEPA, 2007a,b; Combes, 2003). Unfortunately, there remains significant uncertainty about the precise parameters of the location, timing and quantification regarding such changes at the regional, national and local levels. In some regions, the baseline data are so sparse that the climate change scenarios, let alone the precise implications of those scenarios, remain skeletal (Alley et al. 2007). Moreover, increasing temperatures are expected to increase water demand, for example for agriculture (Al Sairafi, 2006).

Management constraints also give rise to uncertainty. To the extent that countries have developed water laws or other environmental laws, many have yet to implement or enforce those laws effectively. So, in many instances, the feasibility and appropriateness of the current legal and institutional responses are at best uncertain. There are many reasons for the limited implementation and enforcement to date. Depending on the particular context, the reasons may include lack of financial, personnel and technical resources; lack of political will; corruption; lack of awareness by the regulators and the regulated community; and laws that are perceived as not being realistic (Zaelke et al. 2005; Kranz et al. 2005b). As a result, there often is significant uncertainty about how effective particular laws and institutions may be over the short or long term. Management is further complicated by the limited information available upon which to base decisions, as well as sensitive international politics associated with water management, particularly of shared water courses.

Despite the complexity and uncertainty inherent in water management, including as a result of climate change, there are immediate and pressing needs that must be met that require managers to make important decisions now. People need water for drinking, to grow food, for industrial and commercial purposes, and for recreation;

delaying decisions on the use and allocation of water until comprehensive studies are conducted would allow for continued unsustainable development and uses for years, further prejudicing the range of options. Similarly, it is not feasible to have a full understanding of the potential impacts of climate change before determining how best to adapt to those impacts (NRC, 2004; Hansen et al. 2003). Indeed, considering the nonlinear and complex nature of the hydrologic cycle and the socio-economic factors affecting water use (Gleick, 1987), such studies would never be able to predict accurately the long-term water needs, availability of water resources, or the specific legal and institutional responses that would be appropriate. Even if it were possible to understand and model perfectly the science of the different non-linear physical, biological and socio-economic factors affecting water availability and use – not to mention the interplay among those factors – their sensitivity to initial conditions makes long-term predictions problematic (Gleick, 1987; Ruhl, 1996; Hornstein, 2005).

Indeed, it was attempts to model weather patterns – and the discovery of its non-linear nature – that led to the birth of nonlinear dynamics, more popularly known as chaos theory (Gleick, 1987). One hallmark of nonlinear dynamics is that the slightest changes in physical conditions can yield different outcomes as those differences increase exponentially. Meteorologists analogised this to a butterfly flapping its wings in Hong Kong that could cause a tornado in Kansas, the so-called butterfly effect. Thus, in a nonlinear system, it is not enough to understand the laws perfectly governing the system; in order to make long-term predictions it is also necessary to have perfect knowledge about the current conditions (including what all the butterflies are doing). This is impossible. This also means that the best that one can hope for in long-term predictions are general trends.

Adaptive management provides a framework for governing water resources in a way that can account for the various uncertainties described above (Holling, 1978). Indeed, "there is broad consensus today among resource managers and academics that adaptive management is the only practical way to implement ecosystem management policy" (Ruhl, 2005). To be certain, climate change is driving much of the resurgent interest in adaptive management (consider, e.g., the dramatic growth over the last few years in the legal literature on adaptive management). However, even if climate change were not an issue, other uncertainties compel consideration of adaptive management for water resources (Neuman, 2001).

In brief, adaptive management – including adaptive water management – is an ongoing, iterative approach that seeks to "learn by doing" (Lee and Lawrence, 1986; Doremus, 2001). This includes:

- The development and adoption of a provisional legal, policy, and institutional framework
- Ongoing monitoring and collection of information
- Periodic assessment of the collected information (to determine the effectiveness of the laws and institutions)
- Modification of the legal and institutional frameworks as appropriate
- Continuing the management cycle of monitoring, assessment, and revision

Adaptive water management thus entails integrating legal and institutional approaches for managing water resources (including water allocation and pollution control), monitoring, modelling, assessing the outcomes of those management approaches, and updating and revising management decisions according to this process. As such, the legal and institutional frameworks at different levels – basin, national, local and project – need to be structured to account for the various uncertainties.

While water managers are often familiar with the principles and operation of adaptive management, most legal and institutional frameworks governing water resources have yet to incorporate specific adaptive management tools and processes. There frequently are disconnects between changing conditions and established legal and institutional responses (Ruhl, 1997): if the context is not static, why should the legal framework be static? Indeed, "stationarity is dead and should no longer serve as a central, default assumption in water-resource risk assessment and planning" (Milly et al. 2008). In many cases, legal frameworks include some of the requisite tools, including monitoring and assessment (e.g. through state-of-the-environment reports). However, these tools are generally inadequate for effective adaptive management. There is rarely any recognition in current frameworks of the necessarily provisional nature of laws and institutions, or of the associated iterative process that defines adaptive water management. Moreover, the tools that do exist tend to operate independently and are not contextualised in a broader rubric of adaptive management. What remains to be done is to put the pieces together.

This chapter examines the basic components of legal and institutional frameworks for adaptive water management. It then surveys experiences in adaptive water management from different regions and contexts. This chapter concludes with some thoughts on the future for adaptive water management, including three sets of activities to facilitate the transition to an adaptive legal and institutional framework: (1) collecting and sharing experiences to date in adaptive water management; (2) implementing pilot projects to test modalities and the extent to which approaches may be adapted to other contexts or scaled up; and (3) building capacity to develop and operationalise legal frameworks that facilitate adaptive water management.

## Legal and Institutional Frameworks for Adaptive Water Management

Adaptive management recognises that there will never be complete knowledge about environmental dynamics, impacts of proposed activities, or future demands, and that many aspects will only be understood through experience, including experimentation (Walters, 1986). The lack of knowledge can be dizzying:

> …as we know, there are known knowns; there are things we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns – the ones we don't know we don't know (Seely, 2003).

Among the unknown unknowns are those things that we think we know that actually are not so. Adaptive management provides a framework for managing in light of this precarious state of (un)knowledge.

The conceptual framework for adaptive management is fairly basic, whether articulated in legal frameworks, institutional mandates or management practices. Within a particular context or problem, the initial response is developed; this may be a law, regulation, policy, permit, and so on. This response is understood to be provisional, due to the limited information that is available (Blann and Light, 2000). Once adopted, the provisional response is then implemented. This step – implementation – is the final stage for most ongoing environmental management efforts. In adaptive environmental management, however, the next step is to monitor progress towards the goals of the provisional response. Monitoring this progress entails the development and application of input and output indicators (Karkkainen, 2002; NRC, 2004; Schueller et al. 2006; Ralph and Poole, 2003) over a timeframe that is sufficient to measure the effects of a particular intervention. Periodically, managers and decision-makers take stock of the monitoring results to assess the extent to which the measures are having the intended effects, whether there are unintended effects, and whether other factors are unexpectedly affecting the outcomes. Ultimately, this periodic assessment seeks to identify whether further action is necessary (or whether the current response is adequate) as well as the nature and scope of any further action. The final stage is the modification of the initial intervention, based on the assessment; then the cycle continues with further stages of implementation, monitoring, assessment and revision.

Adaptive water management can be applied in different contexts. It may apply to the legal framework, with periodic assessment and revisions of laws and regulations governing water resource. Alternatively, it may apply within the legal and regulatory framework, for example to licenses, permits and management plans. Adaptive water management can improve long-term management of water quality and water quantity, as well as integrated management of a range of water resources. The section on "Experiences in Adaptive Water Management" surveys experiences from different contexts that may inform adaptive water management efforts.

In the three decades since Holling's seminal publication on adaptive management (Holling, 1978), the broad conceptual architecture of adaptive management has remained intact. There have been many subsequent formulations, which range along a spectrum from "active" to "passive" adaptive management (Walters, 1986; Karkkainen, 2005). Active adaptive management entails "deliberate probing for information" through experiments that test particular hypotheses. Passive adaptive management is, on the other hand, "a simpler process involving heightened monitoring of key indicators, leading to subsequent adjustments in policies in light of what may be learned through careful observation and data generation" (Karkkainen, 2005). Passive adaptive management starts with the selection of the option that is deemed the best based on existing data, and modifications are made as more information becomes available. "Evolutionary" adaptive management entails trial and error, in which random experiments and experience gradually informs understanding (Walters and Holling, 1990).

## *Adaptive Management and IWRM*

While adaptive management is increasingly recognised as an important aspect of integrated water resources management (IWRM), it has a distinct pedigree and conceptual framework (Pahl-Wostl and Sendzimir, 2005; Medema and Jeffrey, 2005). Adaptive management was initially developed in the late 1960s by Holling and his associates, who used experimentation to understand better the dynamics and functions of specific ecosystems (Gunderson et al. 1995; Cannon, 2005). It has since evolved from use in managing land and forest resources to water resources management. In contrast, IWRM has evolved over the last century to become the dominant paradigm for water management (Rahaman and Varis, 2005).

Adaptive water management and IWRM share a number of goals and concepts, including management at the basin or watershed level and consideration of the ecological system as a whole. However, the two management paradigms are distinct. IWRM is often advocated as a politically feasible approach to managing water resources, and the practice of IWRM does not necessarily incorporate science into the management process (Pahl-Wostl and Sendzimir, 2005). Monitoring is often limited and passive, making science-based periodic assessments and revision difficult (Pahl-Wostl and Sendzimir, 2005). Moreover, while adaptive management focuses specifically on how to deal with uncertainty, IWRM generally does not explicitly focus on this issue (Pahl-Wostl and Sendzimir, 2005; Medema and Jeffrey, 2005).

Notwithstanding these differences, adaptive water management and IWRM are compatible. Indeed, to the extent that IWRM is pursued as a framework for managing a particular waterbody (Biswas, 2004), IWRM can provide a context for adaptive water management, and adaptive water management – and its emphasis on scientific monitoring, assessment and iterative revision – can serve as an essential component necessary to achieve the goals of IWRM (Kabat et al. 2003).

## *The Role of Law in Adaptive Water Management*

Laws and regulations have a critical role to play in supporting adaptive management, for example by providing the underlying mandate for monitoring, public involvement and periodic revision (Kranz et al. 2005a). However, legal, regulatory and administrative frameworks can also hinder the application of adaptive management (Ruhl, 2005; Doremus, 2001; Coleman, 1998). In the United States, the Administrative Procedure Act (APA) and the National Environmental Policy Act (NEPA) have been interpreted and applied to focus on front-end planning while discouraging mid-course modifications. Professor Ruhl has argued that Habitat Conservation Plans (HCPs) under the U.S. Endangered Species Act (ESA) had their adaptive management features removed through procedural rules that form the basis of the APA (Ruhl, 2005), although HCPs may not have been particularly adaptive in the first place (Karkkainen, 2005). More broadly, while the ESA is conducive to adaptive management, the law is not specifically structured to enable –

let alone require – the use of adaptive management (Ruhl, 2004). Two recent U.S. cases involving NEPA further highlight the challenges of implementing adaptive management where there is no enabling legal environment defining the contours for applying adaptive management. An attempt to introduce adaptive management in the management of the Missouri River – which would help species recover but might affect navigation, power generation and flood control – was permitted as long as the adaptive management was consistent with NEPA; the Army Corps of Engineers conceded that if adaptive management led to a "major" policy change, it would undertake the time-consuming process of a supplemental environmental impact statement (In re Operation, 2005). In another case, a U.S. court invalidated a management plan for the Sawtooth National Forest that relied on adaptive management, but failed to provide sufficient details regarding its procedures, objectives or operation (Western Watersheds Project, 2006). Moreover, administrative conflicts can arise between historic top-down decision-making processes and adaptive management processes that adjust actions based on new information (Thrower, 2006). In order to provide a clear mandate for adaptive management and remove administrative, legal and regulatory barriers, Ruhl has proposed a National Adaptive Management Act, akin to NEPA since "there is good reason to doubt whether regulation by adaptive management is possible without substantial change in the administrative law system" (Ruhl, 2005).

In areas where the doctrine of prior appropriation governs the allocation of water, such as the American West, climate change threatens to cut off, rather than curtail, water consumption by junior users. In most instances, these are urban and commercial uses, which are more recent than the initial agricultural claims, although many municipalities now hold senior rights that they acquired from agricultural users. As Professor Neuman observed:

> The prior appropriation system was designed to cope with short-term shortages of the type common only in the last century. Current law is just not up to the task of handling truly severe long-term changes, such as widespread multi-decade drought, without drastic and unacceptable economic dislocations for everything from agriculture to municipal supply (Neuman, 2001).

With the very real prospect of long-term, if not permanent, changes in precipitation associated with climate change (Adger et al. 2007; Alley et al. 2007; IPCC, 2007), there is a strong need to revise legal frameworks governing water to ensure that they become more adaptive and proactive in promoting resilience to climate variability and change.

Many of the limitations in existing legal frameworks are a function of their reliance on an equilibrium-based understanding of ecosystems (Tarlock, 1994; Profeta, 1996). With the development and maturation of nonlinear dynamics and complexity theory, this understanding has been discredited (Neuman, 2001; Ruhl, 2005). At the same time, managers and regulators have experimented with new approaches, often in spite of legal frameworks. In some instances, success in incorporating adaptive management practices has led to subsequent legal or regulatory reforms, as with the development of licensing procedures for federally licensed hydropower dams in the United States (Bruch et al. 2007). Some of these experiences

are discussed in the next section. These experiences demonstrate ways in which legal frameworks will need to be modified to manage actively and adaptively water resources in ways that account for new scientific understanding of ecosystem dynamics and the uncertainties wrought by climate change.

## Experiences in Adaptive Water Management

Over the last few decades, there has been a growing body of experience in adaptive water management. These experiences have sought to improve management of water resources to enhance water quality and water quantity, fisheries, and consumptive and nonconsumptive uses. Most experiences to date have been in developed countries, but there are a number of initiatives underway to introduce adaptive water management in developing countries (Kranz et al. 2005a,c).

### *U.S. Clean Water Act*

The U.S. Clean Water Act takes a phased approach to improving and maintaining water quality of the country's navigable waters (USEPA, n.d.; Gross, 2006; Houck, 2002). Initially, the act focused on reducing pollution from point sources, such as pipes. Companies and other polluters had to comply with technology-based effluent limits (with the control technologies becoming progressively more stringent) set through a national permitting system, which states could administer. It was assumed that, in most cases, such regulation would be effective in achieving the water quality goals of the act (Percival et al. 2006). In some cases, though, there may be too much effluent, not enough flow, or too much nonpoint source pollution. To provide a "safety net" for such contingencies, the act also required monitoring of ambient water quality to determine which water bodies are "water quality limited". The act then provided a process for identifying and prioritising water-quality-limited bodies (and segments of bodies), developing total maximum daily loads of specific pollutants for those water bodies, and translating those loads into permit requirements and other measures (e.g. to address nonpoint source pollution).

The 1972 Act itself has undergone a form of adaptive management through an iterative process of legislative development, implementation, monitoring, assessment, and reform and reauthorisation. As weaknesses in the act became apparent through monitoring and assessment, legislative amendments sought to address those gaps. For example, the 1977 Amendments greatly strengthened the 1972 Act; the 1981 Amendments streamlined the process for grants to build municipal treatment plants; and the Water Quality Act of 1987 inter alia phased out the grants programme and replaced it with a revolving fund. This series of amendments reflects an evolving understanding of the challenges in U.S. water management and the measures necessary to effect the desired objectives.

## *Murray-Darling River Basin*

The Murray-Darling river basin in Australia is home to one of the largest integrated catchment management programmes in the world, covering an area of more than 1 million $km^2$. This programme has integrated an adaptive management approach within the broader framework of IWRM. The basin managers have recognised that decision-making "cannot wait for perfect knowledge"; rather, it is necessary to "make decisions on the best available information, and continuously improve knowledge" (Murray-Darling Basin Ministerial Council, 2001). Accordingly, the Murray-Darling programme has identified interim management targets. As the basin authority pursues those targets, it continues to monitor the status of the basin (indeed, climate change may reduce flow by 10–35% by 2050 (Pittock and Wratt, 2001)), evaluate progress in implementation every 3 years based on the monitoring information, and refine targets and implementation measures as knowledge improves. This initiative is still in the early stages: the basin-wide strategies for setting and managing targets, including the process for reviewing and revising the strategy, have yet to be developed.

The Murray-Darling experience is significant for a few reasons. First, adaptive management in the Murray-Darling basin is being implemented as a matter of policy, rather than law: there is little reference to legislation or legislative requirements. Moreover, despite the scarcity of water resources in the region (or perhaps because of the scarcity), the basin organisation is "prepared to change direction (every 3 years) on the basis of this (new) information" (Murray-Darling Basin Ministerial Council, 2001). Flexibility is not only authorised, but mandated. Finally, the geographic scale and scope of topics included in the adaptive water management scheme is extensive.

## *U.S. Hydropower Dam Licensing and the Clark Fork Project*

Decisions regarding the licensing and relicensing of hydropower dams are often made with imperfect knowledge regarding the impacts of the dams or the effectiveness of potential mitigation measures. Since dam licences may be valid for 40 years or longer (in some countries dams are granted a permanent licence), it is particularly important that the legal and regulatory framework accounts for uncertainties in the implementation of those licences. Adaptive management provides a dynamic approach to reaching certain goals by periodically monitoring progress towards that goal and making adjustments as necessary. This necessarily entails a long-term commitment to monitoring and evaluation.

In the United States, adaptive management is being incorporated into dam licences, especially for environmental and social protection, mitigation and enhancement measures. Licences incorporate adaptive management approaches (including licence amendment procedures) to account for changes in information, technology, management practices, and context (e.g. socio-economic demands and climate

change) over the term of the licence. These provisions allow licensees to adapt to changes while remaining in compliance with their licence.

The relicensing process of the Clark Fork Project in the 1990s established the Living License™, which promotes ongoing problem solving through adaptive management (Bruch et al. 2007). While the impacts of the existing dam were known, the most effective means for mitigating those impacts were unclear. An adaptive management approach provided a framework for testing different measures to see which would be the most effective and then scaling them up. Accordingly, the licensee initially implements those measures that seemed the most likely to succeed. A management committee and technical advisory committees then evaluate the effectiveness of these initial measures using the monitoring programmes established through the settlement agreement. Based on the results of these evaluations, the measures are fine-tuned or replaced, after approval by the Federal Energy Regulatory Commission (the licensing authority). A committee of signatories to the agreement – the management committee – meets biannually to monitor the operation of the dam and determine whether it is complying with the various measures of its licence. If there is noncompliance, operational changes are made with the committee's input and direction. The initial results of this adaptive management approach are promising, including improved habitat for bull trout and successful mitigation of other negative impacts of the dam.

A growing number of U.S. dams have incorporated similar adaptive management provisions into their licences (Bruch et al. 2007). These include, for example, the St. Lawrence-FDR Project (Suloway, 2006), the Pelton Round Butte Project (PGE, 2006), and Glen Canyon Dam (USBR, 2001).

## *Other Experiences*

Managers of other aquatic ecosystems – including the Columbia River, Florida Everglades, Platte River, the North American Great Lakes, Okavango Delta, and the San Francisco Bay-Delta – have also attempted to implement adaptive management (Lee, 1993, 1999; Volkman, 2005; Farber and Freeman, 2005; Anderson and Hamman, 1996; Platte River Recovery Implementation Program, 2006; Ashton et al. 2005; Cannon, 2000; Karkkainen, 2006). Despite the availability of funding and technology, these efforts have had mixed results. For example, an initiative to manage adaptively the Columbia River devoted most of its time and resources on modelling of the river, rather than on adopting a truly iterative approach (Volkman, 2005). The restoration of the Everglades has been criticised for using a passive approach to adaptive management, in part due to the current regulatory framework (NRC, 2003; Anderson and Hamman, 1996). Similarly, the CALFED programme to manage the San Francisco Bay-Delta has suffered from monitoring gaps, for example, regarding the status of the endangered Delta smelt (Ruhl, 2004).

More productive efforts at implementing adaptive management have included the state of Oregon's response to the dramatic decline in anadromous fish in the

state's waters. To mitigate this problem, the state government developed the Oregon Plan for Salmon and Watersheds (Oregon Plan n.d. a). This plan relies on active adaptive management to test hypotheses through management action, learn from the experiences, and then amend policies and management practices. Execution of this plan relies on an iterative process of planning, action, and monitoring, with strong scientific oversight by an Independent Multidisciplinary Science Team. Although the initiative is essentially non-regulatory, a series of state laws and other regulatory measures was necessary to establish it and keep it operating (Oregon Plan n.d. b).

The Netherlands national strategy for adaptation to climate change identified water as the sector that will be most affected by climate change. These effects include those related to sea level rise, river discharges, groundwater, storms and droughts (Leusink, 2006). To respond to these threats, the country is undertaking a number of legal and institutional reforms, including changes to physical planning rules so that land use follows the natural systems, as well as developing a revolving fund to support "climate proofing".

There is a rich body of experience – some effective, some problematic – from wildlife and fisheries management (Williams et al. 2007; Mitchell et al. 2005; Ruhl, 2004; Parma et al. 1998; Garaway and Arthur, 2002; Meretsky et al., 2000; Smith et al. 1998; SPU, 2005), forestry management (Thomas et al. 2006; Bormann et al. 1994; Brunner et al. 2005; Carden, 2006), land management (Doremus, 2001; Moir and Block, 2001), land conservation (Greene, 2005), aquatic ecosystem restoration (Tarlock, 2006), air quality management (Shaver, 2006) and even international trade (Cooney and Lang, 2007) that can inform the development of legal and institutional measures to manage water resources adaptively. These experiences include those in which adaptive management was mandated by law, where it was conducted within the legal framework (although not explicitly required), and examples of where adaptive management was undertaken notwithstanding gaps or impediments in the legal framework.

## *Status of Adaptive Management in Water Laws*

Many elements of adaptive water management currently exist in the water laws and institutions of several countries; however, they usually are not contextualised in an integrated manner necessary for adaptive management. Accordingly, the existing elements may provide a framework upon which to build in adaptive water management, although they do not operate in a complementary or synergistic manner. For example, monitoring often focuses on compliance and enforcement, rather than on identifying how and why management approaches are or are not achieving their goals (although there may be some monitoring on the status of water resources). Monitoring is rarely structured to create a basis for subsequent actions. Similarly, many laws provide for periodic state-of-the-environment reports (UNEP n.d.); however, these assessments do not necessarily feed into a process for reforming the legal or policy framework. Most laws and regulations do not provide for periodic

revision, the linchpin of adaptive management. Since water laws often are based on an equilibrium model of the ecosystem, policymakers engage in a two-step process of developing and implementing water law, without questioning whether the law and institutions are still appropriate and capable of achieving their policy goals, let alone gathering information to answer that question (Gleick, 2000). People are still searching for "silver bullets". What they fail to realise is that water management is undertaken in a non-equilibrium world (Farber, 2003; Wiener, 1996; Flournoy, 1996; Tarlock, 2005; Thrower, 2006).

## Future Directions

Integrating adaptive management into water laws, regulations and institutions is imperative. The numerous assessments of the ongoing and potential future impacts of climate change are driving growing awareness of and emerging consensus on the need for adaptive water management. This awareness motivates calls for actions that render communities and ecosystems more resilient and capable of adapting to the effects of climate change, particularly impacts on water resources. The legal frameworks that govern water and other natural resources can impede effective adaptive management, or they can be designed to manage these resources adaptively. However, adaptive management will be effective only if laws and institutions are reformed to address the many challenges before us by incorporating mechanisms for responding to changing information and policy directions in a reasonably flexible and effective manner.

Adaptive management presents numerous challenges to conventional approaches for water resources management. In the United States, the Northwest Forest Plan was the first regional application of adaptive management in the forestry sector (Thomas et al. 2006; Bormann et al. 1994). With more than a decade of experience, this initiative offers some sober thoughts for the future development and application of adaptive management (Bormann et al. 2007). As with other adaptive management efforts – particularly those not based in specific legal requirements – "scientists are most often disappointed in what managers have been able to implement" (Bormann et al. 2007). One of the major impediments to implementation of adaptive management, and particularly testing of alternate strategies, was that "precaution trumped experimentation" as parties were reluctant to experiment unless it was known that there would be no harm. At the same time, Bormann et al. found that monitoring of data was useful in predicted and surprising ways, and managers developed a deeper appreciation of the uncertainties in long-term management of fisheries and other natural resources. Other lessons learned include the importance of framing the issues, allocating effective resources, modifying assessment approaches, difficulties in effective implementation of multiscale management, and challenges in assessing the results of adaptive management due to long timescales. Finally – and of particular importance when considering the importance of a legal mandate – "when elements of adaptive management were treated as core business … they influenced agency decisions considerably more than elements not treated as core business" (Bormann et al. 2007).

## *Changing Perceptions of Change*

Perhaps the greatest challenge for policymakers lies in introducing the concept of living with change (Neuman, 2001; Pahl-Wostl et al. 2005). Changing a legal framework is resource-intensive; changing it to reflect an underlying paradigm of continuous change and response may be all the more challenging. People and businesses seek stability and certainty. Adaptive management may be viewed as introducing a moving target that could undermine investments of time, money and effort. Moreover, constant flux in the legal and regulatory framework may undermine confidence in the law – how can the law command respect and compliance if it may be changed on a regular basis?

In fact, adaptive management and its attendant flexibility are not inconsistent with law and certainty (Hornstein, 2005; Wailand, 2006; Karkkainen, 2003). For example, laws can (and should) provide a normative framework for adaptive management, including clear objectives and priorities to guide water management; while the objectives remain constant, the specific means for achieving those objectives will likely evolve depending on the context, demands, and lessons learned to date. Some scholars have argued that adaptive management should also allow for the revision of specific objectives; it is possible to provide for the revision of specific objectives while maintaining the overall goals (e.g. ensuring water for human consumption and ecosystem services). The legal framework can also prescribe requirements for monitoring, provide a mandate for active adaptive management through testing of hypotheses and mandate periodic assessment of progress to guide future management interventions, including regulatory reform. It may also be possible to require a specific commitment of resources within which there is some flexibility on how to use that commitment (e.g. requiring that a specified amount of flow be dedicated to environmental uses, without specifying the particular uses). The timeframe for the review and assessment should be appropriate to the context. For example, there may be annual assessments of fisheries management to set catch limits as well as assessments every 5 or 10 years, for example, to reconsider the broader normative and management frameworks.

Concerns about change and uncertainty are understandable, but not unique to adaptive management. Businesses operate in a state of constant flux. New products come on the market, competitors challenge a business' niche and market share, there are disruptions in supply, and news about the harms or benefits of a particular product affect demand. All of these effects are largely independent of the regulatory framework. Successful businesses have become adaptive because they must. Indeed, it is not uncommon for businesses to predict dire consequences of a proposed regulatory regime, only to find after it is implemented that the costs are not nearly as serious as predicted (Ackerman, 2006). There is a natural tendency to seek to minimise uncertainty and risk, but when it is necessary, businesses, governments, and others are adaptive and rely on the basic principles of adaptive management (Ruhl, 2005; Hornstein, 2005). Making the legal and institutional frameworks adaptive, then, need not cause a revolutionary shift in how business is conducted.

Similarly, some environmentalists have expressed concern that the flexibility of adaptive management may allow agencies and regulated entities to delay or avoid taking action (Karkkainen, 2003; Thrower, 2006). The concern is that if a law establishes an adaptive framework with multiple options for pursuing broad goals, the flexibility and lack of specific standards or hard obligations could hinder enforcement of the law. This could be problematic, particularly if an agency seeks to undermine environmental protections without actually changing the law or regulations. Without clear, unambiguous requirements, efforts to challenge an agency action or inaction could be deemed to be within the allowed regulatory flexibility. Moreover, planning documents or mitigation measures (e.g. associated with an environmental impact assessment) could broadly assert that an adaptive approach will be followed without providing clear goals, measures or metrics. These are legitimate concerns, and they can be addressed through providing clear goals and metrics for assessing progress, while providing some flexibility in the precise implementation measures. Moreover, ongoing stakeholder oversight can identify and highlight potential abuses of flexibility.

By engaging a broad range of stakeholders in the process of introducing adaptive water management, governments can build awareness of the need for adaptive management and ultimate acceptance of the new legal and conceptual framework (Shindler and Cheek, 1999; Kabat and van Schaik, 2003; Karkkainen, 2006). A broadly participatory process will also enable stakeholders to provide feedback regarding how best to structure and implement adaptive management (Bruch et al. 2007).

## *Governance Structures*

While there are many permutations of adaptive management that can be applied, depending on the particular context, the concept of adaptive management is based on a number of assumptions that may have implications for water governance structures (Pahl-Wostl et al. 2005; Quirk, 2005; Karkkainen, 2006).

Collecting, sharing and analysing data is central to adaptive management, yet transparency and information sharing can pose political challenges in many countries (van Ginkel, 2005; Karkkainen, 2002). Information is power, and there are numerous disincentives to sharing information. Moreover, while there is a great need to improve information collection about water uses and the status of water resources, monitoring entails an investment of financial and technical resources that few countries have made. Indeed, these issues are indicative of broader resource and political constraints that developing countries face in utilising scientific evidence to inform the development and amendment of environmental policy.

Stakeholder involvement is a critical aspect of adaptive management (Norton, 2005; Pahl-Wostl et al. 2005; Kranz et al. 2005c; Stiftel and Scholz, 2005; Carden, 2006). Accordingly, it is important to design governance structures that allow stakeholders to become part of the decision-making process at multiple levels (basin, subunits and locally). Stakeholder involvement can bring additional

information and perspectives to bear, vet proposed decisions and the information upon which they are based, and build support for the outcome which can help in implementation (Bruch et al. 2005; Scholz and Stiftel 2005). A multi-stakeholder process that builds trust among various interests can also alleviate concerns that adaptive management can provide a loophole for individuals or organisations seeking to avoid taking action (Bruch et al. 2007). Mechanisms to ensure accountability and rule of law – including public access to courts – can also help to provide a principled means of ensuring that the law is followed while projects move forwards.

What is the appropriate scale for adaptive water governance? Adaptive management can be practised at a wide range of levels (Mitchell et al. 2005; Walters, 1986; Norton, 2005; Pahl-Wostl et al. 2005), from management of individual salmon runs to governance of international rivers. Adaptive water management similarly can happen at multiple levels, sometimes simultaneously (Karkkainen, 2006). There is often a preference to manage water adaptively at the basin level (Pahl-Wostl et al. 2005; Neuman, 2001); failure to manage on a basin level increases the vulnerability of the management to actions in other parts of the basin that are beyond the management mandate. For transboundary waters, basin-level management can present significant challenges for coordination among countries, agencies and other actors. Failure of an adaptive management plan to incorporate effectively all the subunits (political or hydrological) could contribute to gaps in monitoring and impair the overall assessment and revision processes. Moreover, since implementation measures often rely on local actions, adaptive water management needs to consider the role, effects, incentives and context of local communities (MacKay et al. 2003).

Working at the basin scale can be challenging, particularly in transboundary basins (Kranz et al. 2005a,b). It can be difficult to align basin ecosystem needs with sovereignty and politics and to determine how to incorporate diverse political and socio-economic systems into an integrated management regime (Karkkainen, 2006). The costs of developing and implementing new institutions to manage at the basin level can be significant, and the distribution of these costs across jurisdictional boundaries may be controversial (Arvai et al. 2006; Pahl-Wostl et al. 2005). The ongoing development of national and international basin organisations illustrates that these concerns can be met to varying degrees by improving coordination across jurisdictions. Inter-sectoral coordination is equally critical (Hoagland, 2005; Hanmer, 2005). For example, the Intergovernmental Panel on Climate Change noted that "Adaptation options for coastal and marine management are most effective when incorporated with policies in other areas, such as disaster mitigation plans and land use plans" (IPCC, 2001).

In order to incorporate learning from data collection and stakeholder input, institutions and decision-makers need to have the mandate, procedures and flexibility to make mid-course adjustments. Considering the various levels at which adaptive management may be practised and the ongoing decentralisation in many countries, this is a matter not only of responsive governance, but also of providing a framework for coordinating information sharing, activities, and institutions across sectors, scales, and national boundaries.

Political considerations can strongly influence the effectiveness and success of adaptive management. Political inertia can impede the development of adaptive management (Arvai et al. 2006). For example, the timescales are mismatched: politicians tend to operate on a relatively short timeframe (namely, until the next election), while adaptive management usually requires a longer timeframe (Bormann et al. 2007). Accordingly, decision-makers may not be willing to allow sufficient time to determine whether particular approaches are effective. Moreover, for transboundary waters, national political leaders are often hesitant to lose sovereignty. To build political support for governance reforms for adaptive management, it may be necessary to raise awareness about the vulnerabilities to climate change and other stressors, the difficulties in predicting water availability inherent in the nonlinear and complex hydrologic system, and security implications of failing to adopt more adaptive approaches.

Experience suggests that capacity is a central determinant of the ability to adapt (Burton et al. 2006; Adger et al. 2007; Pahl-Wostl et al. 2005). Financial, personnel, technical, information, and other resources can greatly facilitate adaptation. Since the most severe effects of climate change are projected to be in developing countries – which are least able to cope or adapt – there is a compelling need to build capacity in developing countries to adaptively manage water and other resources (Burton et al. 2006; Burton, 2000).

## *Transitioning to Adaptive Water Management*

The transition to adaptive management will likely focus on four issues. It is first necessary to build trust. Policymakers, regulated entities and the public must become more comfortable managing with uncertainty (Cooney and Lang 2007; Clarke, 2006; Carden, 2006). This trust can be developed through carefully constructed and implemented adaptive management pilot projects at various geographic and political levels. Second, mechanisms for collecting and sharing information need to be strengthened. Most countries have such mechanisms, but they often suffer from inadequate staff, funding and technical resources. In addition, a clear legal framework for adaptive water management can provide a mandate as well as address barriers to sharing information. Third, processes need to be developed to assess periodically the information that has been gathered. The processes for collecting, sharing and assessing must be tailored to the underlying issues that need to be understood, and it is crucial to articulate these issues clearly and specifically. Moreover, it is important to determine – at the outset, if possible – how to resolve differing interpretations of the data. Finally, there needs to be an ability and willingness to revise periodically the laws, regulations, permits and other measures based on the findings of the assessments. Since provisions requiring periodic revision are not a part of most current environmental laws, especially in developing countries, policymakers need to be educated about why and how to draft the provisions.

While concern regarding the effects of climate change may drive the development of dramatic legal and institutional reforms, adaptive water management may also be introduced gradually – in an adaptive manner. A number of confidence-building measures can be undertaken without legal development or other governmental action. Such confidence-building measures can generate consensus for adaptive management, promote understanding of different constructs of adaptive management, and provide lessons learned to guide the subsequent development and implementation of adaptive management (Bormann et al. 2007). Specific measures could include dialogues on adaptive management for government officials; engaging stakeholders and other civil society members in the discussions; improving information collection, for example, through an information clearinghouse; conducting periodic assessments regarding the state of the water (similar to state-of-the-environment assessments); developing guidance, reference and training resources on adaptive management; and establishing and cultivating networks of stakeholders in the basin that are interested in adaptation and adaptive management.

Adaptive management can be advanced through official governmental ("track I") channels, through less formal channels involving professors and NGOs ("track II" channels), or both (Davidson and Montville, 1981). Track II initiatives frequently involve technical exchanges, collaboration and dialogue. Where there is political deadlock, track II initiatives can build trust, provide opportunities to learn lessons through specific approaches, and lay the groundwork for subsequent official action. For transboundary water management, the Global Environment Facility has developed a strategic assessment and planning process that relies on adaptive management and multiple confidence-building measures designed to lay the groundwork for more formal action (Bloxham et al. 2005; IAEA, 2007). Ultimately, though, formal legal approaches will be essential: "Until control and responsibility are integrated, or at least coordinated, talking about using adaptive management in allocating water is just that – talk" (Neuman, 2001).

## Conclusions

There are innumerable challenges in managing water resources. Water is a multi-sectoral issue with numerous interlinkages and feedback loops: globalisation, energy, technology, information, demographic changes, and dynamic macro- and micro-economic developments all affect water demand and supply. Complexity and non-linearity in the climatic, hydrologic and social systems mean that long-term predictions are problematic. If climate change were not an issue, it may have been possible to muddle forwards as we have over the past few decades, making slow but incremental progress. Such modest progress may have been insufficient, though, in light of population growth and unsustainable patterns of development and consumption; in any case, climate change will have potentially dramatic impacts on regions around the world already facing water scarcity. Indeed, climate change is

already starting to have those effects. There is no choice; we need to make our water governance systems more resilient and adaptive and we need to do it now. This will require new legal and institutional approaches. As Asit Biswas observed, "We cannot identify tomorrow's problems, let alone solve them, with today's mindsets, yesterday's knowledge, and day before yesterday's experience" (Biswas, 2006).

To date, relatively few legal and institutional frameworks have incorporated adaptive water management approaches. This must change. With the growing understanding about the potential scope, severity, rapidity and unpredictability of climate change on water resources – not to mention the impacts of population growth, demographic changes, industrial growth and other drivers of change in water use and demand – there is an urgent need to enhance the resilience and adaptability of water governance structures around the world. Even without adaptation to climate change on the policy agenda, it was evident to most that water management needed to be more resilient and adaptable; climate change makes this need manifest and urgent.

Three key activities are needed. First, we need to learn from experiences to date in adaptive water management. While different countries and regions have explored legal and policy approaches for adaptive management, there has been as yet little meaningful synthesis of experiences (Arvai et al. 2006). Targeted research should collect and analyse these experiences at different levels and identify lessons learned. This research could form the basis for empirical guidance to inform the further development of adaptive water laws and institutions. This research could also help to identify under what circumstances adaptive management is appropriate, the policy tools that can be deployed to implement adaptive management, and whether adaptive management is more effective and efficient than other forms of adaptive management (Wailand, 2006; Rothenberg, 2005). Practical guidance tools – such as legal drafter's handbooks – can then translate the lessons learned to the policymakers, decision-makers and stakeholders.

Second, pilot projects can examine the extent to which certain approaches may be adapted to other contexts or scaled up. Pilot projects can also be invaluable in testing new modalities, including streamlined adaptive management approaches that could be applied in developing countries with limited capacity. They can also help to identify specific contextual factors that affect the effectiveness of particular adaptive management approaches (Kranz et al. 2005a). For example, legislative efforts to mitigate climate change (e.g. through carbon taxes or cap-and-trade systems) have generally proceeded independent of adaptation; the growing interest in linking adaptation to climate change (e.g. by funding some adaptation efforts through carbon taxes) is still largely theoretical and pilot projects could assist in identifying viable approaches.

Third, there is widespread need to build capacity to develop and operationalise legal and institutional frameworks that facilitate adaptive water management. This includes, inter alia, data collection and data management frameworks, as well as scientific, policy and managerial capacity to manage and utilise that information. Considering the breadth of the needs, new modalities for sharing experiences and building capacity are necessary. Traditional local and regional workshops can help, but to really be effective other means are necessary. Sustainable, endogenous

capacity building measures include in-country courses at universities and research centres, regional centres that can provide on-demand technical assistance, networks to share experiences and mentor, and online e-learning.

While this chapter focuses particularly on improving adaptive capacity of domestic legal and institutional frameworks governing water resources, it is also possible to introduce adaptive management into international treaties and frameworks (Feldman and Kahan, 2007), such as those governing particular basins. Indeed, one of the most successful international environmental treaty regimes – governing substances that deplete the ozone layer – has utilised an adaptive approach to monitor progress and regularly adjust the regulated chemicals and timeframes for phaseout (Hunter et al. 2006).

Adaptive management is an essential tool for societies to adapt to the effects of climate change, as well as the uncertainties and stressors inherent in dynamic social, political, economic and natural systems. It is worth noting, though, that this is but one of the necessary tools. Adaptation also entails increasing resilience, improving early warning capacity and strengthening emergency response capacities. Each of these is a separate, albeit related, topic in its own, and the question of how to improve the legal and institutional frameworks governing the respective matters merits further examination.

Water security depends on approaches that manage resources over the long-term. A group of retired U.S. generals and admirals highlighted the long-term security implications of climate change:

> Many developing countries do not have the government and social infrastructures in place to cope with the types of stressors that could be brought on by global climate change. When a government can no longer deliver services to its people, ensure domestic order, and protect the nation's borders from invasion, conditions are ripe for turmoil, extremism and terrorism to fill the vacuum (CNA, 2007).

Laws, institutions and initiatives will never be fully effective unless they account for the dynamic, complex and nonlinear character of water management. With climate change projected to become more pronounced, the need for adaptive water management will only continue to grow.

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