Climate-proofing transboundary water agreements

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Abstract Global climate change will pose a wide range of challenges to freshwater resources, altering water quantity, quality, system operations, and imposing new governance complications. Among the many unresolved challenges is how to integrate information on future hydroclimatological conditions into the politically complex system of transboundary water agreements, including formal treaties, international agreements, and transnational management institutions. Yet, most treaties and international agreements lack important tools for dealing with current challenges, such as flood control and water quality, and they lack adequate mechanisms for addressing changing social, economic or climate conditions. There are a variety of approaches that can be incorporated into existing treaties to allow for flexibility in the face of climate change, including: (1) adjustable allocation strategies and water-quality standards; (2) response strategies for extreme events; (3) amendment and review procedures; and (4) joint management institutions. We offer some explicit examples where specific strategies have been successfully implemented in ways that both reduce the risks of political conflicts over shared waters and lessen vulnerabilities to climatic changes.

Key words water management; transboundary water resources; international agreements; climate change; water quality; extreme events

INTRODUCTION

Political borders and boundaries rarely coincide with borders of watersheds, ensuring that politics inevitably intrude on water policy. Indeed, over 260 river basins and nearly 270 groundwater aquifers are shared by two or more nations (Wolf *et al.*, 1999; UNESCO, 2009). Just as oil creates disputes between states, water has long played a role in international politics and conflicts. Inequities in the distribution, allocation, and use of water have been a source of tension and dispute. In addition, water resources have long been used to achieve military and political goals, including the use of water systems and infrastructure, such as dams and supply canals, as military targets (Gleick, 1993).

The good news is that water disputes are generally resolved diplomatically, and shared water resources are often a source of cooperation and negotiation. An estimated 300 agreements have been developed between riparian states – those states that border a shared river. But the long history of violence associated with transboundary water resources highlights the challenges associated with managing shared water resources. A comprehensive online chronology of water-related violence extending back several thousand years can be found at: http://worldwater.org/chronology.html.

Future pressures, such as population and economic growth, and climate change, could increase tensions, even in areas that in the past have been characterized by cooperation. Global climate change will pose a wide series of challenges for freshwater management as a result of changes in

water quantity and quality, water-system operations, and more. For countries whose watersheds and river basins lie wholly within their own political boundaries, adapting to increasingly severe climate changes will be difficult enough. When those water resources cross borders, bringing in multiple political entities and actors, sustainable management of shared water resources in a changing climate will be especially challenging.

This article explores the degree to which existing transboundary agreements and/or international principles for sharing water can handle the strain of future pressures, particularly climate change (for a more in-depth analysis, see Cooley *et al*., 2009) and offers strategies for reducing those pressures. Climate change will inevitably alter the form, intensity, and timing of water demand, precipitation, and runoff, meaning past climate conditions are no longer an adequate predictor of the future. At the same time, new disputes are arising in transboundary watersheds, and are likely to become more common with increasing pressures. Thus, transboundary agreements are needed now more than ever, but new forms or arrangements for such agreements may be necessary and old agreements may need to be renegotiated in the context of a changing climate.

TRANSBOUNDARY RIVERS AND AQUIFERS

Many rivers, lakes, and groundwater aquifers are shared by two or more nations, and most of the available freshwater of the Earth crosses political borders. International watersheds cover about half of the Earth's land surface, and about 40% of the world's population relies on these shared water sources. In 1958, the United Nations (UN) published the first comprehensive collection of information on shared international rivers of the world (UN, 1958). This early assessment identified 166 major international river basins. In 1978, the United Nations published an updated assessment (UN, 1978) identifying 214 such basins.

The world has changed significantly since the 1978 assessment. The current Registry, prepared by Aaron Wolf and several colleagues (Wolf *et al*., 1999) and updated in 2002, now identifies over 260 major transboundary river basins, covering nearly half of the ice-free land surface of the Earth (Table 1). The increase in the number of basins since the last comprehensive survey reflects changes in the political landscape, improvements in mapping technology, and the inclusion of river basins on island nations. Our abilities to precisely measure topography, identify geographical characteristics in flat terrain, and accurately map both geophysical and geopolitical borders have dramatically improved. Among the most important of these changes has been the disintegration of the Soviet Union – once the largest single country in the world – into 15 separate nations. Many of the world's largest rivers flow in the territories of these nations and the break-up of the Soviet Union has resulted in many new international rivers.

Table 1 The world's transboundary rivers and aquifers. Sources: International river basins from Wolf *et al.* (1999) and updated in 2002; international aquifers from UNESCO (2009).

	Transboundary river basins		Transboundary aquifers*
	Number	% area in international basins	Number
Africa	59	62	40
Asia	57	40	70
Europe	69	55	89
North and Central America	40	37	41
South America	38	59	29
Total (global)	263	48	269

*Data on areas of transboundary aquifers are limited, and only available for selected aquifers.

None of these assessments included information on shared groundwater basins and, until recently, little detailed information on shared groundwater basins was available. Yet an estimated 99% of the Earth's accessible freshwater is found in aquifers, and about two billion people rely on aquifers as the sole source of their water (UNESCO, 2009). In October 2009, UNESCO released

the *Atlas of Transboundary Aquifers*, which identified 269 shared groundwater basins. The areal extent of shared aquifers has not yet been compiled due to uncertainties about the spatial extent of many transboundary aquifers, but it is increasingly apparent that shared groundwater basins may also be vulnerable to climate change as well as catalysts for political disputes both between and within nations.

GENERAL CHARACTERISTICS OF TRANSBOUNDARY AGREEMENTS

Since transboundary watersheds traverse political and jurisdictional lines, heterogeneous and sometimes conflicting national laws and regulatory frameworks make management a major challenge, particularly when no single national government has authority over another. As such, transboundary water management often requires the creation of international guidelines or specific agreements among riparian states. These arrangements typically take two forms: general principles of international behaviour and law, and specific bilateral or multilateral treaties negotiated for particular river basins. This article focuses on transboundary agreements.

The first transboundary water agreements were written in the early and mid-19th century between countries that share the River Rhine, which flows from its headwaters in Switzerland through Germany, Luxembourg, France, and The Netherlands, emptying into the North Sea. These treaties established rules for allowing navigation, dividing fish harvests, and withdrawing water along the Rhine. Today, there are approximately 300 transboundary agreements on record (UNEP/OSU, 2002). Of the 145 agreements negotiated in the 20th century, an overwhelming 86% are bilateral, despite the fact that many of the agreements are in watersheds with more than two political entities, suggesting that many states that should be a party to agreements are excluded (Jägerskog & Phillips, 2006). The Nile Basin Treaty, for example, was negotiated only between Egypt and the Sudan, despite that fact that eight other nations are located upstream of these nations.

Table 2 provides a summary of the transboundary agreements negotiated during the 20th century. Most treaties (40%) focus on hydropower and, not surprisingly, are often amongst mountainous nations at the headwaters of the transboundary rivers. Nepal alone, with an estimated two percent of the world's hydropower potential, has four treaties with India (the Kosi River agreements of 1954, 1966, and 1978, and the Gandak Power Project, 1959) to utilize the huge power potential in the region (Hamner & Wolf, 1998). Just over a third of these treaties address water allocation and include volumetric allocations among riparian countries (Hamner & Wolf, 1998). In cases where volumetric allocations are specified, they often are fixed, leaving little flexibility for changing flow conditions. As discussed below, this characteristic is especially problematic in the context of climate change.

Table 2 Primary focus of transboundary water agreements adopted during the 20th century. Source: Jägerskog & Phillips (2006).

	Focus of transboundary agreements
Hydroelectricity	39%
Water allocation	37%
Flood control	9%
Industrial uses	6%
Navigation	4%
Pollution	4%
Fishing	1%

Even where transboundary agreements exist, important elements of the hydrological cycle are commonly left out. Groundwater is typically excluded; if it is mentioned at all, it is usually in reference to contamination rather than use of groundwater resources. Given that an estimated 99% of the Earth's accessible freshwater is found in aquifers, and about two billion people rely on

aquifers as the sole source of their water (UNESCO, 2009), this is a major concern. A recent agreement on the Guarani Aquifer in South America, however, is a positive development. The Guarani Aquifer is one of the largest groundwater aquifers in the world and is shared by four countries – Brazil, Uruguay, Paraguay and Argentina. In August 2010, these countries signed the Agreement on the Guarani Aquifer, which sets forth a series of principles and objectives for the sustainable management of the groundwater system. Although many of the provisions of the Agreement are weak – it allows "each party to exercise the sovereign territorial control over their portion of the Guarani Aquifer System" in accordance with the norms of international law – it is one of a very limited number of agreements on shared aquifers and is thus an important first-step in promoting the cooperative management of these systems.

Likewise, many transboundary agreements that identify water allocations fail to include any standards for the quality of that water. This omission proved problematic for Mexican farmers in the 1950s and 1960s; although there was a treaty between Mexico and the USA for the Colorado River, increasingly saline Colorado River deliveries impaired crop production in Mexico. Extensive negotiations and several amendments were eventually made to the treaty (Hundley, 1966), and, today, deliveries to Mexico are subject to salinity thresholds. Annual water deliveries to Mexico at the Morelos Dam, for example, must have an average salinity no more than 115 parts per million (ppm) (±30 ppm) greater than the salinity of the river at Imperial Dam, 40 km upstream.

Many transboundary agreements also exclude monitoring, enforcement, and conflict resolution procedures. Only about half of the treaties have provisions for monitoring, and most monitoring efforts include only the most rudimentary elements. This is particularly problematic given that data collection and sharing often provides a basis for negotiation. While disputes can be resolved by technical commissions, basin commissions or government officials, 22% make no provisions for dispute resolution, and 32% of treaties include incomplete or ambiguous dispute-resolution mechanisms (Hamner & Wolf, 1998).

TRANSBOUNDARY WATER MANAGEMENT PRINCIPLES AND CLIMATE CHANGE

Rising greenhouse-gas concentrations from human activities are causing large-scale changes to the Earth's climate system. Because water is a fundamental element of our climate system, these changes will have important implications for the hydrological cycle. Indeed, all comprehensive climate reports, such as those from the Intergovernmental Panel on Climate Change (IPCC), the UN Foundation/Sigma Xi Scientific Expert Group (SEG, 2007), and the USA national assessments (USGCRP, 2000; CCSP, 2008) have concluded that freshwater systems are especially vulnerable. The IPCC Fourth Assessment Report notes that climate change will lead to "changes in all components of the freshwater system" (Kundzewicz *et al.*, 2007, 2008) and includes impacts on water availability, timing, quality and demand.

Most transboundary water agreements, however, are based on the assumption that future water supply and quality will not change. Moreover, most treaties and international agreements fail to include adequate mechanisms for addressing changing social, economic or climate conditions (for an early analysis of this problem, see Goldenman, 1990, and Gleick, 2000). In many cases, adapting to climate change will require changes in the institutions and policies that have been put in place under international treaties. As noted by McCaffrey (2003), in an analysis of a treaty dispute before the International Court of Justice between Hungary and Slovakia, "the law of treaties itself will not ordinarily permit unilateral modification or withdrawal" under changing circumstances, including climate change. Rather, "Parties will be required to work within the framework of existing treaties to respond to changes."

There are a variety of mechanisms that can be incorporated into existing treaties to allow for flexibility in the face of climate change. Fischhendler (2004) and McCaffrey (2003) identify four categories: (1) flexible allocation strategies; (2) drought provisions; (3) amendment and review procedures; and (4) joint management institutions. Although important, these mechanisms are highly focused on water scarcity. They are less applicable to other potential climate change impacts on water resources, including increased frequency and intensity of floods and water

quality concerns. Below, we expand the scope of these mechanisms to include other potential water-related climate change impacts and provide examples where these mechanisms have been implemented.

Flexible water allocation strategies and water quality standards

Given the impact of climate change on water resources, transboundary agreements should address how riparian states will adapt to altered timing and availability of flows. Few treaties, however, address water allocation, perhaps due to its intensely political nature. Among those that do, about a quarter require equal allocations and the rest assign specific amounts to the various riparian states (Hamner & Wolf, 1998). In most cases, these water allocations remain fixed (UNEP/OSU, 2002), which does not provide the flexibility needed to adapt to changing conditions (Goldenman, 1990; McCaffrey, 2003).

There are several legal and institutional arrangements for transboundary cooperation that can accommodate flow variability. A treaty may specify that an upstream riparian state deliver a minimum flow to a downstream riparian state in order to maintain human health and key ecological functions. While this approach may be less restrictive than requiring fixed deliveries, downstream riparians may consider minimum flows to offer too little protection while upstream parties may be concerned about their ability to always deliver that minimum. Another way to enhance treaty flexibility is to allocate water based on a percentage of the flow. This allows flow regimes to respond to both wet and dry conditions, although it requires flexible infrastructure, effective operating rules, and regular communication and data sharing.

Much of the literature on transboundary agreements and climate change has focused on how changes in water flows will affect various water-allocation strategies. Climate change, however, may also exacerbate water-quality concerns in some locations. For example, sea-level rise may intensify saltwater intrusion in deltas; in some cases, downstream water-diversion facilities may become unviable unless freshwater inflows are increased. Greater analysis is needed to evaluate how water quality will be affected by climate change within the context of transboundary agreements. Furthermore, regional climate-change assessments would be more valuable for informing transboundary management and treaty reform if researchers included key water impacts, such as quality, quantity, frequency and intensity of extreme events, and impacts on water demands. One way to do this is to make sure that regional water experts are included in climate assessment planning and implementation, so that key water-related needs and questions are identified early and incorporated into modelling and analysis.

Response strategy for extreme events

Many transboundary agreements include provisions for exceptional circumstances, such as droughts. These provisions vary in their specificity. Within the Nile Basin, the Permanent Joint Technical Commission can make recommendations for new water allocations in response to an extraordinary drought, although this term has never been defined and the Commission has never exercised its power (Conway, 2005). In comparison, in the agreement over the Rio Grande between the USA and Mexico, Mexico is allowed to supply less than the minimum amount of water to the USA during an extraordinary drought for up to five years. During this period, Mexico incurs a water debt that they must then repay by increasing flows during the next five-year cycle.

Provisions on the Colorado River are much more defined and may serve as a model for other transboundary agreements. In 2007, the USA implemented the *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations of Lake Powell and Lake Mead* (referred to as the "Interim Guidelines"). This agreement, developed in the eighth year of the worst drought in over 100 years of record keeping, establishes specific guidelines for reduced water deliveries among the seven Colorado Basin states under drought and low-reservoir conditions. These shortage guidelines, which were developed in consultation with the Mexican government, are triggered at specific reservoir water levels in major reservoirs on the Colorado River (Lake Mead and Lake Powell), thereby providing water users with some indication of the frequency and magnitude of these events. The Interim Guidelines also create a novel multi-year water

augmentation and banking programme known as "Intentionally Created Surplus", allowing lower basin water users to invest in extraordinary conservation efforts and store the water saved or generated by such efforts for delivery in future years. A related programme, called "Developed Shortage Supply", creates similar mechanisms to generate and store water to be delivered during declared shortages, buffering the users against major reductions. These guidelines were drawn up among the USA Colorado Basin states and do not address deliveries to Mexico. Adoption of the Interim Guidelines, however, has provided impetus to Mexico and the USA to begin negotiations to determine the conditions that would prompt Mexico to accept reduced deliveries of Colorado River water, as well as potential mechanisms for adapting to such changes.

Much of the literature on transboundary agreements and climate change emphasizes the impacts of droughts on water-allocation schemes (McCaffrey, 2003; Fischhendler, 2004; Kistin & Ashton, 2008). Floods are often ignored in transboundary water management. Yet, floods pose a real risk for downstream riparian nations and are expected to increase in frequency and intensity in some regions as a result of climate change. The failure to manage these risks can have catastrophic consequences. In a recent analysis, Bakker (2009) found that flood losses were higher in shared basins that lacked the institutional capacity, i.e. international water management bodies and freshwater treaties, for managing these events. An overwhelming 43 international river basins where transboundary floods were frequent during the period 1985–2005 lacked the institutional capacity for managing these events.

Conversely, coordinated flood management can greatly reduce the risk of these events. Flood management was one consideration in the Columbia River Basin Treaty, which stipulates that Canada (the upstream party) will adjust its operation of hydroelectric dams to mitigate flooding in the USA. In the Agreement on the Cooperation for Sustainable Development of the Mekong River Basin, maximum river flow rates are set, and upstream dam operations must be adjusted to meet these requirements. Basin-wide coordination of flood-management activities is critical, and integrating flood-management protocols into all transboundary agreements could prove an effective risk-reduction tool.

Amendment and review process

Even when the understanding about the hydrological dynamics of a particular basin is fairly advanced, conditions may change. Population and economic growth can create new demands for water resources. New water-quality criteria may be adopted. Scientific knowledge and technological capabilities may advance. Societal perceptions about the importance of ecosystems may shift. In addition, global climate change may cause fundamental changes in the hydrological cycle and be more severe and occur more quickly than anticipated. An amendment and review process in transboundary agreements is needed to allow for changing hydrological, social or climatic conditions, or in response to new scientific knowledge (Fischhendler, 2004). Within the Colorado River Basin, for example, amendments are made using "Minutes" that then must be approved by all parties. Since 1922, a total of 317 such amendments have been adopted. A treaty could also be designed such that a separate body, such as a joint commission, could make treaty amendments (McCaffrey, 2003).

Joint institutions

Joint institutions can play an important role in managing transboundary water resources, particularly in light of changing conditions. According to a recent survey, only 106 international river basins have water institutions, and few of them are multilateral (UNEP/OSU, 2002). The roles and authority of these institutions vary widely. The ideal institution would have a broad scope, include all riparian nations, and have management and enforcement authority. Yet, the creation of such a supra-national authority can be perceived as a threat to more politically powerful nations for fear of losing power (Fischhendler, 2004).

A joint body can fulfil a variety of roles to facilitate adaptation to climate change. In particular, such a body could convene a technical committee to develop a common hydrological model of the basin and common climate-change scenarios. The International Commission on the Protection of the Rhine, for example, recently commissioned an assessment of the state of

knowledge on climate change and its expected impacts on the water regime of the Rhine (ICPR, 2009). Most of the hydrological models of future climate change in the Rhine Basin show a risk of an increase in winter runoff and a reduction in summer runoff, indicating a need to adjust the water management regime to accommodate greater variability, especially the equitable allocation of lower summer flows. The Commission established a climate change expert group to develop hydrological scenarios, assess impacts of climate change on water quality and uses, and identify adaptation options. This approach has helped to facilitate a shared understanding of the potential impacts of climate change and is paving the way for the implementation of new adaptation efforts throughout the entire Rhine River Basin.

CONCLUSIONS AND RECOMMENDATIONS

Global climate change will pose a wide range of challenges to freshwater resources, altering water quantity, quality, system operations, and imposing new governance complications. For countries whose watersheds and river basins lie wholly within their own political boundaries, adapting to increasingly severe climatic variability and changes will be difficult enough. When those water resources cross borders and implicate multiple political entities and actors, sustainable management of shared water resources in a changing climate will be especially difficult.

Shared waters can be a source of conflict, but they can also be a source of cooperation and negotiation. Future pressures, such as population and economic growth, and climate change, could increase tensions, even in areas that in the past have been characterized by cooperation. Yet, shared challenges may also be a platform for developing new institutional arrangements to plan for the future. Below, we provide insights from recent transboundary water management efforts that could improve the management of transboundary waters in the face of climate change. Several of these approaches may be useful for addressing a broad range of change conditions, including population and economic growth. The last two concepts specifically address new risks posed by climate change.

Establish agreements in transboundary basins

Formal treaties or agreements for the management of transboundary waters are not universal. Treaties covering transboundary aquifers, in particular, are rare (UNECE, 2009). Climate change increases the need for such agreements to reduce the risk of potential future conflicts. Agreement on new treaties may prove easier to conclude if they are initiated before new conflicts or tensions emerge as a result of changing hydrological conditions.

Bring the UN Convention into force

While the value of transboundary watershed treaties has regularly been demonstrated, there are political and financial constraints that make their adoption difficult in many areas of the world. Therefore, adopting an effective international legal framework with clear criteria and definitions is a critical step for addressing future challenges, particularly climate change. The Convention on the Law of the Non-Navigational Uses of International Watercourses, adopted by the UN General Assembly in May 1997, has not yet come into force. Dellapenna (2007) observes that "None of the most disputed internationally shared fresh waters are covered by agreements involving all interested States, indicating the need, despite the growing prevalence of international agreements regarding internationally shared waters."

Expand the scope of existing agreements

Climate change will affect all elements of the hydrological cycle in complex and sometimes non-linear ways. A number of important elements, especially water quality and flood management, are commonly excluded from transboundary agreements. The expansion of existing agreements to include all elements of the hydrological cycle should be explored. Integrated Water Resources Management, or IWRM, provides one such framework. It recognizes the interdependency of all water uses and seeks to balance social, economic and environmental objectives in the management of water resources, but such management efforts must now include future climatic factors, not simply historical climatic conditions.

Evaluate existing treaties and agreements to assess flexibility in light of changing conditions
No two water treaties are the same. Each is developed under diverse circumstances, addresses different concerns and has a unique set of constraints. Additionally, climate change will affect each basin differently. As a result, each treaty must be independently evaluated to determine what flexibility mechanisms currently exist and where significant vulnerabilities remain. This process should be started before a problem arises so as to improve the atmosphere for cooperation and negotiation.

Amend existing treaties to improve flexibility
Most treaties and international agreements fail to have adequate mechanisms for addressing changing social, economic or climate conditions. Transboundary watershed countries should consider incorporating the following mechanisms into existing treaties to allow for flexibility in the face of change: (1) flexible allocation strategies and water quality criteria; (2) provisions for extreme events; (3) clear amendment and review procedures; and (4) joint management institutions.

Establish joint monitoring programmes
Joint monitoring programmes can improve cooperation among nations and data collection capacities. This exchange of information provides a number of benefits, including expanding and deepening our understanding of climate change impacts and vulnerabilities, and improving hydrological and socio-economic models. Such programmes should include water flow and a range of water-quality parameters. Additionally, early warning systems can reduce the impacts of extreme events.

Conduct climate impact, vulnerability, and adaptation assessments
Riparian countries should work on common scenarios and models to develop a joint understanding of possible impacts. Transboundary cooperation can broaden the knowledge base, enlarge the range of measures available for prevention, preparedness and recovery, and so help identify better and more cost-effective solutions.

Each of these strategies has important strengths and weaknesses. And significant barriers to implementation make it difficult to put them in place in both existing and new agreements. Among the most important barriers are political concerns about sharing data and information on a potentially strategic resource, technical constraints around monitoring and impact assessment, economic pressures that divert financial resources to other national priorities, and more. Nevertheless, the success in some international watersheds, described above, to implement one or more of these strategies suggests that effective transnational watershed management in the context of climatic change is possible and can pay dividends in the form of reduced political tensions and societal vulnerability.

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