Journal of Contemporary Water Research & Education

Issue No. 149 **December 2012**

Water and International Security

Contents

Water and International Security
David Kreamer.....1

Articles

Case Studies on Water Security: Analysis of System Complexity and the Role of Institutions
Jacob D. Petersen-Perlman, Jennifer C. Veilleux, Matthew Zentner, and Aaron T. Wolf.....4

Water Modeling Technologies: A Key to Unlocking Water Conflict in the Middle East?
Al-Sharif Nasser Bin Nasser.....13

Hydrostrategy, Hydropolitics, and the Security in the Kura-Araks Basin of the South Caucasus
Michael E. Campana, Berrin Basak Verner, and Baek Soo Lee.....22

Irrigation Outreach in Afghanistan: Exposure to Afghan Water Security Challenges
Denis Reich and Calvin Pearson.....33

Critiquing Cooperation: Transboundary Water Governance and Adaptive Capacity in the Orange-Senqu Basin
Elizabeth J. Kistin Keller.....41

Climate Vulnerability and Adaptive Strategies along the Rio Grande/Rio Bravo Border of Mexico and the United States
Brian Hurd.....56

Development of an Army Water Security Strategy: Stateside Component
Paul Koch and Marc Kodack.....64

Sustained Dialogue for Ground Water and Energy Resources in Chile
Suzanne A. Pierce, Reed A. Malin, and Eugeno Figueroa.....76

The Past, Present, and Future of Water Conflict and International Security
David Kreamer.....87

Past Issues of JCWRE.....97

JCWRE Subscription 98

Universities Council on Water Resources
Journal of Contemporary Water Research & Education
Issue 149, Pages 1-3, December 2012

Water and International Security

David K. Kreamer

University of Nevada, Las Vegas, NV

"Water, like religion and ideology, has the power to move millions of people. Since the very birth of human civilization, people have moved to settle close to it. People move when there is too little of it. People move when there is too much of it. People journey down it. People write, sing and dance about it. People fight over it. And all people, everywhere and every day, need it."

–Mikhail Gorbachev

This journal issue concerns water and international security. Regional paucity of water creates stress on communities, promotes instability and disputes, and can ignite political ambitions and military action. Our aqueous resources have been both a tool and goal of past conflict, and ominous auguries of regional water scarcity, coupled with population growth, point to future instabilities. This projected instability is due, in part, to overall water use having expanded at over double the rate of population increase over the last century.

According to the United Nations (2012), water shortages could affect 2 billion people in the next 20 years. The UN estimates that presently 700 million people in 43 countries experience water scarcity (defined as less than 1000 m^3 per person per year). Their projections indicate that by 2025, 1.8 billion will be living in countries with absolute water scarcity (defined as less than 500 m^3 per person annually) and two thirds of the global population could suffer from water stressed circumstances (less than 1700 m^3 per person annually). The UN further forecasts that water scarcity in arid and semiarid regions could displace between 24 and 700 million people (United Nations 2012). Chronic water challenges can be physical, where people do not have abundant water close by, and economic, where communities do not have the necessary infrastructure to extract and convey water from rivers, lakes, springs, and aquifers. But the bottom line is: lack of water can foment unrest. Water scarcity has become one of our greatest challenges, and the inability of some regions of the world to address this challenge portends difficulty, social unrest, and perhaps even armed conflict. This special issue of the *Journal of Contemporary Water Research and Education* addresses water's role in community stability and wellbeing.

The first article in this issue, "Case Studies on Water Security: Analysis of System Complexity and The Role of Institutions" by Jacob D. Petersen-Perlman, Jennifer C. Veilleux, Matthew Zentner, and Aaron T. Wolf, defines institutional capacity, and hydropolitical resilience and vulnerability. The authors then insightfully compare very different water basins in North America, Asia, and Africa, drawing compelling conclusions relative to future water security.

These case studies are followed by a second article entitled, "Water Modeling Technologies: A Key to Unlocking Water Conflict in the Middle East?" by Al-Sharif Nasser Bin Nasser. The Middle East is one of the most fractious, ethically and religiously divided regions of the world, and one where disputes over water have been historically contentious. The paper discusses conflict in the Middle East stemming from water disagreements, and presents the intriguing idea that water resources modeling, technology, and management can be more strategically focused in this region, reaping benefits which would promote socio-economic stability.

The third paper in this issue, "Hydrostrategy, Hydropolitics, and Security in the Kura-Araks Basin of the South Caucasus" authored by Michael E. Campana, Berrin Basak Vener, and Baek Soo

Lee examines an international river basin, in an unstable region of the former Soviet Union, with ethnic conflict and evolving bureaucracies. The countries of Armenia, Azerbaijan, and Georgia are attempting to overcome disagreements and cooperatively manage water resources of the large Kura-Araks Basin. The paper provides an unflinching explanation of the water sharing difficulties and prospects for the future.

Irrigation issues in Afghanistan are viewed from an educational point-of-view in this issue's fourth paper. "Irrigation Outreach in Afghanistan: Exposure to Afghan Water Security Challenges" by Denis Reich and Calvin Pearson. This article provides an on-the-ground, up close view of the difficulties of providing water security in a nation plagued with war, contumacy, and privation. Although this country is one of the world's 10 poorest nations, it has received approximately $60 billion in civilian aid since 2002. But Afghanis face an uncertain future, with outside funding for civilian projects anticipated to be reduced to about $4 billion per year over the next four years (Vogt and Khan 2012). Reich and Pearson document a university-based workshop on irrigated agriculture, held in Afghanistan, where food and water security are closely linked. Their paper provides an interesting set of "lessons learned" during the project and a cautionary blueprint for further educational work in the nation.

The fifth paper in this issue is by Elizabeth J. Kistin Keller and is entitled, "Critiquing Cooperation: Transboundary Water Governance and Adaptive Capacity in the Orange-Senqu Basin." In this article, Dr. Keller looks at transboundary agreements in south-central and southwestern Africa when circumstances change and existing agreements must be modified. She engagingly lays out the rich, interactive history of bilateral water agreements and a basin-wide treaty between Lesotho, Botswana, South Africa, and Namibia, and discusses the institutional flexibility of the nations, their improving ability to manage data, the lack of a strong system for intersectoral planning, and regional power asymmetries that affect agreements. Keller's article gives some hope and direction to joint basin scale planning among nations.

Mexico's water challenges are discussed in the sixth article in this issue by Brian H. Hurd. Entitled, "Climate Vulnerability and Adaptive Strategies along the Rio Grande/Rio Bravo Border of Mexico and the United States," Dr. Hurd's article extends the discussion of water security to food security and irrigated agriculture, energy security, and Mexico's vulnerability to likely climate change scenarios. This is a provocative look at potential drivers for instability and unrest in a populous North American country that shares a border, and some of its opportunities and adversities, with the United States.

The seventh article is a view from the U.S. military perspective. U.S. Armed Forces face numerous challenges and are rigorously addressing energy and resource issues, of which many directly or indirectly affect operational efficacy in providing national defense. Directives have been established anticipating response to climate change (153 U.S. naval bases would be susceptible to sea level rise), innovatively reducing energy consumption (the single largest user of energy in the U.S. is the military), and promoting water conservation (Alley 2012). This paper zeros in on the Army's approach to developing a sustaining domestic water policy. The authors, Paul Koch and Mark Kodack focus on community water policies for the military in the U.S. in their article, "Development of an Army Water Security Strategy: Stateside Component."

Suzanne Pierce, Reed Malin, and Eugenio Figueroa Benavides explore the roots of unrest over water and its relation to mining and energy in the Atacama Desert of South America in her article, "Sustained Dialogue for Ground Water and Energy Resources in Chile" In this eighth article of the issue, she effectively advocates solving resource disputes by revisiting and addressing long-term, underlying disagreements and mismatched community values. Particularly, they introduce innovative socio-technical approaches to resolution which blend dialogue and deliberation with the reflective consideration of history and cultural beliefs, and versatile scientific information display and management, in seeking solutions to community unrest over resource development.

The last article, "The Past, Present, and Future of Water Conflict and International Security" by the issue editor, is an overview of the water security challenges facing the world. The article reviews difficulties in supplying clean water throughout the world, how water has been both a strategic tool and object of conflict in the past, recent trends toward regional water conflict, and potential ways to move positively forward and increase international security.

The localized competition between burgeoning population and reliable water supply may emerge as a primary criterion for peace in the world. Will paucity of water incite communities, enflame those seeking an economic development advantage over others, help stir up smoldering antagonisms, and become a war-cry for those impatient with what Tennyson referred to as "the long, long cancer of peace?" Certainly the potential for calamity will continue as long as privation exists, and thirst drives individuals to the frantic, rough edge of civility.

Author Bio and Contact Information

David K. Kreamer is a Professor of Geoscience, and also Graduate Faculty in the Departments of Civil and Environmental Engineering, and Environmental Studies, and is past Director of the interdisciplinary Water Resources Management Graduate Program at the University of Nevada, Las Vegas. He also serves as faculty in the Hydrologic Sciences Program at the University of Nevada, Reno. His Ph.D. is in Hydrology from the University of Arizona, and he was an Assistant Professor in Civil Engineering at Arizona State University. David's research includes environmental contamination, spring sustainability, and clean water supply in developing nations. He has given over 150 invited lectures, seminars and workshops in recent years for U.S. Environmental Protection Agency, U.S. Bureau of Land Management, the National Ground Water Association, and the Superfund University Training Institute, presented short courses for over half the States or Commonwealths in the U. S., and lectured for other groups such as City of Phoenix, University of California Extension, and Hanford Nuclear Site. He has given presentations at over 40 Universities, and has spoken in Europe, Asia, the Caribbean, Pacific island nations, South America, Africa, and the Middle East. He serves as Director of the National Ground Water Association's Division of Scientists and Engineers, is Vice President for North America for the International Association of Hydrogeologists, and serves on the Board of Directors of the Universities Council on Water Resources. He can be contacted at dave.kreamer@unlv.edu.

References

Alley, R. 2012. *Earth: the Operator's Manual*. Public Broadcasting Film, funded by the National Science Foundation under Award 0917564. Available at: http://earththeoperatorsmanual.com/.

United Nations. 2012. UN website on Water Scarcity. Available at: http://www.un.org/waterforlifedecade/scarcity.shtml.

Vogt, H. and M. Khan. 2012. Taliban beheads 17 partygoers. *The Associated Press, Chronicle Herald.* Available at: http://thechronicleherald.ca/world/130481-taliban-beheads-17-partygoers.

Universities Council on Water Resources
Journal of Contemporary Water Research & Education
Issue 149, Pages 4-12, December 2012

Case Studies on Water Security: Analysis of System Complexity and the Role of Institutions

Jacob D. Petersen-Perlman[1], Jennifer C. Veilleux[1],
Matthew Zentner[2], and Aaron T. Wolf[1]

[1]Oregon State University, Corvallis, OR; [2] United States Department of Defense, Washington, DC

Abstract: Water security is a challenge faced within many transboundary river basins. Identifying the resilient factors within a system may reduce water security concerns and enhance cooperation. In this paper, we are examining the dimensions of resilience as influenced by the rate of change and institutional capacity within river basins. Three case studies are analyzed for their water security capacity, including resilience and vulnerability, as well as institutional capacity.

Keywords: *Water security, system resilience, vulnerability*

Water security is the availability of freshwater in the right quantity and quality, at the right times, for dependent systems. This is a prerequisite for human and environmental security, as well as economic growth. Global freshwater resources are vital not only for individual consumption and the natural environment, but also for the agricultural, energy, industrial, and transportation sectors. As a limited resource, water is influenced by a nexus of geophysical conditions, geopolitical agendas, and socio-cultural dynamics on several scales. The relationship between changes to the physical environment and political and social instability has been postulated by numerous scholars, with shifts in freshwater resource access, quality, and quantity often noted as being a key change and influence on societal and political stability (Brown et al. 2007; Eckstein 2010; Swart 1996). Changes in water resources can alter the relative wealth of countries and cause shifts in relative power. In many ways, water is one of the most important components holding societies together. When the rate of change to a water system exceeds its capacity to adapt, the myriad connections to overall security and stability soon become evident.

Global freshwater is increasingly under pressure due to direct human use and alteration, and also due to environmental issues, such as global climate change. Several studies have examined how already-stressed systems that are vulnerable could be driven past a tipping point by shifts in climate (Barnett 2003; Dabelko 2008; Mabey 2007). More than one billion people already lack access to safe drinking water (Gleick 1999; Loftus 2009) and more than 2.4 billion lack access to sanitation worldwide (World Health Organization 2000). Globally, water-related illness and accidents are one of the leading causes of death each year, especially from diarrheal diseases.

International interests, through the creation of agreements, such as the United Nations Millennium Development Goals (MDGs), seek to reduce this number through international development and aid. Discussion of security and stability at different scales and for different sectors is especially useful in the context of freshwater resources and climate change (Buzan 2000; 2001). The impact of freshwater stress is of concern for all sectors of society, sometimes indirectly, with consequences that are largely unpredictable (Allan 2001).

Water interacts with broader national security concerns and can contribute to state instability and social disruptions. Three levels of scale can be employed to describe and understand interactions concerning freshwater resources: the individual,

intranational, and international systems (Buzan and Waever 2009). For individuals, water security can be considered a factor of "life, health, status, wealth, and freedom" (Stone 2009). States have larger, more complicated considerations that include a shifting hierarchy of requirements in often overlapping political, military, economic, societal, and environmental sectors (Buzan 2000; 2001). Each sector impacts security, but these individual sectors are also linked to one another, making a discussion of individual sectors inadequate to address impacts on security (Stone 2009). Due to the complexity at the state level, international systems are even more complicated, attempting to mesh multiple ever-fluctuating state water security aims and goals. This paper will examine the key role that state institutions take at the international level in regard to water security.

Institutional Capacity

Examining the roots of water resources conflicts suggests a relationship between change, institutions, and scale. These types of conflicts tend to occur where the rate of change within a basin exceeds its institutional capacity to absorb that change. Institutional capacity goes beyond the formal water management institutions to include all facets that contribute to water governance, including economy, military, and infrastructure. Evaluating past conflicts also suggests that sudden changes within a basin, either physical (e.g., high rate of population growth, dams) or institutional (e.g., new political boundaries, new governments, economic growth), are more hazardous to a basin's stability than "creeping changes" (e.g., water quality decline, certain aspects of climatic change excluding more severe droughts or floods). When changes occur in the absence of mitigating institutions, there exists the greatest potential for political tensions.

Hydropolitical Resilience and Vulnerability

The concepts of "resilience" and "vulnerability" as related to water resources are often assessed within the framework of "sustainability" and relate to the ability of biophysical systems to adapt to change (Gunderson and Pritchard 2002). As the discourse on sustainability has broadened to include human systems, research has also shifted towards the identification of resilience and vulnerability indicators within this context (Bolte et al. 2004; Lonergan et al. 2000; Turner et al. 2003).

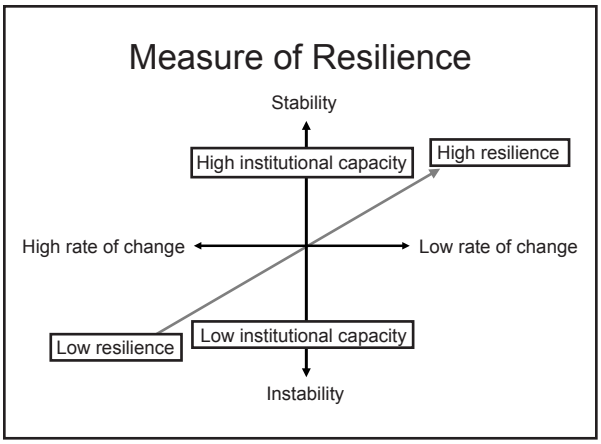


Figure 1. Measuring the resilience of a system. Systems with high institutional capacity and a low rate of change are likely to be highly resilient.

As the potential for conflict and violence regarding international waters has become identified, the term "hydropolitics" has emerged as a descriptor of the ability of geopolitical institutions in their management of shared water resources in a manner that is politically sustainable, meaning without tensions or conflict between political entities. "Hydropolitical resilience," then, is defined as the complex human-environmental system's ability to adapt to permutations and change within these systems, while "hydropolitical vulnerability" is defined by the risk of political dispute over shared water systems (Figure 1). Wolf et al. (2003) suggested the following relationship between change, institutions, and hydropolitical vulnerability: "The likelihood of conflict rises as the rate of change within the basin exceeds the institutional capacity to absorb that change."

Factors Influencing Hydropolitical Resilience and Vulnerability

The general assumption of the relationship between hydropolitical resilience and vulnerability is that rapid change is a stress that can expose or accentuate vulnerability while institutional capacity tends to indicate resilience, and that the



Figure 2. The Columbia River Basin.

two sides need to be assessed in conjunction with each other to gage hydropolitical sustainability more accurately.

The characteristics of a basin that would tend to enhance resilience to change include:

- International agreements and institutions, Such as River Basin Organizations,
- A history of collaborative projects,
- Generally positive political relations,
- Higher levels of economic development,

In contrast, facets that tend towards vulnerability would include,

- Rapid environmental change,
- Increased hydrologic variability,
- Rapid population growth or asymmetric economic growth,
- Major unilateral development projects,
- The absence of institutional capacity,
- The potential for "internationalization" of a basin, and
- Generally hostile relations.

When examining all characteristics in combination, it becomes clear that major water projects, such as dams, diversions, or development schemes in the absence of agreements or collaborative organizations that can mitigate for the transboundary impacts of these projects, are the most likely settings for conflict.

Case Studies

Columbia River Basin

The Columbia River Basin (Figure 2) has had a long history of warm cooperation regarding water management, starting with the Boundary

Waters Treaty of 1903. The Columbia River Treaty has been in effect since 1964. The basin has many characteristics that tend to enhance resilience to change, and therefore promote stability.

Columbia River Treaty

During the 1950's, the need for electricity in the United States increased considerably. Canada was also considering its increasing power demands and economic growth (LeMarquand 1977). Flood control was also cited as a primary concern for both countries along the Columbia mainstem, as communities in both nations suffered heavy damages in the 1948 Columbia River flood.

Canada was initially reluctant to proceed with any collaborative flood control projects unless it was assured of receiving some compensation for the unrealized benefits for in the United States (Barrett 1994; Giordano and Wolf 2003a). The United States believed that Canada would want to develop the Columbia River on its side of the border regardless of what the United States wanted, and so felt that it needed to compensate Canada for constructing the project (Dinar 2009) When Canada threatened to construct an alternate project for hydropower on a different river, which would provide the United States with no benefits, the United States heeded the threat as credible. Canada was therefore able to secure a more attractive deal (Barrett 1994).

Future Issues

One of the facets of the Columbia River Treaty is that either party may terminate it in 2024 at the earliest. However, at least ten years notice must be provided (Columbia River Treaty 1964). Because of this, entities in each nation are undertaking studies to elaborate upon options to be explored by 2014 (U.S. Army Corps of Engineers; and Bonneville Power Administration 2009). Some of the changes that are likely to be considered include: the change in empowerment in local communities and Native American and First Nation governments, the change in the viability of populations of anadromous fish that spawn within the Columbia River system, the change in energy demand, and climate change (Cosens 2010).

Analysis of Basin Resilience and Vulnerability

While climate change and the change in the anadromous fish population are facets towards vulnerability of the system, the Columbia River Basin has all of the facets towards resilience in place, as it has generally positive political relations, strong international agreements, a history of collaborative projects and strong economies in both nations. It is important to note, though, that this does not mean that the Columbia River Basin is a completely resilient system. Changes to the ecosystem over time, changes in public participation and changes for the Native American and First Nation governments, to include political empowerment, will all shape future decisions made for the basin.

Zambezi River Basin

The Zambezi River Basin (Figure 3) has fewer characteristics for basin resilience than the Columbia River Basin. With eight riparian states, all of which have developing economies, cooperation is perhaps more difficult to achieve than in the Columbia River Basin.

Two major dams along the mainstream of the Zambezi River have been constructed with international cooperation as a goal: the Kariba Dam (located between Zambia and Zimbabwe) and the Cahora Bassa Dam (located in Mozambique). Zimbabwe and Zambia's agreement (The Agreement between Zambia and Zimbabwe Concerning the Utilization of the Zambezi River), while focusing primarily on the management of the Kariba Dam, has flexibility by including in its scope the possibility of merging future developments on the river in terms of water and other resources (Giordano and Wolf 2003b). The Cahora Bassa Dam was constructed in the early 1970's, during which Mozambique was a colony of Portugal. Colonial authorities built the dam with the anticipated benefits of expanding irrigated farming, stimulating European settlement, increasing mineral output, facilitating communication and transportation throughout the strategic Zambezi Valley, reducing floods, and providing electric power to South Africa (Isaacman and Sneddon 2000).

However, basin-wide cooperation has remained elusive. Attempts at basin-wide cooperation have been made since 1949, where the European



Figure 3. The Zambezi River Basin.

colonies of Northern and Southern Rhodesia, Nyasaland, Portuguese East and West Africa, and the nation of South Africa held the Conference on the Use and Control of the Zambezi River. The establishment of a Zambezi River Authority (which would involve all basin states) was discussed, but was never established. South Africa was against this, fearing that it would influence similar developments in the Limpopo Basin (Chenje 2003).

In 1987, the Southern Africa Development Community developed the "Action Plan for the Environmentally Sound Management of the Common Zambezi River System" and launched the Zambezi River Action Plan (ZACPLAN) to promote joint management of the water resources of the Zambezi River (World Bank 2010). The first detailed negotiations among riparian countries took place in 1998, but negotiations were terminated in the same year (World Bank 2010). The ZACPLAN process, including negotiations on the establishment of the Zambezi River Commission (ZAMCOM), was initiated again in October 2001. An updated version of the ZAMCOM agreement was signed by seven of eight riparian countries in July 2004. The agreement will come into force when six countries ratify the agreement; however, only five have ratified to date (Zambia is awaiting conclusion of the policy reform process and

institutional alignments) (World Bank 2010). In July 2009, in the absence of a ratified agreement, riparian ministers responsible for water adopted an Interim ZAMCOM Governance Structure (World Bank 2010).

Analysis of Basin Resilience and Vulnerability

The Zambezi River Basin has a number of prevailing constraints that limit basin-wide cooperation. The basin has rapid population growth (averaging 2.9 percent annually); widespread poverty; weak legal and institutional frameworks (including monitoring and enforcement); centralized management systems, including fragmented water management approaches and institutions; and pollution (Chenje 2003). One of the weakest areas of management across the basin is within an environmental context. Most basin countries have many environmental standards and regulations to monitor human impacts and to help enforce environmental laws. However, the enforcement of said laws and regulations is hampered by a lack of resources and poor coordination, among other factors (Chenje 2003).

Amu Darya Basin

The Amu Darya river basin covers portions of Tajikistan, Afghanistan, Turkmenistan, Uzbekistan, and Kyrgyzstan. The river originates in Tajikistan and forms the borders of Tajikistan and Afghanistan, Uzbekistan and Afghanistan, and part of the border between Turkmenistan and Uzbekistan. Historically, the river has been used for regional irrigation. Along with the Syr Darya River, it emptied into the Aral Sea (Figure 4). In many years, due to human alteration for intensive cotton agriculture, the Amu Darya does not reach the Aral Sea. The river basin is considered a water crisis region (Martius et al. 2009) and has high water stress, making it at risk for water security concerns.

Given the regional political and economic instability of the former Soviet States, and the current problems within Afghanistan, practical application of a multi-state water resource management plan for the Amu Darya has been weak. An international agreement and body has been established to manage the Aral Sea Basin, called the Interstate Commission for Water Coordination and was signed in 1992 (Martius et al. 2009; Interstate Commission for Water Coordination in Central Asia 2010). Included within this framework is a body that handles the Amu Darya development and management, though it is not clear to what extent the body is efficient.

Tajikistan is the main source of headwaters to the Amu Darya. It is also the poorest Former Soviet country and harnessing the hydroelectric potential of water resources for domestic and international markets offers a way to address economic and energy concerns (Humber and Khrennikov 2010). Tajikistan has signed a trade agreement, the Central Asia-South Asia (CASA-1000) regional electricity project, whereby Tajikistan and Kyrgyzstan will supply electricity to Afghanistan and Pakistan (Central Asian Economy Newswire 2011). Regional partners can benefit from Tajikistan's economic development (Mahmood 2011). Stability in Tajikistan can help

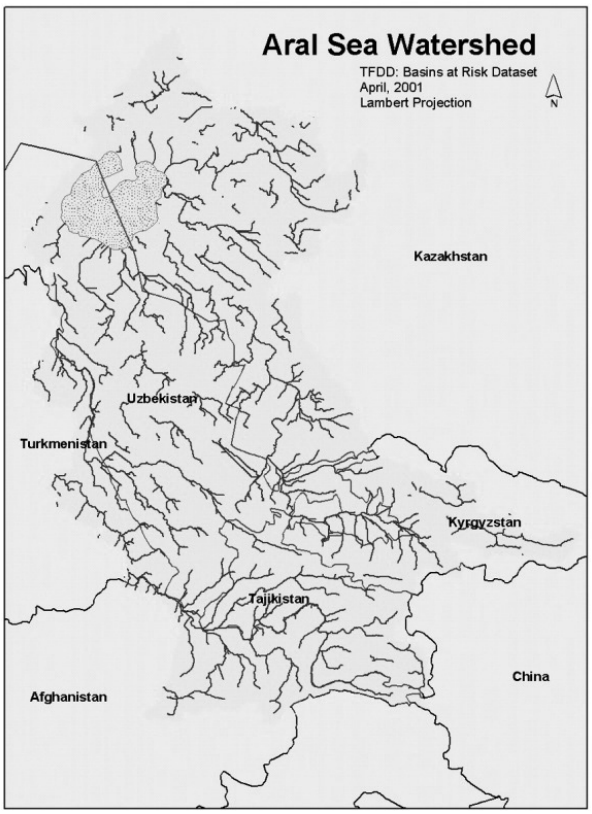


Figure 4. The Aral Sea Watershed.

create regional stability, an issue of particular interest to neighboring country leaders, as well as the United States (Cheema 2012). The Tajikistan government has plans to develop two dams on the Vakhsh River, an upper tributary of the Amu Darya mainstem (TerraDaily 2010). This action has incited public declarations of protest from the Uzbekistan government as well as a blockade of railway transit of supplies from Iran for the dams (Galpern 2009; Central Asia Newswire 2010). Though plans are moving forward with the two dams, there is no solid foreign funding commitment.

Uzbekistan and Turkmenistan are responsible for 83 percent of total river water consumption (Martius et al. 2009). Of Uzbekistan's estimated population of 16 million, 44 percent work in agriculture (CIA World Factbook 2011). Cotton is the main crop, is tightly controlled by the state, and accounts for approximately 40 percent of export earnings (Martius et al. 2009). Despite the central importance of the water to these economies, water resources are said to be managed quite unsustainably (Martius et al. 2009).

Analysis of Basin Vulnerability and Resilience

The Amu Darya Basin appears to be quite vulnerable to additional water and infrastructural changes. The risk to water security is high because of existing uncoordinated water resource management in regard to all the basin users and conflicting needs, as well as uncoordinated development plans in each country. An agreement exists between the basin countries (with the exception of Afghanistan as an observer rather than participant) to manage the Aral Sea Basin. Within this agreement, there is an international framework for the management and development of the Amu Darya. This body could be expanded to handle issues such as the one that currently exists between Tajikistan and Uzbekistan about dam development. Establishment of an outside international body for river management could help coordinate the diplomatic hurdles the countries of Central Asia are currently experiencing in their communication. Regional political and economic instability add to the complexity of shared water resource management, but water could serve as the platform upon which the countries move toward better cooperation.

Legacy culture of state-supported cotton production in Uzbekistan and Turkmenistan are based on a Soviet model of agriculture, and are still state-controlled. Continuation of this unsustainable model, dependent upon an already water-stressed system, can further elevate water security risks. Political legacy from the Soviet era has crippled the Central Asian economies, preventing full entry into the global market, and preventing sizable investment in national infrastructure. Lack of investment in an aging infrastructure creates vulnerability for the entire Basin. Afghanistan experiences regular flood damage along the floodplain, but has plans to develop the river to remove an estimated 10 percent of its flow (Martius et al. 2009). Uncoordinated efforts by the separate countries could lead to further economic and security instability.

The shared water resource itself can also be a source of resilience. The Amu Darya offers a way that these economically and politically challenged countries can develop solutions, if done collaboratively. Even though each country has its own political and economic challenges to solve, the common water resource can offer partial solution to several of the current challenges. Further collaboration and cooperation between countries is necessary to ensure future water security stability.

Conclusion

Examining each of these basins through the factors of hydropolitical resilience and vulnerability reinforces the notion that basins with nations that are more stable economically, environmentally, and politically are better suited to be more hydropolitically resilient. The Columbia River Basin is an example of one basin with a high level of water security. Meanwhile, nations in the Zambezi River Basin have taken steps to increase their water security, but still have much progress to be made. The Amu Darya Basin is politically and economically unstable, with no institutional capacity created to manage transboundary water security issues.

Author Bios and Contact Information

Jacob D. Petersen-Perlman is a Ph.D. Candidate in Geography in the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University. His research interests include water resources and their management in the U.S. and transboundary conflict and cooperation. He is currently conducting field research in the Columbia River Basin of North America and the Zambezi River Basin of Southern Africa. He can be reached at petersej@geo.oregonstate.edu.

Jennifer C. Veilleux is a research assistant and Ph.D. Candidate of Geography in the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University. Her research focuses on water and human security issues surrounding the management of and alterations to transboundary water systems. Her background is in environmental hydrogeology. She is currently conducting field research in the Blue Nile Basin of Ethiopia and the Amu Darya Basin of Central Asia. She can be reached at veilleuj@geo.oregonstate.edu.

Matthew A. Zentner is a hydrologist for the United States Department of Defense. He has a Ph.D. in Geography from Oregon State University, with research interests that include international water law and water resources management. He can be reached at msizentner@gmail.com.

Aaron T. Wolf is a professor of geography in the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University. His research and teaching focus is on the interaction between water science and water policy, particularly as related to conflict prevention and resolution. A trained mediator/facilitator, he directs the Program in Water Conflict Management and Transformation, through which he has offered workshops, facilitations, and mediation in basins throughout the world. He can be reached at wolfa@geo.oregonstate.edu.

References

Allan, J.A. 2001. *The Middle East Water Question: Hydropolitics and the Global Economy*. London: I.B. Tauris.

Barnett, J. 2003. Security and climate change. *Global Environmental Change* 13: 7-17.

Barrett, S. 1994. Conflict and cooperation in managing international water resources. Policy Research Working Paper #1303. Washington, DC: The World Bank.

Bolte, J.P., D.W. Hulse, S.V. Gregory, and C. Smith. 2004. Modeling biocomplexity—actors, landscapes and alternative futures. Keynote speech, proceedings from the International Environmental Modelling and Software Society, Conference on Complexity and Integrated Resources Management, University of Osnabrück, Germany, 14-17 June 2004.

Brown, O., A. Hammill, and R. McLeman. 2007. Climate change as the 'new' security threat: implications for Africa. *International Affairs* 83(6): 1141-1154.

Buzan, B. 2001. Losing control: global security in the twenty-first century. *International Affairs* 77(3): 696-696.

Buzan, B. 2000. Security communities. *International Affairs* 76(1): 154-154.

Buzan, B. and O. Waever. 2009. Macrosecuritisation and security constellations: reconsidering scale in securitisation theory. *Review of International Studies* 35(2): 253-276.

Central Asia Economy Newswire. 2011. CASA-1000 electricity project hits obstacles. October 12, 2011. Universal Newswires. Available at: http://www.universalnewswires.com/centralasia/economy/viewstory.aspx?id=10413.

Cheema, Z. 2012. Pipelinestan re-aligns as US-Pakistan relations unravel. January 9, 2012. Media Monitors Network. Available at: http://usa.mediamonitors.net/content/view/full/93120.

Chenje, M. 2003. Hydropolitics and the quest of the Zambezi River-Basin Organization. In Nayakama, M. (Ed.) *International Waters in Southern Africa.* Tokyo: United Nations University, 189-208.

CIA World Factbook. 2011. Uzbekistan Country Profile: Economic Overview. Available at: https://www.cia.gov/library/publications/the-world-factbook/geos/uz.html.

Cosens, B. 2010. Transboundary river governance in the face of uncertainty: Resilience Theory and the Columbia River Treaty. *Journal of Land, Resources & Environmental Law* 30 (2): 229-265.

Dabelko, G. 2008. An uncommon peace: Environment, development, and the global security agenda. *Environment* 50(3): 33-45.

Dinar, S. 2009. Power asymmetry and negotiations in international river basins. *International Negotiation* 14(1): 329-360.

Eckstein, G. 2010. Water scarcity, conflict, and security in a climate change world: Challenges and opportunities for international law and policy. *Wisconsin International Law Journal* 27(3): 411-424.

Galpern, E. 2009. Tajikistan's water, its dams, and Central Asia. *Foreign Policy* (blogs). Available at: http://foreignpolicyblogs.com/2009/02/17/tajikistans-water-its-dams-and-central-asia/.

Giordano, M. and A.T. Wolf. 2003a. Sharing waters: Post-Rio international water management. *Natural Resources Forum* 27: 163-171.

Giordano, M. and A.T. Wolf. 2003b. Transboundary freshwater treaties. In: Nayakama, M. (Ed.) *International Waters in Southern Africa.* Tokyo: United Nations University, 71-100.

Gleick, P. 1999. The human right to water. *Water Policy* 1(5): 487-503.

Gunderson, L.H. and L. Pritchard. 2002. *Resilience and the behavior of large-scale systems*. Washington, DC: Island Press.

Humber, Y. and I. Khrennikov. 2010. Tajikistan Plans People's IPO for Hydropower 'Plant of Destiny'. Bloomberg. Available at: http://www.bloomberg.com/apps/news?pid=newsarchive&sid=abc7TKT28nNI.

Interstate Commission for Water Coordination in Central Asia. Available at: http://www.icwc-aral.uz/.

Isaacman, A. and C. Sneddon. 2000. Toward a Social and Environmental History of the Cahora Bassa Dam. *Journal of Southern African Studies* 26(4): 597-632.

LeMarquand, D.G. 1977. *International rivers: The politics of cooperation*. Vancouver, Canada: University of British Columbia, Westwater Research Centre.

Lonergan, S., K. Gustavson, and B. Carter. 2000. The index of human insecurity. AVISO Bulletin, Ottowa, ON: GECHS, 6: 1-11.

Mahmood, J. 2011. Pakistan, Tajikistan pledge to combat terror: Al-Qaeda can shatter peace in Central Asia, Rakhmon says. Central Asia Online. 03-09-2011. Available at: http://centralasiaonline.com/en_GB/articles/caii/features/main/2011/03/09/feature-02.

Martius, C., J. Froebrich, and E.A. Nuppenau. 2009. Water Resource Management for Improving Environmental Security and Rural Livelihoods in the Irrigated Amu Darya Lowlands. *Hexagon Series on Human and Environmental Security and Peace* 4(7): 749-761.

Mabey, N. 2007. Security trends and threat misperceptions. In P. Cornish (Ed.) *Britain and Security*. The Smith Institute.

Stone, M. 2009. Security according to Buzan: A comprehensive security analysis. Security Discussion Papers Series 1 Columbia University, School of International and Public Affairs.

Swart, R. 1996. Security risks of global environmental changes. *Global Environmental Change-Human and Policy Dimensions* 6(3): 187-192.

TerraDaily. 2010. "Tajikistan dam project hit by controversy." April 27, 2010. TerraDaily, news about planet earth. Available at: http://www.terradaily.com/reports/Tajikistan_dam_project_hit_by_controversy_999.html.

Treaty Between Canada and the United States of America Relating to Cooperative Development of the Water Resources of the Columbia River Basin ("Columbia River Treaty"), U.S.-Can., Jan. 17, 1961. Available at: http://www.ccrh.org/comm/river/docs/cotreaty.htm.

Turner, B.L. II, R.E. Kasperson, P.A. Matson, J.J. McCarthy, R.W. Corell, L. Christensen, N. Eckley, J.X. Kasperson, A. Luers, M.L. Martello, C. Polsky, A. Pulsipher, and A. Schiller. 2003. A framework for vulnerability analysis in sustainability science. *Proceedings of the National Academy of Science* (USA) 100(14): 8074-8079.

U.S. Army Corps of Engineers and Bonneville Power Administration. 2009. Columbia River Treaty: 2012/2024 Review: Phase 1 Technical Studies. Available at: http://www.bpa.gov/corporate/pubs/Columbia_River_Treaty_Review__2_-_April_2009.pdf.

Wolf, A.T., S.B. Yoffe, and M. Giordano. 2003. International waters: identifying basins at risk. *Water Policy* 5(1): 29-60.

World Bank. 2010. The Zambezi River Basin: A multisector investment opportunity analysis. Volume 1: Summary Report. Available at: http://water.worldbank.org/water/node/83707.

World Health Organization. 2000. Global Water Supply and Sanitation Assessment 2000 Report. Available at: http://www.who.int/docstore/water_sanitation_health/Globassessment/GlobalTOC.htm.

Universities Council on Water Resources
Journal of Contemporary Water Research & Education
Issue 149, Pages 13-21, December 2012

Water Modeling Technologies: A Key to Unlocking Water Conflict in the Middle East?

Al-Sharif Nasser Bin Nasser

Middle East Scientific Institute for Security, Amman, Jordan

Abstract: Several cases of armed conflict in the Middle East have a root cause in competition over resources, with water being the focus of conflict. Water will increasingly become a critical trigger for future conflict as supplies become scarcer and as population pressures continue to grow. With existing talks between riparian countries surrounding the Jordan River and the Tigris-Euphrates Basins either being absent or ineffective, there is a pressing need to develop a new approach to resolve water issues in the Middle East. In this context, water modeling technologies may offer a new and unique tool for regional discussions.

Keywords: *Middle East water conflict, water modeling, Jordan water crisis*

The Arab Human Development Report (2009) emphasizes the importance of the relationship between resource pressures, environmental sustainability, and human security in the Middle East region. The impact of environmental factors on regional security and stability is increasingly being recognized as a trigger for potential future conflict.

Several instances of armed conflict in the Middle East over the past sixty years have water disputes as a root cause. The region has witnessed thirteen developmental disputes over water since 1950, eleven of which resulted in armed conflict or military maneuvers including, many argue, the 1967 War (Gleick 1993; Wolf 1995). This number reaches thirty-five when counting conflicts where the military target or the military tool was water. An example of the former would be when Israel led two air raids in 1969 to destroy the newly-built East Ghor Canal based on the suspicion that Jordan was over diverting the Yarmouk River. An example of the latter is when Turkey threatened to restrict water flow to Syria in 1990 to force it to withdraw support for Kurdish rebels.

Going forward, the conflict over water will be exacerbated by continued population and demographic pressures, increasing resource consumption, decreasing resource availability, climate change, desertification, and other factors. This will make water the most valuable strategic commodity in the region, far outweighing the importance of oil. This is echoed by Dr. Ismail Serageldin, the Former World Bank Vice President, who said that many of the wars of the 20th century were about oil, but the wars of this century will be about water (Serageldin 1997).

Various experts claim the Middle East has long entered a stage of water poverty, based on available per capita renewable water resources one seventh the worldwide average. It is believed that by the year 2025, three hundred million people in the Arab world will be living under conditions of what the UN defines as "absolute water scarcity" with about 500 cubic meters of water per person per year. To put this in perspective, the US currently uses close to 70,000 cubic meters of water per person per year (Joint Arab Economic Report 2001; Watkins 2006).

What makes the water situation in the Middle East all the more critical is that water resources are spread over several countries, yet the management of these resources are largely national tasks.

The main supply of freshwater in the Middle East for the countries of Turkey, Lebanon, Syria and Iraq are surface water sources while the main supply for the countries of Jordan, Palestine and Israel are ground water resources. The major international rivers in the region include:

1. The Jordan River (including its largest tributary the Yarmouk), shared by, Jordan, Palestine, Israel, Lebanon, and Syria;
2. The Tigris and the Euphrates, both shared by Iraq, Syria and Turkey;
3. The Orontes (or Assi), shared by Lebanon, Syria, and Turkey; and
4. The Nile, shared by ten riparian countries.

For the purposes of this study, the focus will be on the first two. There are also a number of shared renewable ground water aquifers in the border areas between:

1. Syria and Turkey,
2. Israel and Lebanon,
3. Jordan and Syria,
4. Iraq and Syria; and
5. Israel and the West Bank.

Others are non-renewable aquifers containing fossil water:

1. The basalt aquifer beneath Jordan and Saudi Arabia; and
2. Beneath the Arabian Peninsula shared by Iraq, Jordan, and Syria.

On the transboundary level, any disruption in either surface or ground water in any of these countries will have serious implications for other riparian countries. Although both the quantity and quality of water is affected by any disruption, the focus of this study will be on the quantity.

The inability of any one country to effectively manage its water resources in isolation from other riparian countries has resulted in the establishment of formal agreements on the management of shared water resources. However, none have resulted in the creation of mechanisms for shared management that are considered to be comprehensive and equitable. The main reason is that cooperation remains heavily influenced by prevailing political conditions. Existing mechanisms to discuss water issues are either seen as confidence building measures, negotiating platforms, or places where technical grievances can be aired, but rarely resolved.

The use of modeling and simulation technologies has been a hitherto overlooked concept in Middle East hydro-politics. These could offer decision-makers with a new and additional tool, as well as approach, to accelerate joint understanding of resource issues and herald cooperation on joint basin management. System dynamics modeling approaches have been emerging as a key management tool addressing transboundary water issues, first in the United States, and now elsewhere. These models can assess multiple future population growth estimates, resource demand and resource management scenarios surrounding a river basin, and evaluate the costs and benefits of different approaches to manage that basin. The models with short run times allow users to simulate many alternative resource management strategies in short periods, making the models valuable for substantive discussions and for informing and educating stakeholders, policy makers, and citizens. Successfully completed model realizations allow stakeholders to thoroughly evaluate the long-term consequences of competing resource management strategies. The completed model allows stakeholders to:

> Evaluate in a rigorous way the long-term consequences of competing resource management strategies. The collaborative discovery process associated with this work, the insight gained by the stakeholders and the modelers, and the model results themselves all combine to assist in the development of strong, scientifically-derived resource management plans, often with a greater degree of consensus among stakeholders than might otherwise have been achieved (Pasell et al. 2010).

The unique characteristic of modeling technologies as apolitical, non-ideological, and science-based tools make them well-suited for the Middle East. The Royal Society in the United Kingdom has focused extensively on the role that scientific communities and technological tools can play in furthering stability in zones of conflict.

The uniqueness of what the Royal Society refers to as "Science Diplomacy" is that it is difficult, if not near impossible, to replicate the universality, transparency, and rationality of scientific values in the political context. Just as importantly, the Royal Society also concludes that establishing and nurturing links between the scientific and foreign policy communities informs scientists and policy makers alike: the former about the realities of policy making; and the latter about the role and limits of science in policy (The Royal Society 2010).

Publicized Use of Systems Dynamics Modeling

A pioneering case for modeling technology began over ten years ago by Sandia National Laboratories and resulted in the creation of a resource model to assist in community-based planning for a three-county region centered on the Rio Grande in New Mexico. Population growth and drought had been main factors contributing to the decision of the Rio Grande community to mobilize and develop a solution to balance their water supply with the pressing demands of a wide range of stakeholders. Coupled with the wide seasonal variation and the semi-arid region, these conditions seem in fact quite similar to the Middle East. The model sought to provide a quantitative basis for comparing alternative water conservation strategies in terms of water savings and costs; to help the public understand the complexity of the regional water system and to engage the public in the decision-making process. The latter was seen as a key factor to the success of this effort.

Construction of the model began in January 2002 and working versions of the model were released and applied to the regional planning process in spring and summer of 2003. While Sandia National Laboratories were responsible for developing the model within the system dynamics framework, organizations from the community were responsible for ensuring that the views of the public and key constituency groups were represented and academic institutions were involved to facilitate group discussions (Tidwell et al. 2004). Selection of the appropriate architecture for the planning model needed to integrate the disparate physical and social systems important to water resource management, while providing an interactive environment for engaging the public (Tidwell et al. 2004).

The result was a PC-based system dynamics model that could generate simulations in less than 10 seconds using sixty-six variables to simulate combinations of hydrological, economic, or demographic conditions. This interactive modeling platform allowed users to visualize problems and their potential solutions and develop different management strategies for each. It could also take into account a variety of new fictional developments into the simulations.

This tool eventually assisted decision-makers and other stakeholders to prepare a 50-year water plan for the Rio Grande River Basin. Discussing the case of the Rio Grande is not meant to diminish from the particularities of Middle East water conflicts. There are many factors in the Middle Eastern context, such as the recent history of conflict and the primacy of ideological politics, that are entirely absent in the case of New Mexico. The discussion of this case is merely meant to illustrate that the technological tools that would allow for joint management over regional river basins are available should the political will also be available and should the prevailing political conditions also allow for it.

Middle Eastern Cases Where Modeling Could Be Used

The Jordan River Basin

The Jordan River is a good example of the complexity of transboundary water issues in the Middle East as it is shared by five countries that have historically been at conflict (Figure 1). Despite the projections that the Jordan River is expected to drop by 80 percent by the end of the century as a result of both climate change and overuse, there is still no basin-level cooperation for its joint management or use (Brown et al. 2009). Excessive dam building and diversion has severely depleted the amount of water flowing in the River and its main tributaries. The future of the Jordan River is also affected by the currently negligible flow of water from Lake Tiberias, also called Sea of



Figure 1. The Jordan River and its feeder rivers are effectively shared by Lebanon, Syria, Israel, Jordan and Palestine (modified from http://en.wikipedia.org/wiki/File:JordanRiver_en.svg).

Galilee, which is subject to the continued conflict between Syria and Israel. In the 1960's the flow of the Jordan River at the Dead Sea was measured at 13,000 million cubic meters (MCM) annually. Today, the flow measures about 100-200 MCM in a wet year and about 10 percent of that in a dry period (Waslekar 2011). Overuse of some parts of the Zarqa River (a tributary located in Jordan) has reduced base flows into the Jordan River to such an extent that most of its summer flow is comprised of treated wastewater.

Likewise, flows of the Yarmouk River (which originates at the border between Jordan and Syria) have decreased by 80-90 percent over the past ten years mostly due to Syrian over-extraction and dam construction (Waslekar 2011). The complexity of the water situation is exacerbated by other political calculations. As a Syrian decision to increase the flow of water of the Yarmouk River will help Jordan but, would also be favorable to Israel, the river has at times been one of several pressure tools for Syria in its broader negotiations with Israel on any number of other topics. The same is also true of Syria's use of the Yarmouk vis-à-vis Jordan.

Jordanian-Syrian discussions on water have not had a positive track record. In 1987, Jordan and Syria signed an agreement that determined the division of water between the two countries, specified the number of ditches that could be built along the river and proposed a joint dam (Treaty Series 2001). At the time, Jordan's share was set at 300 MCM. Presently, Jordan receives only 50-100 MCM. Since the time of the agreement, Jordan has complained that Syria has set up more than 40 dams, ditches, and pumping facilities to store water along the river. Jordan and Syria have regularly disagreed over these figures as well as the amount of Syrian water being extracted for use. A Jordanian initiative spearheaded in the 2006 period led to an agreement to geologically study the Yarmouk Basin. Terms of reference were developed for a Jordanian and a Syrian company to jointly conduct the study as a means to avert disagreement. For reasons believed to be motivated by other regional political considerations, Syria rescinded on this agreement, claiming that the basin could not be studied in its totality because an important part of it was under Israeli territory. Given that Jordan and Syria are estimated to jointly cover 90 percent of the Basin, the Jordanian suggestion was to model the remaining 10 percent. This was the first such mention of modeling tools in bilateral discussions on water. Syria rejected the proposal and blocked Jordanian technical teams from installing recorders in Syria to verify Syria's data (originally seen as a confidence-building measure). Syria was also against the existence of direct channels of communication and cooperation between the two companies that were meant to prepare the basin study.

Since the conclusion of separate Palestinian-Israeli and Jordanian-Israeli peace treaties in 1993 and 1994 respectively, the three sides have established consultative mechanisms to discuss water issues. In January 1995, the Executive Action Committee Team (EXACT) was born out of multi-lateral working groups that were formed to advance the Middle East Peace Process. Supported by the governments of the United States, European Union, Canada, and France, the Committee meets twice each year to plan, coordinate, and direct

project implementation and to share information and keep dialogue open regarding shared water resources (EXACT online portal). Although there has been a genuine willingness on all sides to address water issues, the results have been at times mixed. One success of EXACT has been the Water Data Banks Project that consists of a series of specific actions to be taken by each party to foster the adoption of common, standardized data collection and storage techniques, improve the quality of the water resources data collected in the region, and improve communication among the water experts in each country (EXACT online portal). The project's goal to enable the exchange of consistent, compatible, and reliable water data and information to support decision-making at both local and regional scales is an important starting point for substantive discussions on water. There is an understanding that addressing capacity gaps, improving data, and harmonizing practices are vital; they are only the foundation through which there can be more substantial joint water management in the future. Water discussions between all sides are still heavily influenced by political developments, foremost amongst them is the Palestinian-Israeli peace process. The absence of a long-lasting and genuine peace between Palestine and Israel and the lack of progress on the establishment of an independent Palestinian state make any cooperation between Jordan and Israel difficult, let alone the cooperation between the Palestinian Authority and Israel.

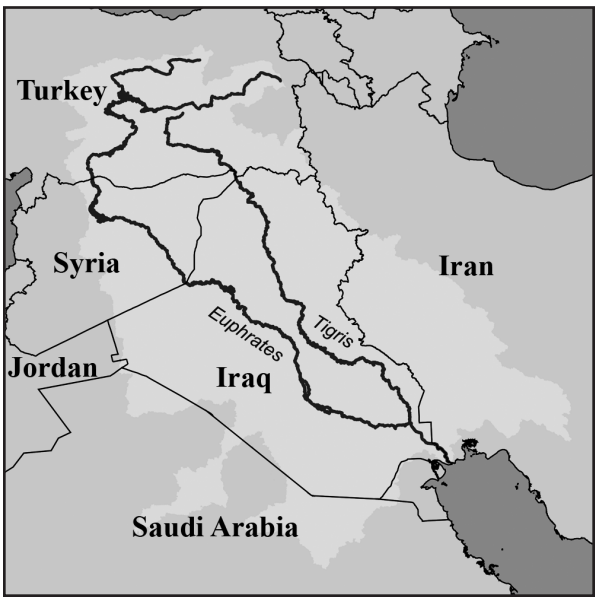


Figure 2. The Euphrates and Tigris originate in Turkey. While the Euphrates flows continues through both Syria and Iraq, the Tigris flows through Iraq only (modified from http://en.wikipedia.org/wiki/File:Tigr-euph.png).

The Euphrates-Tigris Basin

Turkey, Syria, and Iraq all share the Tigris-Euphrates Rivers that originate in eastern Turkey and flow southwards into the Arabian Gulf passing through Syria and Iraq (see Figure 2). The rivers are connected when they merge at the Shatt al-Arab in Iraq. The waterways have long been a source of contention and conflict between the three countries.

The long-term flows of Tigris and Euphrates is declining on account of natural, as well as man-made, factors. The Euphrates River may shrink by 30 percent by 2100 on account of climate change only. There are 32 major dams on the Euphrates and Tigris, with 8 under construction and 13 more planned (Brown et al. 2009). As a result, total storage of dams on the Euphrates is five times its average annual flow with a projected deficit of 2-12 billion cubic meter (BCM) by 2020 if all plans are realized and a surplus of 8-9.7 BCM in the Tigris (Waslekar 2011).

Syria and Iraq have long argued that Turkey's various implemented and planned development projects, including the ambitious 21-dam South-Eastern Anatolia Project (UNEP 2008), have already, and will further, decrease the flow of water running from Turkey to Syria. This in turn would have a direct impact on water agreements between Syria and Iraq over the Euphrates. The project consists of 21 large dams and a price tag of more than $20 billion. Turkey currently has 2000 dams and water projects, of which the largest 260 dams have a storage capacity of 140 BCM (Waslekar 2011).

As with the earlier case, there is also a great amount of contradictory data from each country about the extent of irrigated land, current and projected demand, and economic and industrial development. Turkey claims that both Syrian and Iraqi water needs are overestimated and claim bad management and water loss in both countries is

at the root of their problems. Turkey also maintains that both rivers are sovereign rights of Turkey, as President Suleyman Demirel said during the inauguration of the Ataturk Dam, "Neither Syria nor Iraq can lay claim to Turkey's rivers any more than Ankara could claim their oil. This is a matter of sovereignty. We have a right to do anything we like" (Bulloch and Darwish 1993).

While several bilateral and trilateral meetings have been held, no formal agreements have been reached. A Joint Technical Committee (JTC) between Turkey and Iraq was established in 1980, which Syria joined in 1983. The JTC held sixteen meetings over a decade but did not fulfill any of its objectives. In 1987, an agreement between Turkey and Syria guaranteed the latter a minimum flow of the Euphrates of approximately 15.7 BCM per year or 500 m/s (United Nations Treaty Collections). As per a previous agreement, Syria is obliged to allow about 9.2 BCM to Iraq, leaving 6.7 BCM for its own use. Since the construction of the Ataturk Dam, Syria has accused Turkey of violating this agreement and allowing less water to flow downstream and has supported Kurdish rebels to place pressure on Turkey (Jongerden 2010; Kinzer 1999).

More recent cooperation has proved more fruitful. In 2007, at the behest of Turkey, the three countries agreed to reinstate the JTC meetings which had stopped since 1992. At the first such meeting, numerous areas were defined for cooperation, but most rested on information sharing. The greatest instance of cooperation came in 2009 when an agreement was reached to set up joint measurement stations on the Tigris and Euphrates rivers to track the flow and condition of the river (Joint Statement meetings 2009). This has been a monumental step in the cooperation between the three countries; however, the results of the agreement are yet to be seen. Skeptics believe that the agreement was largely ad hoc and in response to the prolonged drought that Iraq had been witnessing that season.

How Modeling Technologies Can Help

Existing water discussions in the Middle East are for the most part short-term in nature in that agreements are ad hoc and crisis-driven. Even when there is some level of longer-term discussion, as is the case between Jordan, the Palestinians, and Israel, the discussion is not yet at the point where it is basin-level. This is primarily because all three sides likely see that there is little sense in begining such an endeavor when a number of basin countries are not represented. Systems dynamics modeling tools allow for countries already engaged in meaningful discussions to begin such talks using simulated data in lieu of the missing data. At worst, this will raise capacity and awareness about these technologies in anticipation of a time when a greater number of basin countries will be represented in some form or another.

One of the reasons why the system dynamics model is suitable for the Middle East is that it is stakeholder driven. In the context of Middle Eastern hydro-politics, this means that the model will be able to represent the various, at times contradictory, data presented by each country. As the cases of the Jordan River and Euphrates-Tigris Basins illustrate, riparian countries regularly claim drastically differing and contradictory data about their water situation, usage, and needs. At times, contradictory claims can simultaneously be true because countries can focus on data collected in a particular season and/or location to support their claim. System dynamics models are able to adjust for this occurrence by allowing for all data to be incorporated and represented in scenario building. This would lead to a radical shift in the existing discussions on water away from accusations about accuracy and towards projections built around each version of the "truth." The purpose of eliminating the issue of data provenance would inform policy-makers about the impact of their own activities, whether real or fabricated, on the larger picture. This tool would also work where there is data secrecy on water issues, as is the case in Syria.

There is also chance that system dynamics models will encourage the region to shed the zero-sum formulation that has characterized discussions on water in the region. A concept of collective security can only be established when water discussions begin to focus on the basin-level. This is because basin-level discussions inherently suggest a longer-term view of water. This could have the impact of discouraging countries from pursuing shorter-term gains at the expense of longer-term costs. In a sense, whether Syria is genuinely

extracting its share of the Yarmouk or well above it becomes less relevant than a simulation illustrating that current practices will render the entire basin unusable in a given number of years.

Even in cases where conflict is ongoing, as in the Syrian-Israeli case, systems dynamics modeling can encourage some level of understanding without the need for direct talks. As Lake Tiberias is a joint and important resource for all riparian countries, the shared interest in preserving it needs to be enacted in some way. Should Syria and Israel separately use the same systems dynamics modeling tools, it could be the only way in which the Tiberias could be managed in the absence of direct talks.

The Euphrates-Tigris Basin illustrates that there is a need for greater democratization in resource planning between upper riparian countries like Turkey on the one hand and lower riparian countries like Syria and Iraq on the other. This is possible when systems dynamics modeling tools are used because each country will have access to the same tools and no one country will be able to dictate a best course of action. Technology of this sort levels the playing field and decreases instances where weaker states are coerced into unfavorable and unsustainable agreements.

Adopting modeling technologies in water discussions in the Middle East will play an important role in raising awareness of the complexity of regional water issues among the general public. Currently, the general public in most Middle East countries are unaware of the seriousness of their own water situation and also of the extent to which the solution depends on the success of regional cooperation. A broader discussion about the basin-level issues in the region using modeling tools can be an opportunity to educate the public on both of these issues. Extremism and ideological politics are on the rise in the region and tools of this sort could serve to instill a sense of realism and pragmatism in dealing with neighbors, whether Arab or Israeli, as the models are science-based and rooted in fact. What the general public does not seem to recognize is that even the most ardent of adversaries need to depend on each other (or reach unspoken understandings) on issues like water for survival. Adopting a stakeholder driven model will allow civil society to play a greater role in these discussions and will take away the burden on governments to reach solutions on these issues alone.

Finally, the adoption of such integrated modeling tools can offer the region a more comprehensive view of water as it relates to a wider range of socio-economic issues. In the case of Jordanian-Israeli-Palestinian talks, for instance, there has been, to a certain extent, some level of stove-piping when examining water issues in isolation of other issues such as energy or public health. For instance, His Royal Highness Prince Hassan Bin Talal of Jordan has long called for an energy/water nexus as the building blocks of a new Middle East. In his proposal, the parallel is drawn to the role that coal and steel played in stabilizing post-war Europe (NATO Defense College 2010). Should this type of thinking prevail, modeling tools would be needed because they can incorporate as wide as needed a range of inputs. This type of tool could also be used to prioritize investment opportunities or weigh the environmental and social impact of some water schemes. The use of such modeling tools in the Jordanian-Israeli-Palestinian context would reemphasize the importance of technology in the three-legged stool that also includes people and processes as the two other legs.

Conclusion

The Middle East has witnessed tumultuous changes in 2011 and 2012. It is still unclear whether these changes will yield long-lasting positive results. No matter what the outcome, water will remain a persistent and common problem requiring a common solution by all countries in the region. Water modeling technologies could very well be the common solution that would lay the foundation for future joint basin management. Adopting such innovative solutions can reduce the threat of water scarcity and simultaneously contribute to prosperity and peace. While peace is needed for cooperation in water, a collaborative and sustainable approach to water management can build peace. This change in paradigm – from viewing water as an obstacle to viewing water as an opportunity – is the subject of the most exhaustive regional study of water conducted by the Mumbai-based Strategic Foresight Group. The best chance to create that change in paradigm is through water modeling technologies.

Water modeling tools are not predictive tools and should not be resisted because of this concern. All regional countries can stand to benefit from their adoption. The tools are instructive in nature and will allow for a roadmap and commonality of approach in resolving the water issues that have afflicted the region for so long.

Author Bio and Contact Information

Al-Sharif Nasser bin Nasser is the Managing Director of the Middle East Scientific Institute for Security (MESIS) based in Amman, Jordan. In this position, Mr. Nasser focuses on developing and implementing regional and national training programs in the areas of energy, environment and borders with a specific focus on non-proliferation issues. He also works to raise awareness on critical issues by creating a neutral space for scientific communities to interact and discuss shared vulnerabilities and opportunities across the Middle East region.

Nasser is also the first director of the European Union's soon-to-be-inaugurated Regional Centre of Excellence on CBRN issues located in Amman, Jordan which will serve five Arab countries.

Prior to that, Nasser worked in the office of His Majesty King Abdullah II of Jordan where he last served as Senior Analyst in the Foreign Affairs Directorate. During that time, he managed several bilateral and thematic files and led analytical studies on Jordan's regional and international relations.

Nasser is also involved with numerous organizations. He served as the Chairman of a leading insurance company in Jordan, and currently serves as the Vice-Chairman of a public national commission offering support to injured and disabled veterans as well as the President of a charity that offers therapeutic riding services to children with special needs.

He received his master's degree in Near Eastern Studies from Princeton University and his undergraduate degree in Environmental Science and Policy and Business Management from Clark University in Worcester, Massachusetts. Nasser is also the chair of the Princeton alumni committee in Jordan. He can be contacted at shnasser@mesis.jo or Middle East Scientific Institute for Security (MESIS) P.O. Box1438 Amman 11941, Jordan.

References

Arab Human Development Report. 2009. Challenges to Human Security in the Arab Countries. *United Nations Development Program*; Regional Bureau for Arab States. United Nations Publications: New York.

Brown, O. and A. Crawford. 2009. *Rising Temperatures, Rising Tensions: Climate change and the risk of violent conflict in the Middle East.* International Institute for Sustainable Development: Winnipeg.

Bulloch, J. and A. Darwish. 1993. *Water wars: Coming conflicts in the Middle East*. Gollancz: London.

Gleick, P.H. 1993. Water and conflict: Fresh Water Resources and International Security. *International Security* 18: 79-112.

HRH Prince El Hassan. 2010. Supranational Security and the Energy Ellipse. Speech at NATO Defence College, Rome.

Joint Arab Economic Report. 2001. Arab Monetary Fund, Arab Fund for Economic and Social Development, League of Arab States and Organization of Arab Petroleum Exporting Countries (in Arabic): Cairo.

Joint Statement of the First Meeting of the High Level Strategic Cooperation Council Between the Syrian Arab Republic and the Republic of Turkey, Damascus, December 22-23, 2009. Available at: http://www.mfa.gov.tr/turkiye---suriye-ydsik-1_-toplantisi-ortak-bildirisi_-22-23-aralik_-sam.en.mfa.

Jongerden, J. 2010. Dams and Politics in Turkey: Utilizing Water, Developing Conflict. *Middle East Policy* XVii, no. 1, Spring: 137-148.

Kinzer, S. 1999. Where Kurds Seek a Land, Turks Want the Water. *New York Times*.

Passell, H., M. Reno, J. Roach, V. Tidwell, and W. Khairy. 2010. Collaborative, Stakeholder-Driven Resource Modeling and Management. In *Handbook of Research on Hydroinformatics: Technologies, Theories and Applications*. T. Gamelseid (Ed.) IGI Global Press: Hershey: 37.

The Royal Society. 2010. New Frontiers in Science Diplomacy: Navigating the changing balance of power. London.

Serageldin, I. 1997. Water Diplomacy and the 21st Century: From Conflict to Cooperation. Associated Event of the Fifth World Bank Conference, Washington, DC, 10 Oct. 1997.

Tidwell, V., H.D. Passell, S.H. Conrad, and R.P. Thomas. 2004. System dynamics modeling for community-based water planning: Application to the Middle Rio Grande. *Aquatic Sciences* 2004: 357-372.

Treaty Series: Treaties and international agreements registered or filed and recorded with the Secretariat of the United Nations Vol. 1870 I Nos. 31875-31939: *United Nations Treaty Collections* 279-297.

United Nations, Syrian Arab Republic and Turkey: Protocol on Matters Pertaining to Economic Cooperation Signed at Damascus on 17 July 1987 Vol. 1724, 1-30069: *United Nations Treaty Collections* 3-8.

United Nations Environment Programme. 2008. Vital Water Graphics: An Overview of the State of the World's Fresh and Marine Waters 2nd Edition. United Nations Environment Programme.

Waslekar, S. 2011. The Blue Peace: Rethinking Middle East Water. Strategic Foresight Group: Mumbai.

Watkins, K. 2006. Beyond scarcity: Power, Poverty and the Global Water Crisis. United Nations Development Program. *Human Development Report*. Palgrave Macmillan: New York.

Website Maintained by the Executive Action Team (EXACT), the Multilateral Working Group on Water Resources and Water Data Banks Project, Available at: http://exact-me.org/index.htm.

Wolf, A.T. 1995. *Hydropolitics Along the Jordan River: Scarce water and its impact on the Arab-Israeli conflict*. United Nations University Press: New York.

Universities Council on Water Resources
Journal of Contemporary Water Research & Education
Issue 149, Pages 22-32, December 2012

Hydrostrategy, Hydropolitics, and Security in the Kura-Araks Basin of the South Caucasus

Michael E. Campana[1], Berrin Basak Vener[2], and Baek Soo Lee[1]

[1]Oregon State University, Corvallis, OR; [2]University of New Mexico, Albuquerque, NM

Abstract: After the Soviet Union's dissolution, the Kura-Araks Basin became an international river basin with respect to the South Caucasus states of Armenia, Azerbaijan, and Georgia. Despite differences among these countries, they depend greatly on the Kura-Araks Basin. They proposed to jointly monitor Kura-Araks Basin surface water quality and obtained funding to do so from the North Atlantic Treaty Organization's Science for Peace Programme. Thus, the South Caucasus River Monitoring Project was born in late 2002. The South Caucasus River Monitoring Project formally ended in December 2009, and was a model of collaboration and cooperation in a region where such traits have at times been in short supply. Not only were valuable data collected, but collegial professional relationships also were forged among the participants. In the long run, this latter aspect will likely prove to be the most important product, not just for the South Caucasus, but for others as well.

Keywords: *South Caucasus, water*

"People are willing to do horrible things to each other. What they seem not willing to do is turn off each other's water." – Aaron T. Wolf

The South Caucasus region is comprised of Georgia, Armenia, and Azerbaijan. The region is bordered by the Black Sea to the west, the Caspian Sea to the east, the Caucasus Mountains and Russia to the north, and Turkey and Iran to the south (Figure 1). The three countries have a total population of about 16 million, with Azerbaijan comprising almost 50 percent of the total (Table 1).

The three countries gained their independence from the USSR in 1991. After the USSR was dismantled, industrial production, which was very well established in the 1970's and 1980's, sharply declined in the region because of the energy crisis and the dissolution of economic ties among the former Soviet Republics. In the ten years following the USSR's demise, gross domestic product decreased by about 50 percent, poverty levels reached 60 percent, and unemployment skyrocketed (Swedish International Development Cooperation Agency 2002). On top of these problems the region was faced with environmental degradation stemming from agriculture and industry during the Soviet era.

The Kura-Araks (sometimes spelled "Aras"or "Arax") Basin is the major river system in the South Caucasus. Both rivers rise in Turkey and flow into the Caspian Sea after joining in Azerbaijan. Of the total 188,200 km^2 basin area, almost two-thirds, or about 122,200 km^2, are in the three South Caucasus countries; the remaining basin area is in Turkey and Iran. The Kura-Araks is one of the "new" transboundary river systems of the former "Second World" whose problems are largely unknown to the West (Van Harten 2002).

The water users in all three countries are faced with water quality and quantity problems. In general terms, Georgia has an oversupply of water, Armenia has some shortages based on poor management, and Azerbaijan has a lack of water (Technical Assistance to Commonwealth of Independent States 2003). The main use of Kura-Araks water in Georgia is agriculture, and in Armenia, it is agriculture and industry. In Azerbaijan, the Kura-Araks

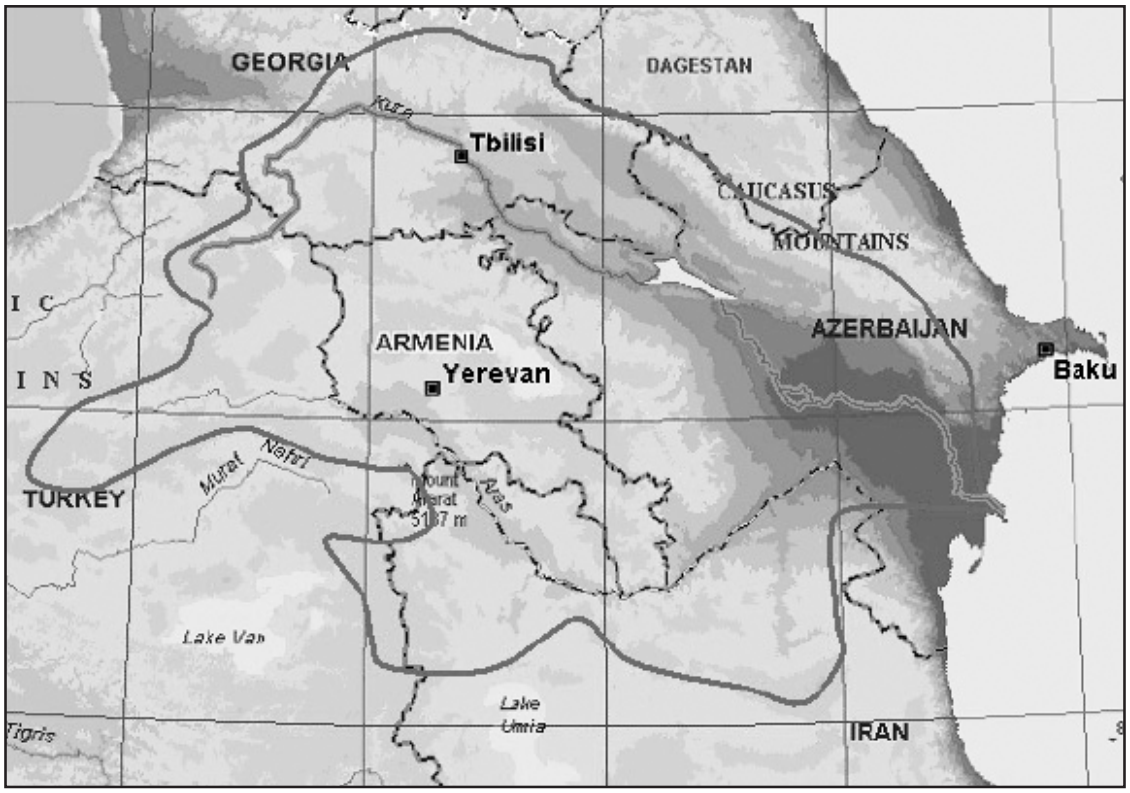


Figure 1. Map of South Caucasus with the Kura-Araks basin outlined in solid line (from Vener 2006).

Table 1. Watershed area of the Kura and Araks Rivers in each country of the South Caucasus (Technical Assistance to Commonwealth of Independent States 2003; USAID 2002; U.S. Central Intelligence Agency 2004; Vener 2006).

Country	Population (millions) (July 2003 est)	Kura River		Araks River	
		% of total basin area	Area (km^2)	% of total basin area	Area (km^2)
Armenia	3.3	15.79	29,741	22	22,090
Azerbaijan	7.8	30.70	57,800	18	18,000
Georgia	4.9	18.43	34,700	-	-
Turkey & Iran	-	35.06	66,000	60	61,000
Total	16.0	100.00	188,241	100	101,090

River water is their primary source of fresh water as well as drinking water. Almost 80 percent of the countries' wastewater loads are discharged into the surface waters of the Kura-Araks Basin (United Nations Economic Committee for Europe 2003). The basin is excessively polluted due to a lack of treatment for urban wastewater and agricultural return flows, pesticides such as DDT that are used in Azerbaijan, and the resurgence of chemical and metallurgical industries in Georgia and Armenia (Technical Assistance to Commonwealth of Independent States 2002).

Water Resources of the South Caucasus and the Kura-Araks Basin

The Kura-Araks Basin is situated south of the Caucasus Mountains. Its borders are northeastern Turkey, central and eastern Georgia, and northwestern Iran. It contains almost all of Azerbaijan and all of Armenia (Figure 1).

Table 2. Land use in the Kura-Araks Basin (km^2), (Joint River management Programme of Technical Assistance to Commonwealth of Independent States 2003; U.S. Central Intelligence Agency 2004; Vener 2006).

State	Land Area	Disputed Area	Forested Area	Agriculture			
				Arable Land		Meadow/ Pasture	Other
				JRMP	USCIA		
Armenia	29,800	1,500	4,250	5,600	5,215	8,300	10,091
Azerbaijan	86,600	2,000	7,590	15,290	16,714	20,936	12,000
Georgia	67,700	600	10,900	7,700	7,813	NA	NA

The Kura River originates in northern Turkey, flows through Georgia and Azerbaijan, and then directly discharges into the Caspian Sea. The Kura River's total length is about 1,515 kilometers and average discharge at its mouth is 575 million cubic meters per year (MCM/yr) (CEO 2002).

The Araks River originates in Turkey and after 300 km forms part of the international borders between Armenia and Turkey, for a very short distance between Azerbaijan and Turkey, between Armenia and Iran, and between Azerbaijan and Iran. The Araks River joins the Kura River in Azerbaijan (Technical Assistance to Commonwealth of Independent States 2003). It is about 1,072 km long and has an average discharge of 210 MCM/yr.

Table 1 shows the distribution of watershed area by country. Table 2 shows land use in the region. Table 3 shows that water resources are not distributed equally in the South Caucasus. While Georgia has more water than it needs, Azerbaijan is left with a water deficit; furthermore, its ground water is of poor quality. It obtains 70 percent of its drinking water from the Kura-Araks Rivers. Armenia has a surface water shortage but has a large fresh ground water stock that it uses for drinking water (Technical Assistance to Commonwealth of Independent States 2003). Table 3 shows that the most precipitation and evaporation occurs in Azerbaijan followed by Georgia and Armenia in that order.

Table 3. Kura-Araks Basin average annual water balance (km^3) (Technical Assistance to Commonwealth of Independent States 2003; Vener 2006). Parentheses indicate depletion.

	AR	AZ	GE
Precipitation	18	31	26
Evaporation	(11)	(29)	(13)
River Inflow	1	15	1
River Outflow	(8)	(18)	(12)
Underground Inflow	1	3	1
Underground Outflow	(1)	(2)	(3)

Water is used for municipal, industrial, agricultural, irrigation, fishery, recreation, and transportation purposes. The main water use is agriculture, followed by industry and household uses. Table 2 shows that Azerbaijan has the most arable land followed by Georgia and Armenia. Even though Azerbaijan has the most arable land, it is the one facing a water deficit.

Azerbaijan withdraws 57.9 percent of its actual renewable water resources, Armenia withdraws 28.2 percent, whereas Georgia withdraws only 5.2 percent. However, as a water resources-rich country Georgia's withdrawal per capita is 635 m^3 while Azerbaijan's is 2,151 m^3, and Armenia's is 784 m^3. It is evident that per capita water withdrawal is disproportionate to water availability among the three countries (Vener 2006). The main rivers have only two reservoirs but the tributaries have more than 130 major reservoirs. The total capacity of the reservoirs and ponds is almost 13,100 MCM (Technical Assistance to Commonwealth of Independent States 2003). With respect to storm water and sewage effluent discharges, the Kura-Araks receives 100 percent of Armenia's, 60 percent of Georgia's, and 50 percent of Azerbaijan's.

Political, Social, and Economic Landscape

Introduction

Armenia, Azerbaijan, and Georgia gained their independence from the Union of Soviet Socialist Republics (USSR) in 1991. The South Caucasus states are neither fully democratic nor fully authoritarian states. All three countries attempted

to introduce democratic systems, and held relatively free elections in 1990-1992 (Swedish International Development Cooperation Agency 2002). However, the region reverted to increased authoritarian rule because of the pressures from war, threats of economic collapse, and the countries' inexperience with participatory politics.

A series of ethnic conflicts erupted in Nagorno-Karabakh, Abkhazia, Javakheti, and other regions. Because of these internal and international ethnic conflicts the region has about 1,500,000 refugees and/or Internally Displaced Persons (Internal Displacement Monitoring Centre 2008; Swedish International Development Cooperation Agency 2002). The South Caucasus region remains in turmoil because of ethnic conflicts, poor economies, environmental degradation, and political instability. In addition, Russia and Georgia engaged in a brief conflict over South Ossetia in August 2008.

Of the three countries, Georgia has made the greatest progress towards building a democratic polity. Azerbaijan and Armenia are still in somewhat of a transition period from authoritarian regimes to full democracies; Azerbaijan in particular is more authoritarian than the other two. Political violence was once a constant threat in the three countries; all experienced coups d'état, insurrections, or attempts to assassinate political leaders in the decade following independence (Swedish International Development Cooperation Agency 2002). As a result, political and socio-economic reform processes in all three countries were slow and suffered setbacks. Widespread corruption, bureaucratic difficulties, and political instability cemented the South Caucasus' reputation as a relatively high-risk area for business in the decade following independence (Swedish International Development Cooperation Agency 2002; U.S. Department of State 2003).

However, the senior author has noted changes that have occurred in the region since he started traveling there in 2002. All three countries' economies have improved, led by Azerbaijan with its oil and gas revenues. All are more stable than the pre-2003 period. Azerbaijan even hosted the 2012 Eurovision Song Contest, and staged a lavish affair designed to showcase its economic progress.

Hydropolitics

During the Soviet era, each country was within the USSR sphere and water resources management of the basin was contingent upon the policy promulgated by the USSR. When they became independent states, the three countries had neither water resources management regulations nor water codes. However, each country has adopted a water code since 1992: Armenia in 1992 and revised in 2002 according to the European Union Water Framework Directives; and Georgia and Azerbaijan in 1997. Nevertheless, there is no uniform control and/or management system for the rivers and, in the post-Soviet period, no water quality monitoring by the riparian countries since 2002.

While the three countries are willing to cooperate on water-related issues, they have not solved their political, economic, and social issues. There are currently no water treaties among the three countries, a condition directly related to the political situation in the region. There is recognition of the importance of integrated water resources management, which provides the countries with a good foundation for a transboundary water management agreement (Vener and Campana 2010).

There are political issues which make agreements difficult among the countries. Nagorno-Karabakh is one of the main obstacles, making it difficult for Azerbaijan and Armenia to sign a treaty even though it may relate only to water resources management (Vener and Campana 2010). The Nagorno-Karabakh region is predominantly an Armenian-populated area in western Azerbaijan. Armenia supports ethnic Armenian secessionists in Nagorno-Karabakh and militarily occupies Nagorno-Karabakh, 16 percent of Azerbaijan's land area. After the occupation, more than 800,000 Azerbaijanis were forced to leave the occupied lands; another estimated 230,000 ethnic Armenians were forced to leave their homes in Azerbaijan and flee into Armenia (U.S. Central Intelligence Agency 2004; U.S. Department of State 2003). A cease-fire between Armenia and Azerbaijan was signed in May 1994 and has held without major violations ever since. The Minsk Group, part of Organization for Security and Co-operation in Europe, continues to mediate disputes.

Another obstacle is the Javakheti region of Georgia. Javakheti is an area that is part of Georgia bordering Turkey, and has a total population of 100,000 people. Almost 90 percent of the population is Armenian. Thus, Javakheti is often cited as a secessionist region (National Intelligence Council 2000). The region is more integrated with Armenia than Georgia and the former supports demands for local autonomy.

European Union - South Caucasus Relationship

Even though a form of cooperation existed between the European Union (EU) and the three republics prior to 1999, it was based mostly on financial and technical assistance. Indeed, after the South Caucasus countries achieved independence in 1991, the EU devoted over 1 billion euros of European Commission assistance to the region (EU-SC 2004).

The relationship between the EU and the South Caucasus is legally conducted within the framework of the Partnership and Cooperation Agreements. These agreements between the South Caucasus states and the EU were signed on April 22, 1996 in Luxembourg and entered into force on July 1, 1999 (EU Parliament 2001). The EU strategy was based on bilateral Partnership and Cooperation Agreements that encourage regional cooperation through the Technical Assistance to Commonwealth of Independent States and Transport Corridor Europe Caucasus Asia projects. Technical Assistance to Commonwealth of Independent States was the most comprehensive project related to the South Caucasus.

In 1999, the EU developed the Luxembourg Declaration to encourage a more intense and opportunist policy toward the South Caucasus. In truth, the Partnership and Cooperation Agreements had not worked as planned and the EU felt disturbed over Russia's "divide and rule" policy towards the South Caucasus, which contributed to the stalemate over ethnic conflicts in the region (Vener 2006). As a result, the EU declared in the Luxembourg Declaration that the increasing instability in the South and North Caucasus States threatened the EU's security. The EU also stated in the Luxembourg Declaration that it would not provide assistance to support the status quo unless there was evidence of positive change (Western European Union Council of Ministers 1999). The EU also declared that they were ready to enhance their contribution to conflict prevention and post-conflict rehabilitation through the Organization for Security and Co-operation in Europe and the UN, as well as promote regional cooperation through the Technical Assistance to Commonwealth of Independent States Program and the Regional Environmental Center for the Caucasus (Technical Assistance to Commonwealth of Independent States 2002).

In addition to the EU's security concerns, as reflected in the Luxembourg Declaration, there are many reasons for the EU's policy changes in the region (Vener 2006):

1. The EU is welcoming new members which would expand its boundaries close to the South Caucasus;
2. Energy resources are important to the gas-hungry European states;
3. The potential energy market in the region is important for the European companies; and
4. The Caucasus states are transit routes for drugs and illegal goods, which indirectly affect the EU.

From the viewpoint of the South Caucasus countries, the EU is important for three reasons (Vener 2006):

1. They all want to join the EU and be part of the balance of power in the region instead of being isolated or threatened by other powers in the region like Russia, Iran, and Turkey;
2. The assistance from the EU is both financially and technically important, and they do not want to lose it; and
3. The EU is an important market for the South Caucasus countries.

Ultimately, the EU is the path that will lead the South Caucasus states to a prosperous future from almost every perspective. For this reason, Armenia, Azerbaijan, and Georgia have become members of the Council of Europe.

The 2008 Russian invasion of Georgia showed that some in the region were right about their concerns regarding Russia and that they needed to

be a part of the EU in order to avoid these kinds of conflicts (Vener and Campana 2010). Russia also recognizes the independence of Abkhazia, an autonomous region bordering the Black Sea in the northwest part of Georgia.

Rationale: The NATO Science for Peace Programme Report

The previous section indicated the importance of EU – South Caucasus relations and the strategic importance of the latter to the former. But the North Atlantic Treaty Organization (NATO) is a security organization; why would it fund a project related to water quality, especially involving countries that are not part of NATO? The senior author served as the NATO project director and was involved almost from its inception. The following discussion is based upon his participation at various meetings, especially during the early stages of NATO's South Caucasus River Monitoring Project, and visits to the South Caucasus countries.

The South Caucasus River Monitoring Project, in existence from 2002 through 2009, was funded at the cost of 1.2 million euros under the auspices of NATO's now-defunct Science for Peace Programme (SfPP) with some funding through the Organization for Security and Co-operation in Europe. The SfPP was established primarily to fund scientists, technicians, and engineers (especially those formerly engaged in defense work) in former Soviet republics or Eastern Bloc countries. The SfPP's project emphasis generally focused on those with an economic orientation (i.e., projects that focused on the development of a process or product that could be marketed). By encouraging the production of a marketable commodity the SfPP sought to improve the economy of a particular country and provide an income stream to former Soviet and Eastern Bloc defense workers. This was done so that they might be less inclined to sell their services to countries or organizations whose interests were inimical to the NATO countries and its allies. But the SfPP also considered "environmental" projects in which there were no recognizable economic payoff, or projects that might foster peace in a region considered strategically important by NATO. Such was the case in the South Caucasus River Monitoring Project, the first environmental SfPP project.

The location of the South Caucasus was a key factor influencing SfPP funding. The South Caucasus lies on the ancient Silk Road trade route and the region acts as a natural bridge between Europe and Asia, and is surrounded by three regional powers: Russia, Iran, and Turkey. It has a favorable geographic location at the crossroads of Asia, Europe, and the Middle East. It is just across the Caspian Sea from Central Asia and "the Stans," former fellow Soviet republics Tajikistan, Kyrgyzstan, Turkmenistan, Uzbekistan, and Kazakhstan. The latter three countries, as well as Azerbaijan, have substantial amounts of natural gas, among other important natural resources.

The location of the region is one of the reasons Europe and much of the international community began to realize the geopolitical and geoeconomic importance of the South Caucasus in the world (Swedish International Development Cooperation Agency 2002). Thus, the three states were eager to develop east–west and north–south transport corridors through their territory, such as the recent Baku–Tbilisi–Ceyhan oil and Baku-Tbilisi-Erzurum gas pipelines, both of which originate in or near Baku, Azerbaijan, and terminate at the Turkish Mediterranean port of Ceyhan (Baku–Tbilisi–Ceyhan) or the interior city of Erzurum (Baku-Tbilisi-Erzurum), where it is supposed to connect to the Nabucco pipeline (Ivanova 2009) to transport natural gas to Europe. In other words, restoration of the ancient Silk Road may help restore the socioeconomic and political stability to the region (Swedish International Development Cooperation Agency 2002).

Azerbaijan is especially aggressive in developing the Silk Road concept; the senior author was introduced to this concept on a visit to Baku in 2009; (see also Ivanova 2009). Unlike its neighbors Georgia and Armenia, Azerbaijan has substantial hydrocarbon resources, especially in its portion of the Caspian Sea reservoir. Foreign countries and companies are investing in Azerbaijan, which has its own oil and gas revenues. It is developing a new oil-gas-shipping terminal on the Caspian Sea and is actively promoting an undersea pipeline to obtain Turkmenistan's, and possibly Kazakhstan's, natural gas for its Baku-Tbilisi- Erzurum pipeline. Such a gas pipeline to Europe would compete with Russian pipelines

and minimize Russia's ability to hold European customers hostage, especially during the winter months. It should be noted that as of this writing, the discovery of shale gas deposits in Europe could be a proverbial "game changer" with respect to the current and future gas suppliers to Europe (Gas Strategies 2010; Wright 2012). Extensive shale gas development in Europe could interfere with Azerbaijan's effort to become a natural gas hub, linking its Caspian Sea deposits and those of Central Asia to Europe.

NATO and the Organization for Security and Co-operation in Europe were anxious to have political stability in the South Caucasus to:

1. Protect access to natural gas and other resources, not only in the South Caucasus but also in Central Asia;
2. Thwart Russian hegemony; and
3. Prevent violence from spilling over into adjacent areas.

Therefore, it was in NATO's best interests to encourage cooperation and harmony among the three countries, and the South Caucasus River Monitoring Project, brought to them from the countries themselves, afforded a means to promote those characteristics. It would do NATO no good to have the South Caucasus countries fighting over water, and if they could work together on water issues, perhaps other contentious issues could also be resolved.

In some ways the NATO and the Organization for Security and Co-operation in Europe's interest in the South Caucasus was a new version of the Great Game, with Russia and the West jockeying for primacy in a region (Ivanova 2009). In the old version, Russia and Great Britain each sought primacy in Central Asia.

One last item is worth noting. Neither the Azerbaijan nor Armenian government was keen on cooperating with the other. Each country's government might have been hard-pressed to explain to its citizens why it was cooperating with its sworn enemy. In fact, one condition for project approval was the deletion of the word "cooperative" from the project title, thus changing the South Caucasus Cooperative River Monitoring Project to the South Caucasus River Monitoring Project. Each of the three countries agreed to approve the South Caucasus River Monitoring Project as long as the project kept a fairly low profile. The ministries were not directly involved in the implementation of the project; the operative organizations were Tbilisi State University in Georgia and subunits of the national academies of science in Azerbaijan and Armenia.

Project Description

Initial Phase

The goal of the South Caucasus River Monitoring Project was to foster collaboration and cooperation among the three countries so as to promote the peaceful resolution of not only water resources issues, but all issues. As the senior author was fond of saying, the project was to promote the "upward diffusion" of harmony and collaboration through each government's hierarchy. By encouraging the countries to work together on water resources, perhaps other issues could be addressed in a similar fashion. Doing so would promote stability in the region.

The project's goal was to establish the social and technical infrastructure for international, cooperative transboundary river water quality and quantity monitoring, data sharing, and watershed management among the Republics of Armenia, Azerbaijan, and Georgia. Its objectives were to (Campana et al. 2008):

- Increase technical capabilities including analytical chemistry and its application to water resources sampling and monitoring, database management, and communications, among the partner countries;
- Cooperatively establish standardized common sampling, analytical, and data management techniques for all partner countries and implement standards for good laboratory practice, quality assurance and quality control;
- Establish database management, GIS, and model-sharing systems accessible to all partners via the WWW;
- Establish a social framework (i.e., annual international meetings) for integrated water resources management; and
- Involve stakeholders.

Monthly monitoring was conducted for water quantity (discharge) and water quality parameters at ten locations in each country. Water quality monitoring consisted of the usual basic parameters (major and minor ions, pH, etc.) plus selected heavy metals, radionuclides, and Persistent Organic Pollutants.

Most of the money was spent on analytical, computational, and sampling equipment. Identical field and laboratory equipment was purchased for each country. Sampling and analytical protocols were agreed upon by all parties. The protocols and identical equipment helped minimize complaints from any of the riparians about someone else's erroneous data.

The group held a meeting at least once per year to discuss current work, equipment needs, planned work, and to present results. The meetings were held in Tbilisi, Georgia, since the political situation between Armenia and Azerbaijan made Tbilisi the most convenient venue.

Data were posted on the project website, maintained by Azerbaijan. Posting ensured that all had access to all the data; the site was not password-protected. The website is no longer operational and data are no longer online and are now with each country. The senior author also has some of the data.

These data were to be used to construct a simple dynamic simulation model of the watershed, which would ultimately form the basis for a more sophisticated river basin management model. The dynamic simulation model itself could be used as the basis for a "shared vision planning" or "mediated modeling" (Van den Belt 2004) approach to conflict management and the development of a treaty or compact to manage the system. To that end, a two-day workshop on dynamic simulation modeling, conducted by one of the senior author's graduate students, was held during the October 2005 annual meeting in Tbilisi. Unfortunately, the project never reached the point where basin-scale modeling, not contractually required, was feasible.

Final Phase and the Future

The South Caucasus River Monitoring Project formally ended in December 2009, although all involved were anxious to continue monitoring. To our knowledge, only Azerbaijan is continuing to monitor because it has the funds, and the incentive – it is the downstream riparian.

The project was a model of collaboration and cooperation in a region where such traits have at times been in short supply. Not only were valuable data collected, but collegial professional relationships also were established among the participants. In the long run, this latter aspect will likely prove to be the more important product.

The region could benefit from an expanded project to address the following:

- Ground water. The South Caucasus River Monitoring Project did not explicitly consider the presence of ground water, an important source of water and intimately connected to streamflow. The countries were not particularly anxious to consider ground water. In fairness to all countries, lack of enthusiasm was likely motivated by the lack of resources necessary to include ground water.
- Develop requirements for environmental flows and ecosystems needs.
- Public health monitoring. Ewing (2003) cited the concern over public health related issues (e.g., waterborne diseases, pathogenic organisms), since much untreated sewage is discharged directly into the waters of the Kura-Araks basin. She also designed a surface water monitoring plan that could be used as a template for public health monitoring.
- Involve Turkey and Iran, the other two riparians. Note that about one-third of the basin is outside the South Caucasus and both rivers originate in Turkey. Why were these countries omitted? Neither was eligible for SfPP funding; Turkey because it was a NATO country and Iran because it was not a former Eastern Bloc country or Soviet republic. Informal collaboration was not encouraged.
- Develop an international agreement. This would provide a framework for joint integrated management of the Kura-Araks basin: surface water, transboundary ground water, water quality, and ecosystem health.

The project could also serve as a template for other regions, such as Central Asia. The senior author was invited to make just such a presentation at a meeting in Tajikistan in 2010 but was unable to attend.

Reflections

After the dissolution of the Soviet Union the Kura-Araks basin became a transboundary basin with respect to the former Soviet republics of Armenia, Azerbaijan, and Georgia. No formal water allocation agreement existed, little water quality monitoring had occurred since the republics became independent, and no mechanisms had been devised to manage the waters of the basin. These countries occupy a region of great strategic importance to the EU and its allies, and stability is paramount. To encourage cooperation on technical issues and mitigate potential conflicts that might threaten their security, NATO and the Organization for Security and Co-operation in Europe funded a bottom-up project enabling all three riparians to monitor surface water quality and quantity on a monthly basis and post data on a transparent website maintained by Azerbaijan. The data could be used to develop a dynamic simulation model of the basin, which could form the basis for a "mediated modeling" approach to the creation of a basin treaty. Although the current project was a much-needed first step, more work must be done, especially with respect to the inclusion of ground water, ecosystem needs, and public health monitoring.

Political differences among the countries, especially the Nagorno-Karabakh issue between Armenia and Azerbaijan, must be resolved before a meaningful agreement among all three countries regarding water allocation, quality, and ecosystem requirements can be developed and implemented (Vener 2006). Any such agreement must also consider Turkey and Iran, the other two riparians in the basin.

Will stability flourish in the South Caucasus? Only time will tell if cooperation over water resources will effect lasting peace, but the South Caucasus River Monitoring Project has provided a strong basis.

Acknowledgements

The authors are grateful to NATO's Science for Peace Programme for supporting project SfP 977991 South Caucasus River Monitoring, and OSCE for its support. Special thanks are due to NATO SfPP's Dr. Chris De Wispelaere (Director) and Dr. Susanne Michaelis (Associate Director), whose help and understanding were invaluable. We also extend our thanks to the South Caucasus River Monitoring Project country directors Professor Nodar Kekelidze (Georgia), Dr. Armen Saghatelyan (Armenia), and Dr. Bahruz Suleymanov (Azerbaijan); and NATO experts Professor Freddy Adams (Belgium) and Professor Eiliv Steinnes (Norway). The authors also thank Dr. David Kreamer of the University of Nevada, Las Vegas, and three anonymous reviewers for their helpful comments. Dr. Kreamer deserves special thanks for encouraging the authors to submit this paper and editing the special issue in which it appears. The Water Resources Program of the University of New Mexico and the Institute for Water and Watersheds of Oregon State University provided financial support.

Author Bios and Contact Information

Michael Campana is currently a Professor of Hydrogeology and Water Resources Management at Oregon State University. Prior to that he was a professor at the University of New Mexico, where he held the Black Chair in Hydrogeology and directed UNM's Water Resources Program, and a research hydrologist at the Desert Research Institute and professor at the University of Nevada, Reno. His graduate work was in hydrology at the University of Arizona, where he received his MS (1973) and Ph.D. with a mathematics minor (1975). His interests are water resources policy and management, hydrogeology, and water, sanitation, and hygiene (WaSH) in developing regions. He founded and runs the non-profit Ann Campana Judge Foundation (http://www.acjfoundation.org) and blogs (http://www.waterwired.org) and Tweets (http://twitter.com/waterwired) more than he should. He can be reached at aquadoc@oregonstate.edu, or College of Earth, Ocean, and Atmospheric Sciences, 104 CEOAS Administration Building, Oregon State University, Corvallis, OR 97331-5503.

Basak Vener worked at the Prime Ministry of Turkey's Southeastern Anatolia Regional Development Project for over ten years and at the Middle Rio Grande Conservancy District, in Albuquerque, NM, for almost five years. At both places she managed a broad spectrum of projects. Her expertise is regional development, water resources management, water rights, dispute resolution, resettlement, resilience, and environmental peace-building. She holds two

Masters degrees: in Water Resources from the University of New Mexico and in Hydropolitics from the University of Hacettepe, Ankara, Turkey. She is a trained mediator and is currently working on her Ph.D. in Political Science at the University of New Mexico, Albuquerque, NM. She can be reached at Berrin Basak Vener, Department of Political Science, University of New Mexico, Albuquerque, NM 87131, or bvener@unm.edu.

Baek Soo Lee is a Ph.D. student in Water Resources Science at Oregon State University. She currently examines land-use effects on surface water quality in watersheds of the South Caucasus, Japan, and Oregon. She earned a BS in Environmental Science from the University of Idaho and an MS in Hydrology from the University of Nevada, Reno. Her MS thesis tested the feasibility of using hyperspectral remote sensing techniques to detect water quality degradation through changes in aquatic vegetation in rivers. She worked as a staff hydrologist at a firm in northern Virginia before matriculating at OSU. She can be reached at leeb@onid.orst.edu, or College of Earth, Ocean, and Atmospheric Sciences, 104 CEOAS Administration Building, Oregon State University, Corvallis, OR 97331-5503.

References

Campana, M.E., B.B. Vener, N.P. Kekelidze, B. Suleymanov, and A. Saghatelyan. 2008. Science for peace: monitoring water quality and quantity in the Kura-Araks Basin of the South Caucasus. In *Transboundary Water Resources: A Foundation for Regional Stability in Central Asia. NATO Science for Peace and Security Series C*: *Environmental Security*. J.E. Moerlins, M.K. Khankhasayev, S.F. Leitman, and E.J. Makhmudov (Eds.) Berlin: Springer, 153-170.

Caucasus Environmental Outlook (CEO). 2002. Caucasus Environmental Outlook Report, completed through financial assistance provided by UNDP and Swiss Agency for Environment, Forest, and Landscape. Available at: http://www.gridtb.org/projects/CEO/full.htm.

European Union Security Council (EU-SC). 2004. The Gahrton Report. The EU-South Caucasus-The Gahrton Report. Speech by the Rt Hon Chris Patten, European Parliament, Brussels, 26 February 2004. Available at: http://eur-lex.europa.eu/JOHtml.do?uri=OJ:C:2004:098E:SOM:en:HTML and http://www.armenian-genocide.org/Affirmation.217/current_category.7/affirmation_detail.html.

EU Parliament. 2001. Information Note on Delegation for Relations with The South Caucasian Republics: Armenia, Azerbaijan and Georgia. Available at: http://www.europarl.europa.eu/parliament/expert/displayFtu.do?language=en&id=74&ftuId=FTU_6.4.3.html and http://www.armenian-genocide.org/Affirmation.217/current_category.7/affirmation_detail.html.

Ewing, A. 2003. Water Quality and Public Health Monitoring of Surface Waters in the Kura-Araks River Basin of Armenia, Azerbaijan and Georgia. Publication No. WRP-8, Water Resources Program. University of New Mexico, Albuquerque, NM. Available at: www.unm.edu/~wrp/wrp-8.pdf.

Gas Strategies. 2010. Shale gas in Europe: A revolution in the making? Available at: http://www.gasstrategies.com/files/files/euro%20shale%20gas_final.pdf.

Internal Displacement Monitoring Centre. 2008. Available at: http://www.internal-displacement.org.

Ivanova, N. 2009. The Forgotten South Caucasus: Where Oil and Water Mix. Circle of Blue. Available at: http://www.circleofblue.org/waternews/2009/world/the-forgotten-south-caucasus-where-oil-and-water-mix/#more-3915.

National Intelligence Council. 2000. Central Asia and South Caucasus: Reorientations, International Transitions, and Strategic Dynamics Conference Report, October 2000. Available at: http://www.fas.org/irp/nic/central_asia.html.

Swedish International Development Cooperation Agency. 2002. The South Caucasus: Regional Overview and Conflict Assessment, Prepared by Cornell Caspian consulting (CCC) under the contract by SIDA. Available at: http://www.cornellcaspian.com/sida/sida.html.

Technical Assistance to Commonwealth of Independent States. 2003. European Commission Inception Report, Joint River Management Programme of the Kura Basin, Annex 6: Georgia Country Report. Available at: http://www.parliament.the-stationery-office.co.uk/pa/ld199798/ldselect/ldeucom/157/15703.htm.

Technical Assistance to Commonwealth of Independent States. 2002. Partnership and Trust: The TACIS Program, 157/1570. Available at: http://www.parliament.the-stationary-office.co.uk/pa/ld1999798/ldselect/ldeucom/157/1570.

Wright, S. 2012. Unconventional Bonanza. *The Economist Special Report*, 14 July 2012. 1-18 Available at: http://www.economist.com/node/21558432.

United Nations Economic Committee for Europe (UNECE). 2003. Environmental Performance Review 2003. Available at: http://www.unece.org /env/epr/studies/htm.

U.S. Agency for International Development (USAID). 2002. Mission for the South Caucasus. *Water Management in the South Caucasus Analytical Report: Water Quantity and Quality in Armenia, Azerbaijan and Georgia*, prepared by Development Alternatives, Inc., for USAID.

U.S. Central Intelligence Agency. 2004. Factbook, Country Profiles: Azerbaijan, Armenia and Georgia. Available at: https://www.cia.gov/library /publications/the-world-factbook/geos/aj.html.

U.S. Department of State. 2003. U.S. Government Assistance to and Cooperative Activities with Eurasia, Bureau of European and Eurasian Affairs. Available at: http://www.state.gov/p/eur/rls /rpt/23603.htm.

Van den Belt, M. 2004. *Mediated Modeling: A Systems Dynamics Approach to Environmental Consensus Building*. Washington, DC, Island Press, 296.

Van Harten, M. 2002. Europe's troubled waters. A role for the OSCE: the case of the Kura-Araks. *Helsinki Monitor* 13(4): 338-349.

Vener, B.B. 2006. The Kura-Araks Basin: Obstacles and Common Objectives for an Integrated Water Resources Management Model among Armenia, Azerbaijan, and Georgia. Master of Water Resources Professional Project, Water Resources Program. University of New Mexico, Albuquerque, NM.

Vener, B.B. and M.E. Campana. 2010. Conflict and cooperation in the South Caucasus: the Kura-Araks Basin of Armenia, Azerbaijan, and Georgia. In M. Arsel and M. Spoor (Eds.) *Water, Environmental Security and Sustainable Rural Development: Conflict and Cooperation in Central Eurasia*. Oxford, UK: Routledge, 144-174.

Western European Union Council of Ministers. 24 November 1999. Luxembourg Declaration, Document 1675.

Universities Council on Water Resources
Journal of Contemporary Water Research & Education
Issue 149, Pages 33-40, December 2012

Irrigation Outreach in Afghanistan: Exposure to Afghan Water Security Challenges

Denis Reich and Calvin Pearson

Colorado State University, Fort Collins, CO

Abstract: The authors, from Colorado State University were invited by the United Sates Department of Agriculture's Foreign Agriculture Service and Afghanistan's Ministry for Agriculture Irrigation and Livestock to lead a "train-the-trainer" workshop with Afghanistan's best and brightest irrigation outreach professionals. The six day workshop on the outskirts of Kabul helped clarify that prolonged conflict has damaged agriculture's access to what should be a plentiful supply of irrigation water. The violence of two wars still lingers today continuing to inhibit foreign aid's ability to rebuild Afghanistan's water resources infrastructure. In spite of these challenges participants in the workshop demonstrated remarkable resourcefulness and courage helping producers throughout Afghanistan take advantage of improvements as they came online. With continued assistance from Western researchers and extension professionals that is sensitive to the traditional methods of water administration, there is reason to be hopeful for the future success of Afghanistan's agricultural sector.

Keywords: *Irrigation, Afghanistan, workshop*

In recent years Afghanistan has emerged from the obscurity of its remote South Asian location to become one of the most scrutinized nations on earth. It's a landlocked state that represents some of the most sparsely populated and ethnically diverse landholdings to emerge from the ancient Mongol and Persian empires. Perched on the south western corner of the Himalayas, its topography includes a range of elevations such as the remote valleys and steep peaks of the Hindu Kush range. From altitudes of up to almost 8,000 meters, snowmelt and rains form four major river systems: the Amu Daria to the north, Helmand to the south, Harirud or Herierod to the west, and Kabul to the east. Reports vary on arable land and available water resources in Afghanistan (Cookson et al. 1992; International Union for the Conservation of Nature 2010; Qureshi 2002). The United States Department of Agriculture Economic Research Services describes an annual average water yield of about 75 billion m^3, or around 60 million acre feet. Of this about 21 percent or 15.8 billion m^3 is river water used for irrigation, 4 percent or 2.8 billion m^3 is ground water used for irrigation, and roughly 2 percent or 1.4 billion m^3 is either river or well water for other uses including domestic (International Union for the Conservation of Nature 2010; Persaud 2012). The remainder is either untapped or unmeasured. Additionally only 2.6 million hectares or half of the country's irrigable area is currently being farmed (Kelly 2003; Qureshi 2002). Despite its arid appearance Afghanistan is far from short of farmland or water.

A unique feature of land-locked Afghanistan is the rivers never reach the ocean (except for the smaller Kabul that joins the Indus after a steep white-watered descent into Pakistan). This amplifies Afghanistan's remote and complex nature since its rivers are impractical as trade byways and underutilized as sources of electricity. Water storage is also limited and the few large reservoirs that exist are vulnerable to sediment problems since watersheds have been heavily deforested for fire wood and timber. Even with these challenges, the potential for irrigated "reclamation" – 55 billion m^3 of water is potentially available to water the remaining 2.4 million hectares of irrigable land (Persaud 2012) – is large, but the nation's fragile

politics and poor security situation have inhibited water's effective utilization during the prolonged recovery process (The Asia Foundation 2006). Being a headwaters state without any legal obligation to deliver water downstream, the lack of infrastructure versus lack of water has become the primary obstacle preventing Afghanis gaining access to water (Peter 2010).

Of the 28 million people living in Afghanistan, about 5.5 million live in the larger cities such as Kabul and Kandahar. The majority rural population is spread across about 20,000 villages, most with 1,000 people or less. Farms less than 20 hectares account for about 60 percent of land ownership; in irrigated areas 97 percent of land holdings are 6 hectares or less (Qureshi 2002). Villages depend heavily on surrounding agriculture and town planning is dictated by if land is irrigated (abi) or dryland (lalmi), with canals and wells having priority. In western and southern Afghanistan some areas depend on underground well and canal networks (khareez, qanat, or herez), ancient Persian systems that reduce evaporative losses. The majority of irrigation occurs in the lowlands with wheat being the dominant crop. Wheat is also the foundation of the Afghan diet, making up 54 percent of the average Afghans' daily caloric intake. In the higher elevations, larger tracts of land are prepared for hardier small grains, such as barley, to be watered by snowmelt or spring rains. Fruits and nuts are also an integral part of upland agriculture. Livestock (mostly cattle and goats) management usually involves moving herds to summer grazing pastures and stalling over the winter. Nomadic pastoralists account for about 6 percent of the rural population and follow seasonal pasture year round (Barfield 2010).

Afghanistan's water resource challenges are reflected in its recent food security problems. While food availability and distribution are sensitive to a number of variables, insufficient irrigation, water, or delivery problems have consistently stifled crop yields. In one assessment of 163 nations, Afghanistan ranked last in food security, the next 11 worst being African nations (Morales 2010). Afghanistan was once known for its dried fruit exports (e.g., pomegranate is showing export potential), but the ghosts of two major wars and an entrenched opium poppy industry are greatly inhibiting growth in the horticultural sector.

As Afghanistan and its allies embark on an ambitious nation building effort, its agricultural sector is seen as the linchpin for hastening recovery and sustainable growth. Even with the brutal nature of prolonged and recent conflict, personal security for Afghan citizens is showing signs of improvement. In the Kabul valley, and to a smaller degree outward into the more remote and war-torn provinces, well-publicized suicide bombing events are decreasing and the repair and construction of infrastructure is gaining momentum (The Asia Foundation 2006). As communities rediscover their entrepreneurial spirit after years of being trapped in survival mode, local agriculture and reliable access to irrigation water has become the subject of increased attention and investment (The Asia Foundation 2006).

The fact that irrigated agriculture is considered a key piece in the Afghan recovery puzzle was evidenced by the invitation extended to Colorado State University Extension, and Agricultural Experiment Station, to lead a 6-day train-the-trainer workshop on irrigated agriculture for Afghan irrigation and agricultural professionals. Colorado State University staff in cooperation with the U.S. Department of Agriculture

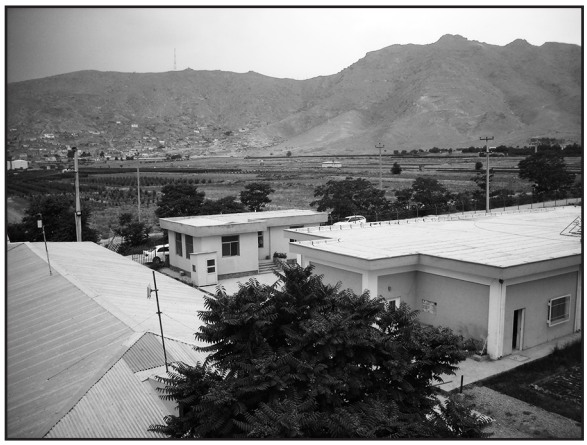


Figure 1. A view of Badam Bagh Farm. Established by the United Nations Food and Agriculture Organization in 2006, it is now owned and managed by the Afghani Ministry for Agriculture, Irrigation, and Livestock.

Foreign Service, U.S. Agency of International Development, and the Afghan Ministry for Agriculture, Irrigation, and Livestock, organized a series of workshops at the Badam Bagh Farm outside Kabul (Figure 1) to train federal and provincial extension personnel on the latest techniques and science in irrigated agriculture.

Workshop Insights

It makes good sense that irrigation expertise from Western Colorado was invited to assist with the educational aspect of Afghan on-farm water management. The irrigated areas of the Upper Colorado Plateau, though half a world away from Afghanistan, share many similarities. They both feature extensive high altitude runoff irrigating dry arid valley bottoms concentrated with alkaline clay soils, and plenty of bindweed. Also they both have many hectares of wheat, orchard fruits, melons, onions, alfalfa with some corn, and a plentiful mix of livestock. The commonalities Colorado State University personnel enjoyed with the workshop hosts enhanced the discussion around on-farm water management immeasurably. Six days is a short time to make a lasting impact, but it did provide some insight into Afghanistan's status as an agricultural nation, and how it might inform international water resource security.

Utilizing Afghanistan's water optimally is a key piece of the nation's security status. Even with reprieves from the violence, water security problems (usually caused by conflict) also compromise efforts to permanently stabilize the region (Qureshi 2002). While few would dispute such a salient observation, it's a little harder to define "water security" in the Afghan context. Afghanistan is an old nation, culturally, technologically, and structurally that doesn't compare easily to mainstream definitions of water security. Settlement in Afghanistan is still governed by access to river or aquifer water, since storage is limited and capital works projects to move water outside basins of origin are not on aid agencies' immediate agendas. Each country has its own water security challenges. In India water delivery infrastructure is reasonably well developed, and access to water depends mostly on healthy precipitation and snowpack. In the West users tend to be comforted by their own ambivalence to this "most precious resource," which perhaps explains why water in the United States often "evades institutional classification and eludes legal generalizations" (Wolf 1999). In Afghanistan water is plentiful and water access is generally limited infrastructure. More importantly, long and healthy lives remain a rare commodity, so most Afghans are yet to enjoy the luxury of academic debates over their water resources future. Small incremental improvements are often received with much joy and gratitude.

Afghanistan spent many centuries needing little in the way of institutional or legal frameworks for water. A land of many ethnicities, with some of them extremely isolated, the nomadic societies and valley-centric provinces within its boundaries enjoyed low population densities surviving on a predictable if not excessive supply of water (Qureshi 2002). These villages and hamlets remained largely invisible to outsiders until the Russian invasion of the 1980's (Cookson et al. 1992). Today there are approximately 11, mostly Sunni Muslim tribal groups (the dominant being Pashtun), that co-exist relatively peacefully in the Afghan region, as they have for some time (Barfield 2010). It might be surprising to learn prior to the upheavals of the late 20th Century, the central rulers were often heavy handed maintaining the status quo. It was a "political horse trade" of sorts: rural communities gave up wealth and control in return for an absence of federal interference. This understanding usually included, (a) protection should a community be threatened from outside Afghanistan's borders, and (b) swift arbitration if an internal dispute escalated (Barfield 2010).

Without interference from Kabul, most of these smaller rural societies were able to effectively maintain the ancient Mongol system of local governance for millennia, sometimes known as the "three M's." A leading Mullah was responsible for overseeing religious matters, a Malik for land and commerce administration, and the Mirab for administering water distribution and resolving disputes. Some townships elected these positions while others preferred the titles to be inherited (Brick 2008; Thomas 2009). With modern

Afghanistan attempting to replace the ruins of multiple conflicts with a new internationally viable society, the benefits of foreign funding has had unintended consequences on this elegant system.

Development aid and the accompanying spike in cash flow has improved water delivery in a number of areas (The Asia Foundation 2006). Replacing the heroin poppy trade with alternative food crop mixes has provided additional incentive for many of these delivery improvements (Boone 2008; National Solidarity Program 2011). While some of these efforts are successful, others have compounded the rapidly shifting balance of water distribution among neighboring users (Scott 2008) and exacerbated local water quality problems such as salinity. Corruption over water allocation has also increased (The Asia Foundation 2006). Such challenges have surfaced at a pace that has often outstripped local governments' ability to resolve them. A water administration system that relies heavily on a few individuals, such as the local Mirab, means these schisms can quickly undermine any sense of restored order for the local farming community. With trust so integral to rebuilding local governance, such compromises are hard to reverse. Each time local leaders are stretched beyond their authority, it highlights the demoralizing effects of inequality that are always lurking when striving to improve quality of life in the developing world (Watkins 2005).

Without considerations by foreign development agencies for how ingrained the Mongol approach is in the psyche of Afghans, it's fair to expect significant growing pains bringing Afghanistan into the 21st century. Block grants from the National Solidarity Program initiated in 2003 have helped address some of the many small-scale technological and structural problems with approximately US$300 million disbursed in the water resources sector (National Solidarity Program 2011). What is unclear is how sustainable such projects will be as program recognition among Afghans is limited (The Asia Foundation 2006). Some of these projects are designed to encourage entrepreneurship and a more commercial approach to agriculture. Historically, water has been allocated at the family or field level since the labor-intensive nature of subsistence farming has removed the incentive to aspire for more (Barfield 2010). Whether capitalism can be successfully integrated into a society that strives to preserve its communal nature, sometimes at the expense of the individual, remains unproven.

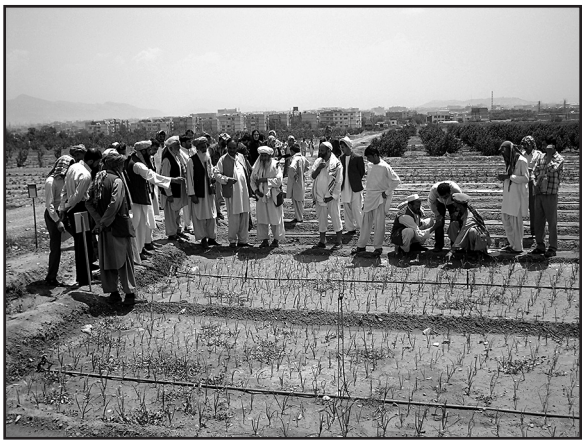


Figure 2. Workshop participants practice soil moisture measurement techniques in research plots at the Badam Bagh farm.

As the workshops progressed, the traditional roles of instructor and participant were gradually replaced by a more collegiate atmosphere and open exchange of experience and knowledge. Field visits enhanced this interaction which included hands-on examination of live systems. Additional hands-on sessions included strategizing effective technology demonstrations, new methods for measuring crop water use (Figure 2), and effective irrigation scheduling. Employing a train-the-trainer model, the Colorado State University workshop agenda was designed primarily for end users who are already benefiting from recent equipment upgrades. The objective for workshop participants was to ensure this group of irrigators translates these improvements into yield increases. Those still awaiting improvements would ideally report some increase in availability through the collective reduction of wasted water. As extension agents, this collection of engineers, agronomists, and hydrologists clearly had the ambition, scientific understanding, and relationships with local producers to execute highly impactful irrigation outreach in their provinces. Providing effective programming in spite of persistent provincial violence was the primary concern for most

attendees. Helmets and bullet-proof vests were only seen on security personnel in Kabul, but there is much to suggest that rural Afghanistan has yet to become a safe place to work (The Asia Foundation 2006).

Many of the larger Afghan tribal groups are wise to the value of diplomacy even if neighborly cooperation has often been imperfect (Barfield 2010). Water may have sparked some smaller skirmishes, but between these groups a pragmatic peace has generally prevailed (Barfield 2010). Academia is somewhat divided on where human access to water resources fits into the larger national security discussion. The traditional view has been that as water scarcity spreads, it is inevitable that conflict potential across the globe will increase due to a perceived or real lack of access to water (Gleick 1993; Remans 1995; Samson 1997). The progressive and increasingly accepted view is that water is valued separately from land, oil, or mineral wealth. It is also more likely be a catalyst for cooperation between nations, even those that might otherwise be at odds (Carson 2004; Wolf 2003). Afghanistan poses a slightly different question since the reverse problem applies: conflict is creating scarcity. The inability to utilize Afghanistan's abundant water is in most cases caused by outdated or war-damaged infrastructure, and a lack of safe opportunity for repair.

Today, a new democratic Afghan government is struggling to establish credibility in the face of a creatively persistent insurgency. This challenge is exacerbated by how little Afghans have previously needed or wanted to consider the political and personnel shifts inside the palace walls. The ability to divert water safely and consistently for local use will undoubtedly be the most potent catalyst for how Afghans measure immediate and long term recovery. The group of extension personnel attending this workshop were clearly fearful that many of the ditch-level gentleman's agreements will be ignored as the current wave of irrigation upgrades and reforms are implemented (International Union for the Conservation of Nature 2010). Foreign aid is being injected into the rebuilding effort at a rate of about US$2 billion a year, with the United States the largest contributor, delivering about 85 percent (Hersch 2012). As a pertinent example, Japan has been supporting the rice growing efforts in Nangahar, Kabul, and Bamiyan provinces, providing improved water delivery and opportunities to expand rice growing acreage. Rice is an important staple in Asian countries. Not only does it underpin the domestic food supply, but its shelf life and transportability opens doors for international trade long closed by war. In spite of this, rice's thirst for irrigation water is notorious and regional expansion of its acreage has profound implications for neighboring users. With a lack of basin-level water adjudication, Mirabs in downstream communities being shorted by upstream overages have little at their disposal to effectively serve their communities (International Union for the Conservation of Nature 2010).

Other Considerations

If Afghanistan is able to harness its significant water resources and improve its security situation, it represents a rich source of "virtual water" – the consumed water responsible for raising cereals, vegetables, fiber, and fruits – food that crosses watershed or international boundaries (Allan 1998). Some nations facing water and food supply constraints are already investing in off-shore food production – more cynically known as land and water "grabs" (Wolf 2003). A stabilized and rebuilt Afghanistan is likely to be an agricultural target for future land transactions of this nature, especially Saudi Arabian and Chinese interests, considering their growing participation in the practice and proximity. The effectiveness of the central government will be central to ensuring that, should this activity start to occur, it does so in the nation's interests.

Potable water infrastructure has also declined, often in parallel with agriculture. This problem is evidenced by limited access to safe drinking water and sanitation (Lone 2011). Less than half of Afghanistan's population has access to safe drinking water and only about a third benefit from adequate sanitation. Rapid population growth and climate change will only exacerbate these setbacks, putting additional stress on water services and food supplies already failing to keep pace with demand (Cincotta 2009).

Hydro power may be the bedrock for a successful Afghan future. Much foreign aid and human life was spent in recent years attempting to repair and expand Afghansitan's largest hydroelectric plant: the Kajaki dam in war-ravaged Helmand province (Urban 2011). Kajaki is one of six plants that account for 239 MW, or about 40 percent of Afghanistan's power-producing capacity. Many Afghans see only intermittent access to electricity, much of which is imported from Uzbekistan. Micro-hydro has had better success. Badakhshan province, for example, recently became the successful recipient of six micro-hydro plants producing a total of 1.3 MW, bringing light and power to 63,000 people. Importantly the project was preceded with three years of outreach to ensure the project was implemented appropriately and effectively. The impact has been profound with almost complete elimination of fires and smoky kerosene lamps to heat water and produce light (Wright 2012), also removing the labor and negative impacts of harvesting fire wood. While terrorist activity remains a threat, this community-based piecemeal approach may be the key to meeting Afghanistan's estimated 2020 demand of 3,000 MW (Flak 2012).

Conclusions

At the conclusion of the workshop it wasn't clear who had benefited the most. The experience was undoubtedly eye-opening and rewarding for all. Prior to their attendance, workshop participants had already achieved much with little, and their ambition and resourcefulness were a lesson well-learned by Colorado State University representatives. Armed with more refined irrigation management tools, there is no doubt that these inspiring extension professionals will quickly build on their prior outreach successes. Noticeably, there were some basic tools that would likely accelerate their progress dramatically:

- Weed control was clearly a problem. Access to backpack sprayers, safety equipment, and modern pesticides could greatly improve yields and the return on investment in new irrigation systems;
- Experimental design and management was not a task anyone in the group had been exposed to. Residency in a western university, or an extended visit to their communities from western extension or experiment station personnel would greatly assist with effectively promoting appropriate technologies; and
- While many of the attendants had water resource knowledge that exceeded their Colorado State University instructors, synthesizing this information into a concise, digestible form, whether as a brief presentation (Figure 3), or simple fact sheet was largely foreign to many; another skill that could be acquired via residency or an extended visit from accredited professionals.



Figure 3. Delivering farmer-friendly presentations were a requirement of the workshop program.

Whatever aspirations the large coalition of foreign aid agencies has for a new Afghanistan, the security of its water supply and a strong local agricultural sector are still patently vulnerable. Although critical administration improvements and the self-regulating benefits of cultural practices continue to be overlooked in favor of larger more noticeable projects, it's not unreasonable to expect continued problems in stabilizing the country. It might be easy to dismiss the Mongol water management system as antiquated, but ways to integrate it with a more advanced water adjudication system are yet to be fully explored. An interim method could be to cap diversions at the district level to more closely match crop water use, which would also provide an incentive for on-farm efficiency and more precise water accounting. When local Mirabs flag overages within their districts that

they are unable to resolve, a basin referee could be employed as a third party adjudicator. Whichever rubric is chosen, there must be some means for downstream users to peacefully protect themselves from excessive upstream diversions. Without this degree of water security for the agricultural sector, those who would seek to undermine Afghanistan's recovery will continue to have ample opportunity.

Acknowledgements

The authors would like to acknowledge Dr. Ajay Jha of the Department of Horticulture at Colorado State University, and Dr. Otto Gonzalez of the United States Department of Agriculture's Foreign Agricultural Service for providing the opportunity to visit Kabul and work with some of Afghanistan's best and brightest irrigation professionals. Much appreciation also goes to Dr. Curtis Swift of Colorado State University Extension for conducting workshops in advance of the authors' arrival, and whose experience and wisdom greatly assisted with the authors' preparation. A special thanks also to Mr. Abdul Wassey Nassrey for being the consummate host for the authors' short visit to Kabul.

Author Bio and Contact Information

Denis Reich is a Water Resources Specialist for the Colorado Water Institute and Colorado State University Extension based in the Upper Colorado River Basin. A Chemical Engineering graduate from Sydney Australia, he worked for a number of years around the world on membrane filtration systems before completing a Master of Science at Iowa State University in Sustainable Agriculture and Economics. He currently leads a number of applied research, outreach, and stakeholder engagement projects. He is also the current chair of the Colorado Mesa University Water Center and is a Colorado Water Institute liaison to the state water planning process. He can be contacted at Denis.Reich@Colostate.edu or (970) 242-8683.

Calvin Pearson, Ph.D. is a professor in Colorado State University's Department of Soil and Crop Sciences and a senior research agronomist at the Fruita Research Station, which is part of Colorado State University's network of six Agricultural Experiment Stations. Over a 28-year career in irrigated crop research, Calvin has lead multiple collaborative projects with private industry, federal and state agencies, international research centers, and local grower organizations, raising almost $4 million in grants from a wide array of sponsors. He is a fellow of the American Society of Agronomy and the Interim Senior Editor at the Scientific Journal Crop Management. He can be contacted at calvin.pearson@colostate.edu or (970) 858-2629 ex. 2.

References

Allan, J.A. 1998. Virtual water: a strategic resource - Global solutions to regional deficits. *Groundwater* 36(4): 545-546.

Barfield, T. 2010. *Afghanistan, A Cultural and Political History*. Princeton University Press, 350.

Boone, J. 2008. *Wheat versus Poppy on Helmand Front Line*. Financial Times. Available at: http://www.ft.com/cms/s/0/04e1f37c-6d85-11dd-857b-0000779fd18c.html#axzz2Au6fUxAT.

Brick, J. 2008. The Political Economy of Customary Village Organizations in Rural Afghanistan. University of Wisconsin, Madison, 49.

Carson, D. 2004. From headwater tributaries to international River: Obersving adapting to climate variability and change in the Nile basin. *Global Envrionmental Change* 25: 99-114.

Cincotta, R. 2009. *Afghanistan's Sky-high Birthrate Seems To Be Declining – and That's a Very Good Thing*. Stimson. Available at: http://www.stimson.org/spotlight/afghanistans-sky-high-birthrate-seems-to-be-declining-and-thats-a-very-good-thing/.

Cookson, F., D. Thirkill, A.A. Ferogh, M. Girma, and G. W. Azoy. 1992. *Afghan Water Constraints Overview Analysis*. United States Agency for International Development Representative for Afghanistan Affairs. Nathan-Berger Afghanistan Studies Project, 119.

Flak, A. 2012. *Electricity only reaches one in three Afghans*. Reuters. Available at: http://www.reuters.com/article/2012/01/09/us-afghanistan-power-idUSTRE8080C920120109.

Gleick, P.H. 1993. Water and conflict. *International Security* 18(1): 79-112.

Hersch, J. 2012. *Afghanistan's Squandered Foreign Aid has Young Businessman Worried About the Future*. Huffington Post. Available at: http://www.huffingtonpost.com/2012/05/18/afghanistan-foreign-aid_n_1526493.html.

International Union for the Conservation of Nature. 2010. *Towards Kabul Water Treaty: Managing Shared Water Resources – Policy Issues and Options*. International Union for the Conservation of Nature Pakistan, Karachi, 11.

Kelly, A.T. 2003. *Rebuilding Afghanistan's Agriculture Sector*. Asian Development Bank, Manila, Phillippines, 33.

Lone, P. 2011. Finnish funding enables UNICEF to provide safe water to school children in Afghanistan. Unicef Newsline, May 21st.

Morales, A. and F. Angelini. 2010. *Afghanistan's Food Supply is Least Secure in 163-Nation Ranking*. Bloomberg. Available at: http://www.bloomberg.com/news/2010-08-18/afghanistan-s-food-supply-is-the-least-secure-in-a-ranking-of-163-nations.html.

National Solidarity Programme. 2011. *Villages Speak and the Nation Listens: The Third National Consultation Conference of Afghanistan's Community Development Councils*. Ministry of Rural Rehabilitation and Development: Kabul, Afghanistan, 40.

Persaud, S. 2012. *Long-Term Growth Prospects for Wheat Production in Afghanistan*. A Report from the United States Department of Agriculture, Economic Research Service, 33.

Peter, A. 2010. Afghanistan's woeful water management delights neighbors. *Christian Science Monitor*. Available at: http://www.csmonitor.com/World/Asia-South-Central/2010/0615/Afghanistan-s-woeful-water-management-delights-neighbors.

Qureshi, A.S. 2002. Water Resources Management in Afghanistan: The Issues and Options. *International Water Management Institute.* Working Paper 49, Pakistan Country Series No. 14: 24.

Remans, W. 1995. Water and war. *Humanatares Vokerrecht* 8: 1.

Samson, P. and B. Charrier. 1997. *International freshwater conflict: issues and prevention strategies. Green Cross Draft Report*, May.

Scott, R. 2008. *Reconstruction and Opium Poppy Cultivation in Central Helmand – The Need for an Integrated Program*. Conference on Afghanistan Reconstruction: The Future. University of Nebraska at Omaha, 22.

The Asia Foundation. 2006. *Afghanistan in 2006 – A Survey of the Afghan People*. The Asia Foundation: Kabul, Afhanistan, 128.

Thomas, V. and M. Ahmad. 2009. *A Historical Perspective on the Mirab System*: A Case Study of the Jangharoq Canal, Baghlan. Afghanistan Research and Evaluation Unit Case Study Series: Kabul, Afghanistan, 66.

Urban, M. 2011. What went wrong with Afghanistan Kajaki power project? *bbcnews*. Available at: http://www.bbc.co.uk/news/13925886.

Watkins, K. 2005. *Human Development Report, 2005 – International Development at a Crossroads: Aid, Trade, and Security in an Unequal World.* United Nations Development Program, 372.

Wolf, A.T. 1999. Water and Human Security. *AVISO: An Information Bulletin on Global Environmental Change and Human Security* 3: 29-37.

Wolf, A.T., S.B. Yoffe, and M. Giordana. 2003. International waters: identifying basins at risk. *Water Policy* 5:29-60.

Wright, M. 2012. Inside Afghanistan's hydropower revolution *Green Futures*, July 6th.

Universities Council on Water Resources
Journal of Contemporary Water Research & Education
Issue 149, Pages 41-55, December 2012

Critiquing Cooperation: Transboundary Water Governance and Adaptive Capacity in the Orange-Senqu Basin

Elizabeth J. Kistin Keller

University of New Mexico, Albuquerque, NM

Abstract: This article analyzes the effects of the Orange-Senqu transboundary water governance regime on adaptive capacity by examining the influence of international water management institutions and interstate interactions on treaty flexibility, information management, actor networks, and financial resources. This study provides fresh insights into the dynamic effects of transboundary water governance. This is done by tracing changes in the components of adaptive capacity and the patterns of resource use and allocation over the regime's life and by determining the extent to which observed changes are caused by regime performance or other factors. Drawing on document analysis and in-depth interviews, this article examines the assumption that cooperation between riparian states will enhance the ability of parties to recognize and respond to changing circumstances. It also examines the factors enabling and constraining reflexivity and joint planning in the basin.

Keywords: *Transboundary, water, governance, adaptation, cooperation*

Continuously changing patterns of water flow and utilization in the Orange-Senqu basin are driven by climatic characteristics, population growth, economic development and changing resource management practices (Kistin and Ashton 2008). The general expectation is that cooperation between riparian states will bolster adaptive capacity by allowing them to recognize (through data collection, exchange, and utilization) and respond to (through joint planning and policy implementation) changing circumstances in the basin (Raadgever et al. 2008; Turton and Ohlsson 2000; Yohe and Tol 2002).

Drawing on a growing body of literature analyzing adaptive capacity at the national and basin levels (e.g., Goulden et al 2008; Smit and Wandel 2006; Yohe and Tol 2002), this study focuses on four core components of adaptive capacity in transboundary basins: institutional flexibility, information management, actor networks, and financial resources. Document analysis and in-depth interviews were used to trace changes in these four components between 1980 and 2008, determine the extent to which changes were caused by regime performance or other factors, and assess the underlying determinants affecting the regime's performance.

The analysis presented in this article differs from other known analyses of a similar subject, such as Kranz and Vidaurre (2008) and Raadgever et al. (2008), in two important ways. It extends the analysis beyond the performance of Orange-Senqu River Commission (ORASECOM) to consider contributions from all four international water management institutions comprising the regime. It also assesses not just the regime's effects, but also the causal factors contributing to the regime's influence on adaptive capacity.

Physical and Institutional Landscape of the Orange-Senqu Basin

The Orange-Senqu River is shared between four countries: Lesotho, Botswana, South Africa and Namibia. Rising in the Maluti Mountains of Lesotho, the Orange-Senqu River flows through central and western South Africa, receiving inflows from several important tributaries before flowing

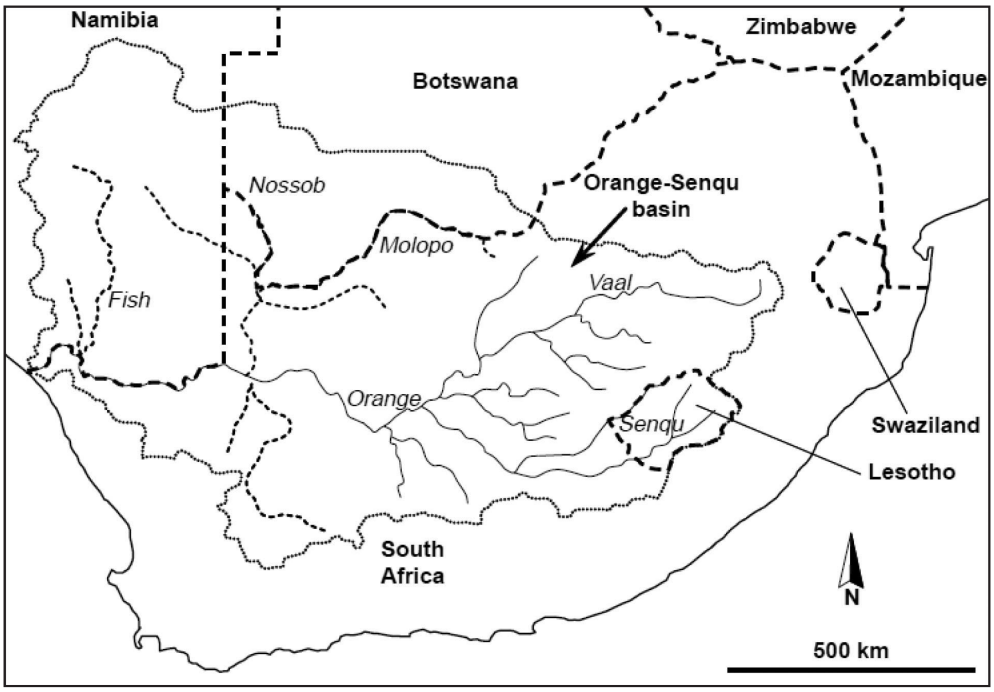


Figure 1. Map showing the location and extent of the Orange-Senqu River basin and the major tributaries in the basin. Source: Kistin and Ashton (2008).

along the border between Namibia and South Africa and entering the Atlantic Ocean (Figure 1).

The Orange-Senqu basin is characterized by a rich history of interstate interaction over water resources and a multiplicity of international water management institutions that have emerged and evolved over time (Kistin and Ashton 2008). In addition to the two regional South African Development Community water protocols signed in 1995 and 2000, the four riparian states have established six bilateral agreements and one basin-wide treaty (Kistin and Ashton 2008; Figure 2).

Four of these agreements are particularly relevant to the current management of the Orange-Senqu basin:

1. The 1986 treaty providing the framework for the Lesotho Highlands Water Project (LHWP);
2. The 1992 agreement establishing the Vioolsdrift and Noordoewer Joint Irrigation Scheme;
3. The 1992 agreement creating the Permanent Water Commission; and
4. The 2000 agreement establishing the basin-wide ORASECOM.

The 1986 LHWP treaty and the 1992 Vioolsdrift and Noordoewer Joint Irrigation Scheme agreement address the planning, operation, and maintenance of joint projects in the basin, while agreements establishing the Permanent Water Commission and ORASECOM create joint institutions to advise parties on the development and utilization of shared waters. As the arrows in Figure 2 illustrate, the ORASECOM has no formal oversight, advisory, or coordinating powers with respect to the pre-existing bilateral commissions.

Impacts on Adaptive Capacity

Institutional Flexibility

Flexible water treaties that anticipate the possibility of gradual and sudden changes in shared basins and incorporate mechanisms to allow parties to adjust management practices to changing circumstances are important for adaptive water management (McCaffrey 2003). Countries may employ a variety of mechanisms for enhancing the flexibility of a water treaty including allocation strategies, drought response provisions, amendment and review mechanisms, revocation clauses, and adaptation responsibilities (Kistin and

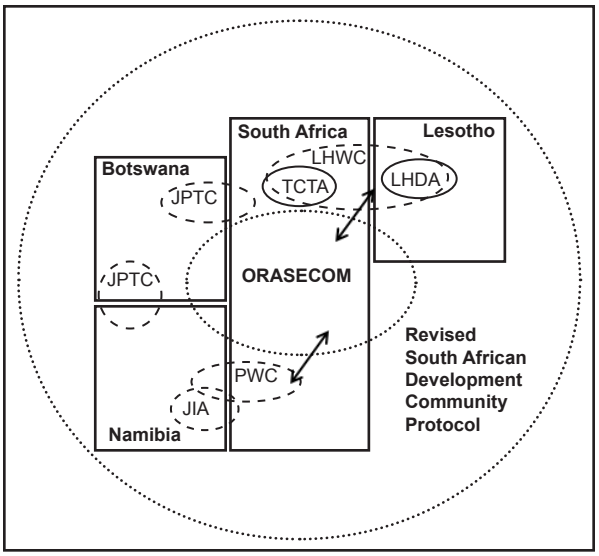


Figure 2. Schematic diagram illustrating the landscape of international water agreements and management institutions pertaining to the Orange-Senqu basin. Source: Kistin and Ashton (2008). JIA = Joint Irrigation Authority, JPTC = Joint Permanent Technical Committee, LHDA = Lesotho Highlands Development Authority, LHWC = Lesotho Highlands Water Commission, ORASECOM = Orange-Senqu River Commission, PWC = Permanent Water Commission, TCTA = Trans-Caledon Tunnel Authority.

Ashton 2008). Institutional flexibility also requires that adaptation opportunities embedded in formal governance structures be accompanied by the willingness of joint organizations to recognize and respond to changing circumstances.

The Orange-Senqu water regime contains a variety of flexibility mechanisms (Table 1). Project-oriented agreements (i.e., the LHWP and the Vioolsdrift and Noordoewer Joint Irrigation Scheme) tend to include more specific flexibility mechanisms, but overall, the parties rely heavily on joint organizations to guide the adaptation process. Discursive structures also play a significant role in shaping actual opportunities for recognizing and responding to changing circumstances.

As Kistin and Ashton (2008) describe in great detail, the existing agreements pertaining to the Orange-Senqu River basin contain several flexibility mechanisms, some of which have not yet been needed or used by the parties. Others, such as the progressive allocation and protocol amendment strategies adopted for the LHWP, provide specific guidelines that may help parties adapt to changing circumstances by requiring management policies and procedures to be reviewed, and if necessary, modified over time. The institutions that have been established to oversee basin projects and advise parties are enabled by the existing agreements to help drive the adaptive process. In particular, the broad mandates of the Permanent Water Commission and ORASECOM to advise parties on several specific issues, plus any other matter deemed important by the commissions, allow these institutions to recognise the need for change and advise the parties to take appropriate action.

Yet, while the agreements themselves do not restrict adaptive capacity, discursive structures within the basin prevent meaningful discussion of major infrastructure projects in the upper and lower basin at ORASECOM meetings, limiting opportunities for basin-wide planning and consequently constraining adaptive capacity. One manifestation of South Africa's efforts to restrict the extent of discussion occurred at a 2007 ORASECOM meeting attended by representatives of all four riparian states, as well as donor organizations and consulting firms active in ORASECOM activities. When a consultant asked the assembled audience when they expected the feasibility for Phase 2 studies of the LHWP to be completed, a member of the South African delegation quickly replied, "We don't discuss those matters here. This is the ORASECOM" (Kistin 2010).

While the reply gave slight pause to the consultant, it did not surprise the representatives from the riparian states who, according to Othusitse Katai, director of Botswana's international waters unit, have become accustomed to South Africa's reluctance to openly discuss the bilateral infrastructure projects (i.e., Phase 2 of the LHWP and the proposed re-regulating dam on the border between South Africa and Namibia) within the basin-wide forum (pers. comm. 2007). What this exchange illustrated is that, despite the ample flexibility afforded in the formal water governance structures, the South African delegations' broader efforts to restrict the boundaries of what can and cannot be discussed limits the ability of ORASECOM to engage in serious basin-level planning or recognize and respond to changing circumstances.

Table 1. Flexibility mechanisms embedded in the Orange-Senqu basin's water governance agreements.

Flexibility Mechanisms	Relevant annexes, articles, and protocols from Orange-Senqu agreements			
	2000	**1992**	**1992**	**1986**
Allocation				Art. 7 (2) Annex II
Drought Provisions		Art. 3	Art. 3 (5)	Art. 7 (2) Art. 9 (19) Art. 14 (1)
Amendments/Review	Art. 11	Art. 5	Art. 14	Art. 6
Revocation Clause	Art. 9	Art. 5	Art. 14	Art. 9 (7,8)
Institutional Responsibilities	Art. 1 [ORASECOM]	Art. 1 [PWC]	Art. 5 [JIA]	Art. 9 [JPTC] Protocol 6 [LHWC] Art. 7 [LHDA] Art. 8 [TCTA]

Source: Previously published in Kistin and Ashton (2008). Note: Section numbers given in parentheses. Water governance organisations created by treaties given in brackets. Art. = Article, JIA = Joint Irrigation Authority, JPTC = Joint Permanent Technical Committee, LHDA = Lesotho Highlands Development Authority, LHWC = Lesotho Highlands Water Commission, ORASECOM = Orange-Senqu River Commission, PWC = Permanent Water Commission, TCTA = Trans-Caledon Tunnel Authority, VNJIS = Vioolsdrift/Noordoewer Joint Irrigation Scheme.

Information Management

The process of adaptation in transboundary basins requires the collection, exchange, and utilization of information. For shared data to be used fully, issues of compatibility and credibility must be addressed. In addition to hydrological information, data on the full range of changing circumstances (climatic, economic, social, and political) are critical for developing a shared knowledge base and mutual understanding of the system and supporting decision making within shared basins (Goulden et al. 2008; Timmerman and Langaas 2005).

Over the last four decades, the collection, exchange, credibility, and compatibility of data and information related to water resources in the Orange-Senqu basin have increased (Table 2). The execution of joint studies, the adoption of and compliance with requirements for information exchange, and the development of interpersonal relationships have all contributed to this trend.

The bilateral, basin-wide, and regional agreements signed by riparian states in the Orange-Senqu basin require them to exchange data and information and provide prior notification of any activity having a significant impact on the quantity, quality, or flow of the basin (Kistin 2010). The bilateral agreements between Namibia and South Africa include fairly general expectations, while the bilateral agreement regarding the LWHP and the basin-wide treaty establishing ORASECOM outline more detailed requirements for riparian parties. In addition to the basin-specific agreements, all riparian states are also party to the South African Development Community Revised Protocol on Shared Watercourses, which reiterates the prior notification and information exchange requirements. Basin managers report a high level of compliance with formal requirements and increasing openness on information issues over time.

In addition to the contributions made by formal data-sharing requirements, several basin managers credited the increased interaction and improved interpersonal relationships with counterparts in neighboring countries as a key factor underpinning improvements in the level of information exchange. "Once you get to know these guys face

Table 2. Impacts on the collection, exchange, credibility, and compatibility of data and information.

	Observed Changes	Regime Contributions	External Factors	Remaining Barriers
Collection	Increased	Joint studies	Studies by national governments, parastatal organizations, private sector companies, and scientists	Financial resources, political priorities
Exchange	Increased	Treaty requirements, interpersonal relationships, joint studies	Change in regional political context, technological advances, regional monitoring initiatives	Political reluctance, staff capacity, competition within the private sector
Credibility & Compatibility	Moderately increased	Technology trainings, interpersonal relationships, joint studies	Change in regional political context, regional monitoring initiatives	Lack of data protocol or minimum standards guidelines, cost of new equipment and training, political reluctance

to face," explained Othusitse Katai, the director of the international waters unit in Botswana's Department of Water Affairs, "it's much easier to call them up with questions, if necessary, or make small requests for information that would otherwise get bogged down in bureaucratic formalities" (pers. comm. 2007).

The South African Department of Water Affairs also offered technology training to water ministries in neighboring countries as a means of increasing the transparency of the modeling methods it uses domestically to manage water resources. According to Dudley Biggs, the former head of Namibia's technical task team to ORASECOM, the week-long training sessions provided interesting information but served largely as a symbolic gesture of openness. "You would have to spend a year or two to understand the complexities of their systems," Biggs explained. "But we don't have that kind of expertise here or the resources to invest in that kind of technology . . . nevertheless, it demonstrated a willingness to share and contributed to levels of trust and credibility between our departments" (pers. comm. 2007).

The execution of joint studies in the basin has augmented the collection and compatibility of valuable data and information. Major joint studies include the Lower Orange River Management Study, the first phase of the ORASECOM Integrated Water Resources Management Plan, and the Phase 2 feasibility study for the LHWP. The Commission has also ordered studies on the wetlands at the river's source and the hydrology of the Molopo-Nossob system in Botswana.

Beyond the water regime, additional factors influencing improvements in information management include the data and information collected at the national level, political transformations in the region, technological advances, and regional-level efforts (Table 2).

Several basin managers described the high degree of tension, mistrust, and secrecy that developed between riparian states during the domestic and interstate conflicts of the 1980's. Parties viewed all shared data with great suspicion, diminishing the utility of information exchange. "The overwhelming sense of doubt caused us to check numbers constantly," recalled Neil van Wyk, a member of South Africa's technical task team. "The base assumption was that the other side was manipulating the figures to get a better deal" (pers. comm. 2007). The basin managers credited political transformations in the region for increasing the openness between governments and the information exchange level. Political transitions to democracy in both South Africa and Lesotho thus contributed to a decline in secrecy and suspicion regarding water resources data and increased openness between riparian states (Lesoma, pers. comm. 2007; Pyke, pers. comm. 2007).

Efforts to create a regional database of hydrological data and the ability to access and transfer data via the Internet have also contributed to improvements in information availability. The regional South African Development Community Hydrological Cycle Observing System is designed to serve as a central depository for regional water data. Though it faced technical and political roadblocks limiting its effectiveness in its early stages (see Ratashobya and Wellens-Mensah 2002), the South African Development Community water sector is currently in the process of planning for Phase 2 of the system (Ramoeli, pers. comm. 2007).

Despite these important advancements in data collection and exchange, limitations are evident on the willingness of upstream riparian states to share information openly. In 2007, the Namibian delegation to ORASECOM requested permission to participate as an observer in bilateral planning sessions regarding Phase 2 of the LHWP. Disappointed with the lack of meaningful discussion in ORASECOM regarding the development of major infrastructure in the upper basin, the Namibian delegation proposed the arrangement as an alternative avenue for communication. Although the exact wording of the appeal is unclear, retellings suggest the request was framed by Namibian representatives as a minor procedural modification to existing efforts to share information in the basin. According to Piet Heyns, the basic question posed to South Africa and Lesotho was, "Given that we are all committed to sharing information, what difference would it make if we were in the room while the planning was taking place?" (pers. comm. 2007).

For South Africa and Lesotho, the difference was significant. Delegations from both countries rejected Namibia's appeal and remain reluctant to alter current protocols for communication and information sharing between riparian states and basin commissions (Heyns, pers. comm. 2007). The rejection stemmed from concerns by both upper riparian states that involvement of a third party during the planning process would jeopardize their interests in the negotiation and implementation of Phase 2. "The primary concern," explained Peter Nthathakane, "was that the inclusion of Namibia would stall the already delayed process. For us, that means a delay in payment, and for South Africa, a delay in water, and both resources our countries urgently need" (pers. comm. 2007).

Basin managers in South Africa and Lesotho provided a range of reasons to explain their rejection of Namibia's request including the efficiency of bilateral partnerships for project implementation (Mwakwalumbwa, pers. comm. 2007), the logistical complexities of including additional states (Lesoma, pers. comm. 2007), and the belief that the current levels of communication and interaction with ORASECOM provided sufficient opportunities for the involvement of downstream states (Dlamini, pers. comm. 2007). South African leaders also framed their position as benefiting Namibia by saving them from wasting their time at multiple meetings or getting too bogged down in inconsequential details (Heyns, pers. comm. 2007). But as Heyns put it, "We asked in the first place because we know that we will feel the consequences here of their decisions upstream" (pers. comm. 2007).

Additional barriers described by basin managers to the accumulation of accessible and compatible information to support adaptive capacity in the basin include the lack of human, financial, and technical resources; the lack of political will and data protocols; and competition among private consultants. Basin managers in Lesotho, Botswana, and Namibia noted the lack of funding for data gathering and processing as a significant barrier to information management. The high levels of staff turnover in each riparian country were also noted as a significant obstacle. The establishment of data protocols is a politically sensitive issue in the basin. Certain political representatives are reluctant to have someone else dictate their procedures. On a pragmatic level, leaders are also worried about the high costs of retraining personnel if significant changes are made. Finally, beyond the riparian states, private consultants also play an important role in water resources information collection and exchange. Because their wealth of data and information determines their ability to win public and private contracts in the region, consulting firms do not have strong incentives to share data and information openly, nor are they bound by the same governance rules mandating the exchange of information between states.

Actor Networks

Recognizing the need for change, gathering information on it, making decisions about what needs to be changed, how to do it, and implementing and monitoring strategies depends on numerous actors (Smit and Wandel 2006). The stronger the linkages between different actors involved in different aspects of governance, the more equipped the regime is for recognizing and responding to changing circumstances (Yohe and Tol 2002).

Because there are a variety of networks influencing transboundary basins' adaptive capacity, this article considers four types of networks identified by interviewees as crucial linkages for recognizing and responding to changing circumstances in the Orange-Senqu River basin. These networks interact through communication, data collection and dissemination, and policy development, implementation, and monitoring. They are:

- International basin managers who serve on joint water commissions and authorities that facilitate communication and planning across national boundaries;
- Technical and political representatives within joint commissions who influence the way in which data and information are translated into goals and strategies;
- Representatives who act intersectorially within the water ministries and related government sectors (e.g., agriculture, energy, and environment) and who influence how problems are framed, data are collected and disseminated, and policies are implemented; and
- Basin organizations and stakeholders who exchange information and implement policy.

Actor networks related to water governance in the Orange-Senqu basin have grown in strength and scope over the last four decades (Table 3). In particular, the networks between basin managers from each riparian state have grown stronger as the result of basin-specific governance initiatives and regular meetings of commissioners and technical task teams. Regional efforts to support dialogue and planning among water managers, international conferences, and donor-sponsored field trips also contribute to the development of these networks. In a few cases, basin managers developed relationships before assuming leadership roles in their respective countries.

Beyond the networks linking joint commission representatives, other types of actor networks expected to support adaptive capacity remain variable or weak within the Orange-Senqu basin. Discussion and decision making regarding water

Table 3. Actor networks impact on water governance in the Orange-Senqu basin.

Type of Network	Impact	Regime Contributions	External Factors	Remaining Barriers
Basin Managers	strong	Regular meetings	Conferences, field visits, prior relationships	Staff turnover
Technical and Political Representatives	mixed	Meetings	National departmental structures	Communication
Intersectoral	weak	-	Workshops	Time and resources
Basin Organizations & Stakeholders	weak	Roadmap (ORASECOM); NGO forum (LHDA)	NGO partnerships, donor funding, political context	Political reluctance, institutional design

Note: LHDA = Lesotho Highlands Development Authority, NGO = Nongovernmental Organization, ORASECOM = Orange-Senqu River Commission.

management is concentrated heavily within the departments of water and agricultural affairs in the four riparian states, with little engagement with other governmental departments. In some cases, the representatives to the joint commissions oversee broader ministries, but thus far there has been no formal participation from departments of mining, environment, or tourism.

In general, basin managers noted that the lack of intersectoral actor networks for transboundary water management reflects general levels of interdepartmental disconnect within the government systems. As Peter Pyke, a South African member of ORASECOM's technical task team noted, "Different departments will come together around a specific project. There is not a strong system yet for intersectoral planning and with everyone so busy on their own tasks, there is no time for dialogue for the sake of dialogue" (pers. comm. 2007). Interestingly enough, efforts to streamline water management in Lesotho by consolidating all water-related offices under a single umbrella organization, the Water Commission, has effectively isolated water issues from other departments and decreased cross departmental communication (Lesoma, pers. comm. 2007; Tibbets-Abbett-McCarthy-Stratton Consortium 1995).

Stakeholder engagement in the basin varies by joint institution. The Commission has made a nominal commitment to promoting public participation in decision making around basin resources, but there has been no implementation of it to date (ORASECOM 2007). In contrast, the Joint Irrigation Authority was designed to delegate water resources management in the binational irrigation scheme to direct stakeholders. As such, the authority is comprised of three farmers from each side of the border and one representative each from the South African and Namibian governments. Although the Joint Irrigation Authority has historically recognized farmers as its primary stakeholders in the region, discussions started in 2007 about expanding outreach (and membership on the Joint Irrigation Authority) to allow participation from a wider body of stakeholders including business owners and tourism operators (Liebenberg, pers. comm. 2007).

Finally, the turbulent relationship between the Lesotho Highlands Water Commision and communities affected by the construction of the joint project is well documented. The network between the Lesotho Highlands Development Authority and affected communities started off poorly with little communication between the two groups in the planning and early implementation of Phase 1A (Hoover 2001; Panel of Experts 2002). Yet after a network of local and international NGOs joined affected communities in launching protests, the parties negotiated new strategies for communication, consultation, and compensation (Lesotho Highlands Development Authority 2008). It has yet to be seen how the evolving network between the Lesotho Highlands Development Authority and various stakeholders will influence the implementation of Phase 2 of the LHWP.

Financial Resources

Finally, financial capital is widely regarded as a critical component of adaptive capacity (Allan 2001; Turton and Ohlsson 2000; Yohe and Tol 2002). Levels of economic development in the Orange-Senqu basin states vary greatly, affecting the distribution of wealth and the capacity of each country individually to recognize and respond to changing circumstances (Kistin and Ashton 2008). South Africa's relatively high GDP, for example, enables the country to invest in human, technological, and infrastructure resources to support advanced water management and adaptation at a level beyond that of its neighboring states. Cognisant of this interstate disparity, this article examines two additional facets of financial resources affecting adaptive capacity in the basin: the effect of the water regime on cost saving and revenue generation and access to financing for transboundary water governance initiatives.

Joint governance initiatives in the Orange-Senqu basin contribute variably to the financial resources available to the riparian states (Table 4). At the basin level, ORASECOM has yet to make major, on-the-ground impacts, but it has contributed to cost savings by engaging parties in joint studies (Tompkins 2007). At the project level, the joint governance of the Vioolsdrift and Noordoewer Joint Irrigation Scheme allowed farmers on both sides of the border to continue production after Namibia gained independence.

Table 4. Impact of joint water governance initiatives on cost savings and revenue generation in the Orange-Senqu basin.

Joint Initiative	Resource Generation	External Factors	Remaining Barriers
Studies	Cost saving	Donor funding	Eliminating overlap & redundancy
Vioolsdrift and Noordoewer Joint Irrigation Scheme	Continued water delivery/ agriculture production	Processing/marketing	Allocating water within the scheme
Lesotho Highlands Water Project	Royalties, hydropower and infrastructure to Lesotho; reliable water supply to South Africa	Additional water transfers	Phase 2; compensation/ distribution of wealth

Agricultural production and employment linked to the scheme contribute only marginally to national incomes in South Africa and Namibia, but they make a significant impact on the producers and laborers in the border region (Permanent Water Commission 2005). The LHWP, by contrast, contributes more substantially to resource generation for upper riparian states by enabling a reliable supply of water to support agricultural, mining, and industrial production in South Africa and generating hydropower and royalty payments for Lesotho (Lesotho Highlands Development Authority 2008). The allocation of water and related benefits at the national and subnational levels is discussed in Kistin (2010).

Over the last four decades, the Orange-Senqu water regime has played an important role in attracting investment and donor support in the basin and the region. In the early 1980's, the partnership between Lesotho and South Africa opened doors to financing from the World Bank and other international donors that otherwise might have been impossible given sanctions against the apartheid regime (Hoover 2001). Moreover, since 2000 and the establishment of ORASECOM, the Orange-Senqu basin has attracted substantial support for transboundary water governance initiatives from multiple international partners (Kistin 2010; South African Development Community 2008). Donor support in the basin bolsters the resources available to ORASECOM, in particular, and helps to facilitate adaptation by financing joint studies, meetings, training, and workshops. Yet basin managers also report duplication and overlap as a result of the influx of external donor partners with some suggesting that donor saturation diminishes adaptive capacity in the basin. Furthermore, as Kistin (2010) explains in greater detail, donor initiatives in the basin tend to focus on technocratic approaches to enhancing cooperation and overlook the political barriers constraining adaptive capacity in the basin.

Cumulative Effects on Adaptive Capacity

The previous four sections have shown that the Orange-Senqu water governance regime both enables and constrains different aspects of adaptive capacity. Table 5 provides a summary of the regime's positive and negative effects on institutional flexibility, information management, actor networks, and financial resources.

In terms of institutional flexibility, the analysis showed that the formal treaties do not restrict the ability of riparian states to recognize and respond to changing circumstances. They contain multiple flexibility mechanisms. Joint authorities were granted broad powers for adapting management strategies and joint commissions were granted broad mandates to advise on all matters deemed important to cooperating parties. However, discursive structures established by South Africa, which keep major bilateral infrastructure projects beyond the realm of acceptable discussion at ORASECOM meetings, limit the opportunities for meaningful basin-wide planning, and consequently, constrain the ability of riparian states to recognize and respond to changing circumstances. This finding also challenges the assumption held by many donor organization that ORASECOM serves as the overarching planning organization in the basin.

Table 5. Cumulative effects of the Orange-Senqu water regime on adaptive capacity in the basin.

Component	Regime Contributions	
	Positive	**Negative**
Institutional Flexibility	• Multiple flexibility mechanisms embedded in basin treaties • Joint authorities granted broad powers for adapting management strategies • Joint commissions granted mandate to advise on all matters deemed important to cooperating parties	• Discursive structures prevent basin-wide dialogue regarding major infrastructure in the basin, restricting ORASECOM's advisory ability
Information Management	• Procedural compliance with exchange requirements • Overall increase in openness	• South Africa and Lesotho rejected Namibia's request to participate in the LHWP's Phase 2 discussions
Actor Networks	• Strengthening of interstate networks of government water officials	• South Africa and Lesotho privilege bilateral networks, limiting strategic planning at the basin-wide level
Financial Resources	• Joint studies save money • Joint projects make major (i.e., LHWP) and minor (i.e., VNJIS) contributions to national wealth • Cooperative governance arrangements help states secure financing and donor support	• The LHWP, while mutually beneficial at the national level, is not necessarily a win–win scenario at the regional or subnational level • Donor saturation in the basin leads to overlap and duplication of efforts to support adaptive management • Donor initiatives tend to overlook the political barriers constraining adaptive capacity in the basin

Note: LHWP = Lesotho Highlands Water Project, ORASECOM = Orange-Senqu River Commission, VNJIS = Vioolsdrift/Noordower Joint Irrigation Scheme.

The analysis of information management showed that the water governance regime made important contributions to data collection and exchange. Parties have largely complied with procedural requirements for data sharing and prior notification of projects in the basin. Yet there is a reluctance to engage the basin-wide commission in discussions about bilateral infrastructure projects and refusal to allow Namibia to participate as an observer in Phase 2 deliberations regarding the LHWP. The recalcitrance signals limitations to the willingness of upstream riparians to share information openly.

A similar trend emerged in the analysis of actor networks. Overall, the water governance regime has contributed to the strengthening of relationships and communication between basin managers in all four riparian governments. Efforts to avoid undue interference with the LHWP, however, meant that Lesotho and South Africa privileged bilateral networks as the primary means for water resources planning.

In terms of wealth and financial resources, collaboration between riparian states has contributed to various levels of cost savings and revenue generation. The costs and benefits of transboundary water cooperation, however, have not always been distributed evenly at the subnational scale (Kistin 2010). The ORASECOM's formation has also attracted significant financial support from bilateral and multilateral donors. However, donor initiatives tend to focus on technocratic approaches to enhancing cooperation and overlook the political barriers constraining adaptive capacity in the basin (Kistin 2010).

Overall, the hypothesis that ongoing hydro-political cooperation enhances adaptive capacity

by enabling information exchange and use while facilitating joint planning cannot be fully corroborated. Although the regime contributes to both too a certain degree, discursive governance structures limiting the scope of discussions within ORASECOM constrain the parties' abilities to recognize and respond to changing circumstances and engage in joint planning at the basin scale.

Causal Factors

Multiple factors contribute to the Orange-Senqu water governance regime's influence on adaptive capacity components. This section takes a closer look at the influences of power asymmetry, problem structure, expert networks, and political context on the ability of riparian states to recognize and respond to changing circumstances in the basin (Table 6).

Power Asymmetry

Power asymmetry in the Orange-Senqu basin plays a significant role in shaping the water regime's effects on adaptive capacity. This section takes a deeper look at the political nature of flexibility mechanisms, information management, actor networks, and financial resources while examining how South Africa's dominance in the basin influences each core component of adaptive capacity. It illustrates the South African government's behavior as both a pusher and a laggard with respect to different aspects of information sharing and joint planning, and discusses the implication of this behavior for the prospects of recognizing and responding to changing circumstances in the basin.

First, the formal governance structures comprising the Orange-Senqu water regime contain ample flexibility mechanisms that provide riparian states with opportunities to recognise and respond to changing circumstances over time. However, the ability to invoke and operationalize these mechanisms is dependent on power endowments and political negotiation. South Africa's dominance in the basin has allowed the country to invoke certain flexibility mechanisms embedded in the institutional structure while obstructing others. For example, South Africa delayed discussions of Phase 2 of the LHWP after recalculating projected water demands and determining that additional supplies would not be necessary until 2020 (Hedricks 2008). Using a combination of tactics including silence and sanctioned discourse, however, South Africa also obstructs the ability of ORASECOM to advise riparian governments on "any matter deemed important" by restricting the scope of discussion in the basin-wide forum. These covert efforts to shape the decision-making process are often overlooked by donors and analysts who assume that ORASECOM serves as the overarching planning organization in the basin (Malzbender and Earle 2009; Veelen 2009).

Second, decisions about whether and how to collect and exchange information related to shared water resources are fundamentally political and driven by the power and interests of riparian parties. South Africa can be seen as both a pusher and a laggard in this area. Given the importance of transboundary water resources in sustaining its economy, the South African government has long prioritized the collection of data and information

Table 6. Factors enabling and constraining adaptive capacity in the Orange-Senqu basin.

Component	Enabling Factors	Constraining Factors
Institutional Flexibility	Uncertainty	Power/Interests
Information Management	Riparian Resources Enternal Support Political Context	Riparian Resources Power/Interests
Actor Networks	Institutional Design External Support	Institutional Design Riparian Resources Power/Interests
Financial Resources	Institutional Design External Support	Institutional Design Riparian Resources Power/Interests

related to water resources and continues to lead globally in the development of highly sophisticated tools for adaptive water management in arid and semiarid climates (Tompkins 2007). Since the transition to democracy in 1994, South Africa has complied with its commitments to transparency and regional cooperation by sharing existing data, leading joint studies, and offering free personnel training and technology transfers to other water ministries within the South African Development Community (Biggs, pers. comm. 2007; van Niekerk, pers. comm. 2007). Together, these efforts have had a substantial impact on the breadth, depth, and compatibility of water resources information in the region. Yet, the refusal to engage in project discussions at the basin-wide level and the reluctance to include Namibia at the table for discussions regarding Phase 2 of the LHWP signals limitations to South Africa's willingness to share information openly.

Third, South Africa's relative power endowments and the use of utilitarian tactics allow the country to choose what kind of actor networks to pursue and privilege. South Africa's strong bilateral alliance with Lesotho and the benefits provided by South Africa to the upstream riparian state have made Lesotho a significant ally to South Africa in the perpetuation of the bilateral planning model. The potential provision of water supplies from the LHWP through a bilateral deal with South Africa has also rendered Botswana unlikely to push for more substantive engagement at the basin scale. South Africa also uses discursive tactics to downplay the significance of Namibia's request for observer status while emphasizing its procedural compliance with notification and exchange requirements, and the basin-wide benefits generated by the LHWP.

Finally, in terms of attracting and securing international financing and donor assistance, South Africa plays an interesting role. Following its transition to democracy in 1994, international donors sought to engage in a wide range of national and regional issues. In addition to democratization, donors viewed water resources management as a critical action area linked to issues of growth, poverty, health, redistribution, and capacity building. As such, officials within the South African Department of Water Affairs have been able to leverage strong relationships with international donors to secure financial support for transboundary water governance initiatives.

However, South Africa's relative wealth in the region also makes them more of a laggard when it comes to the general pursuit of international donor funds. As a result, when donor saturation emerged as an issue in the Orange-Senqu basin, members of the South African delegation felt more comfortable speaking up on the issue. As one official noted anonymously, "They are less dependent on donor assistance than we are so it's easier for them to recognize the point when too much help becomes counterproductive." Indeed, while the smaller states in the basin perceive themselves to need donors to cover the cost of both domestic and international water projects, the perception among many South African representatives is that the dependence runs the other way (i.e., that the donors actually need recipients of funds to endorse and legitimize their projects). This dynamic has allowed South Africa to take the lead in demanding better coordination among donor partners to avoid the duplication and overlap of transboundary water governance initiatives. This dynamic is discussed in more detail in Kistin (2010). Overall, analyzing the influence of power asymmetries on adaptive capacity in the Orange-Senqu basin illuminates South Africa's significant ability to control the agenda and shape boundaries for discussion and planning.

Problem Structure

Intertwined with the influence of power asymmetry, the combination of interest asymmetry, uncertainty, and commitment requirements also play an important role in shaping the influence of the Orange-Senqu water regime on adaptive capacity.

The analysis of the Orange-Senqu water governance regime's effects on adaptive capacity demonstrated that the competing interests that characterized the formation of ORASECOM (i.e., Namibia's desire for basin-wide planning and South African interest in maintaining bilateral organizations as the core planning mechanisms) continue to influence the implementation of governance arrangements. As Kistin (2010) describes, South Africa acted as a catalyst in establishing bilateral institutions in the basin

(e.g., the Lesotho Highlands Water Commision and Permanent Water Commission), but engaged in ORASECOM's formation as a more reluctant participant due to its lack of interest in planning or allocating water at the basin-wide level. Since the basin-wide Commission emerged in 2000, South African delegates to ORASCOM have been active participants in meetings and activities, and they contribute significantly to strengthening the professional relationships between political and technical representatives in all four riparian states. In terms of strategic planning, however, the South African government continues to privilege the bilateral network upstream.

Unpacking the components of problem structure reveals that South Africa's preference for bilateral planning is linked to both commitment requirements and uncertainty associated with the prospect of basin-wide planning. As my section on information management demonstrated, parties have performed well in collecting and exchanging information when commitment requirements are perceived to be low (e.g., the execution of joint studies or the compilation of existing information). However, when commitment requirements are perceived as more substantial (e.g., establishing a basin-wide data protocol, opening Phase 2 discussions, or engaging in planning at the basin level) progress has been blocked, stalled, or slower to materialize. Combined with the high levels of normative uncertainty and the intangibility of what basin-wide planning might entail, the perception of high commitment requirements contributes to South Africa's zero-sum mentality. They are concerned that efforts to engage in significant planning or water allocation at the basin scale will threaten their current and future access to water resources.

Recognizing the existence of interest asymmetry within the wider context of riparian cooperation draws attention to the fact that problem structures are not always resolved in the formation of agreements and organizations. Consequently, efforts to motivate a powerful country's engagement in certain issues may require the structuring of incentives and the adjustment of commitment requirements in a way that entices powerful actors to take part in envisioning a more regional approach.

Expert Networks

Adaptive capacity in the Orange-Senqu basin has been influenced by two primary clusters of expert networks: private consultants and donor organizations. Both of these networks have played a significant role in enabling the collection, exchange, and utilization of information in the basin. Experience from the Orange-Senqu basin, however, cautions against broad assumptions that involvement by expert networks will necessarily bolster the implementation of transboundary water governance arrangements.

Like the riparian states, the quasi-internal network of consultants operating in the Orange-Senqu basin also demonstrated reluctance to share information openly with competitors in their field. This can diminish the ability of riparian states to recognize and respond to changing circumstances. Although the data and information collected through joint studies technically belongs to the joint commissions and contracting states, the capacity to interpret, utilize, and integrate the data frequently lies outside of riparian governments and within the consulting firms.

Donor organizations within the basin have also played a substantial role in decreasing informational uncertainty through the financing of joint studies. However, less attention is paid to the political barriers obstructing issues like basin-wide planning. Without acknowledging or addressing these important obstacles, interventions by this network may simply reinforce the status quo.

Political Context

The shift in politics following South Africa's transition from apartheid to democracy contributed significantly to the levels of openness between riparian states and their opportunities and willingness to exchange information. This has increased adaptive capacity in the basin by allowing states to construct a more complete picture of basin resources and changing circumstances. Increasing levels of regional integration have not, however, significantly increased South Africa's willingness to engage in planning at the basin level, which limits the extent to which adaptive capacity can be achieved.

Conclusion

This article set out to analyze the effects of the Orange-Senqu transboundary water governance regime on adaptive capacity by examining the influence of international water management institutions and interstate interactions on treaty flexibility, information management, actor networks, and financial resources. It showed that the water governance regime has both enabled and constrained adaptive capacity in the basin. While international water management institutions and riparian interactions have made valuable contributions to information exchange and joint planning, discursive structures limiting the scope of discussions within ORASECOM constrain the parties' abilities to recognize and respond to changing circumstances and engage in joint planning at the basin scale.

The analysis further illustrated how power asymmetry, problem structure, expert networks, and political context all influenced adaptive capacity in the basin. What this analysis suggests is that efforts to envision alternatives to the current planning model in the Orange-Senqu basin and influence change will require a firm understanding of the multilayered and power-laden processes that influence the negotiation and implementation of transboundary water governance regimes.

Acknowledgements

The author thanks the many policy makers, academics and practitioners who generously shared their experiences and opinions with regard to the complexities and effects of transboundary water cooperation in southern Africa. This work was conducted as part of wider Ph.D. research and supported by the University of Oxford and South Africa's Council for Scientific and Industrial Research.

Author Bio and Contact Information

Elizabeth Kistin Keller was born and raised along the banks of the Rio Grande River in New Mexico. She received her BA in Political Science and Latin American Studies from the University of North Carolina-Chapel Hill. Upon receiving a Rhodes Scholarship, Elizabeth continued her studies at the University of Oxford where she received her Masters and Ph.D. in International Studies. She has spent time working on transboundary water resource issues in Southern Africa, South East Asia and North America. She teaches as an adjunct professor in the University of New Mexico's masters program on water resources management. She can be reached by email at ekistin@unm.edu and by mail at 11023 Vistazo PL SE, Albuquerque, NM 87123.

References

Allan, J.A. 2001. *The Middle East Water Question: Hydropolitics and the Global Economy*. London: I. B. Tauris.

Biggs, D. (Former Deputy Director of Planning for the Nambian Department of Water Affairs), in discussion with author, September 2007.

Dlamini, Z. (South African Delegate to the Lesotho Highlands Water Commission), in discussion with author, April 2007.

Fischhendler, I. 2004. Legal and Institutional Adaptation to Climate Uncertainty: A Study of International Rivers. *Water Policy* 6: 281-302.

Goulden, M., D. Conway, and A. Persechino. 2008. Adaptation to Climate Change in International River basins in Africa: A review. *Tyndall Working Paper, No. 127*. Norwich, UK: University of East Anglia.

Hendricks, L.B. "Policy Review Debate on Budget Vote 34 of 2008/09." Speech, Cape Town, Western Cape, June 18, 2008.

Heyns, P.S.V.H. (Former Head of the Namibian Department of Water Affairs and a Commissioner in the Permanent Water Commission and the ORASECOM), in discussion with author, September 2007.

Hiddema, U. (Legal Counsel to the Trans-Caledon Tunnel Authority), in discussion with author, March 2007.

Hoover R. 2001. Pipe Dreams: The World Bank's Failed Efforts to Resolve Lives and Livelihoods of Dam-Affected People in Lesotho. Maseru: Transformation Resources Centre.

Katai, O. (Director of Botwana's International Water Division within the Department of Water Affairs), in discussion with author, November 2007.

Kistin, E.J. 2010. *Critiquing Cooperation: The Dynamic Effects of Transboundary Water Regimes*. Ph.D. Thesis. University of Oxford: UK.

Kistin, E.J. and P.J. Ashton. 2008. Adapting to Change in Transboundary Rivers: An Analysis of Treaty Flexibility on the Orange-Senqu River Basin. *International Journal of Water Resources Development* 24(3): 385–400.

Kranz, N. and R. Vidaurre. 2008. *Institution-Based Water Regime Analysis, Orange-Senqu Basin: Emerging river basin organisation for adaptive water management.* Ecologic–Institute for International and European Environmental Policy.

Lesoma, M. (Director of the Lesotho Water Commission), in discussion with author, April 2007.

Lesotho Highlands Development Authority. 2008. *Annual Report 2007/2008*. Maseru: Lesotho Highlands Development Authority.

Liebenberg, P. (Chief Engineer, Namibian Department of Agriculture Water and Forestry), in discussion with author, September 2007

Malzbender, D. and A. Earle. 2009. Water Resources of South African Development Community: Demands, dependencies, and governance responses. In M. Pressend and T. Othieno, (Eds.) *Rethinking Natural Resources in Southern Africa*. Midrand, South Africa: Institute for Global Dialogue.

McCaffrey, S. 2003. The need for flexibility in freshwater treaty regimes. *Natural Resources Forum* 27:156-62.

Mwakalumbwa, C. (Lesotho delegate to the Lesotho Highlands Water Commision), in discussion with author, April 2007.

Nthathakane, P. (Chief Technical Officer, Lesotho Water Commission), in discussion with author, February 2007.

Panel of Experts. 2002. Report prepared for the Lesotho Highlands Development Authority. Maseru: Lesotho Highlands Development Authority.

Permanent Water Commission. 2005. Pre-feasibility study into measures to improve the management of the lower Orange River and to provide for future developments along the border between Namibia and South Africa. *DWA Namibia Report No: 400/8/1/P-13*. Windhoek: Department of Water Affairs.

Pyke, P. (Chief Engineer, South African Department of Water Affairs and member of the ORASECOM technical task team), discussion with author, February 2007.

Raadgever, G.T., E. Mostert, N. Kranz, E. Interwies, and J.G. Timmerman. 2008. Assessing Management Regimes in Transboundary River Basins: Do They Support Adaptive Management? *Ecology and Society* 13(1): 14–23.

Ramoeli, P. (Senior Water Program Manager at South African Development Community), in discussion with author, November 2007.

Ratashobya, D.G. and J. Wellens-Mensah. 2002. SADC-HYCOS Evaluation Mission Report. Gaborone: South African Development Community.

Setloboko, T. (Principal Hydrologist for Botswana's Department of Water Affairs and Member of ORASECOM's technical task team), in discussion with author, November 2007.

Smit, B. and J. Wandel. 2006. Adaptation, adaptive capacity and vulnerability. *Global Environmental Change* 16(3): 282-92.

Southern African Development Community. 2008. Activities of International Cooperating Partners (ICPs) in Transboundary Water Cooperation in the South African Development Community Region. Southern African Development Community Water Division.

TAMS (Tibbets-Abbett-McCarthy-Stratton Consortium). 1996. Water Resources Management: Policy and Strategies, final report. Maseru: Ministry of Natural Resources.

Timmerman, J.G. and S. Langaas. 2005. Water information: What is it good for? The use of information in transboundary water management. *Regional Environmental Change* 5(4): 177-87.

Tompkins, R. 2007. *Institutional Structures in the Four Orange Basin States*. Orange-Senqu River Commission. Pretoria.

Turton A.R. and L. Ohlsson. 2000. Water Scarcity and Social Stability: Towards a Deeper Understanding of the Key Concepts Needed to Manage Water Scarcity in Developing Countries. *SOAS Occasional Paper 17.* London: SOAS Water Issues Group.

van Niekerk, P. (Chief Director of Integrated Water Resources Planning at South Africa's Department of Water Affairs and Delegate to the ORASECOM and Permanent Water Commission), in discussion with author, March 2007.

van Wyk, N. (Chief Engineer, South African Department of Water Affairs), in discussion with author, February 2007.

Veelen, M.V., K. Pema, D. Esterhuizen, T. Baker, H. Thompson. 2009. *ORASECOM: Capacity Building Programme*. ILISO Consulting.

Yohe, G. and R.S.J. Tol. 2002. Indicators for social and economic coping capacity: Moving toward a working definition of adaptive capacity. *Global Environmental Change* 12(1): 25-40.

Universities Council on Water Resources
Journal of Contemporary Water Research & Education
Issue 149, Pages 56-63, December 2012

Climate Vulnerability and Adaptive Strategies Along the Rio Grande/Rio Bravo Border of Mexico and the United States

Brian Hurd

New Mexico State University, Las Cruces, NM

Abstract: Climate change and growing populations are dual stresses that are particularly challenging to communities along the US/Mexican border where adaptive capacity is limited, infrastructure is lacking, and economic resources are scarce. Although regional precipitation projections vary significantly in both timing and amount, projections of temperature changes produce a more robust signal of raised temperatures. A summary look is provided that highlights the climatic changes that are projected, identifies key systems and sectors that are vulnerable to climate change, describes and summarizes the role of adaptation and the development of adaptation strategies. A promising look at binational co-adaptation is highlighted and illustrates the potential for building regional adaptive capacity.

Keywords: *Climate change, adaptation, Rio Grande, U.S. Mexico Border*

Populations along both sides of the Rio Grande/Rio Bravo border between Mexico and the United States are likely to be increasingly challenged by the compounding dual effects of population growth and climate change. Growing populations heighten competition for water in an already water-scarce region, where water is most commonly used to grow food. Regional climate change projections vary significantly with respect to precipitation change but are generally consistent in predicting higher temperatures and the drying effects they will have on crops, surface storage, and natural vegetation. Not only is climate change expected to bring more frequent, severe, and enduring droughts, but sea level and the frequency and intensity of storms, including hurricanes and floods are also expected to rise (Parry et al. 2007; Solomon et al. 2007). Although both sides of the border share exposure to water scarcity, population growth, and changing climate, resiliency may be lower and vulnerability higher in Mexico. Relative to U.S. border communities, adaptive capacity in Mexico's border communities is constrained by fewer economic and institutional resources, limited capacities for restoration and disaster-relief, and greater risk-exposure by disadvantaged communities (Ibarrarán et al. 2008; Martínez 2007).

Population Growth and Cimate Change: Drivers of Vulnerability Along the Border

The climatic changes expected for Mexico over the mid-to-long-run are likely to compound the social, economic and other environmental stresses it faces. For example, rising temperatures will increase consumptive water-use requirements of urban and agricultural users at the same time that supplies are likely to decline as streamflow falls, evaporation losses increase, and both reservoir and ground water levels diminish. Scott et al. (2012) provide a comprehensive assessment and discussion on the water-sensitive region of the Arizona and Sonora border region along the Santa Cruz River and the transboundary Santa Cruz aquifer. There they observe the challenges of meeting the water needs of agriculture and urban water users, where the local population growth

rate is about 1.3 percent per year, and where aquifer pumping often exceeds rates of recharge – a condition that Scott et al. (2012) suggests could be worsened under drier projections of climate change.

Climate Change Projections

Climate change assessments from the Intergovernmental Panel on Climate Change Fourth Assessment Report under the A1B emissions scenario project temperature warming of between 2.6 °C and 3.6 °C over the coming century (Solomon et al. 2007; Parry et al. 2007). Under this same A1B emissions scenario, the estimated change in annual precipitation ranges from -16 percent to -5 percent (with a median of -9 percent). Although projected temperature changes are relatively consistent across emissions scenarios, projected precipitation changes are not. Scott et al. (2012) include A1B, B1 and A2 emissions scenarios in their analysis and using the HadCM3 Global Climate Model show change of annual precipitation ranging between -20.9 percent and +19.9 percent.

Figure 1 reproduces the figure from the Intergovernmental Panel on Climate Change showing the effects of the A1B scenario across Mexico, Central America, and South America. The top panel shows likely temperature changes annually and for the winter and summer months,

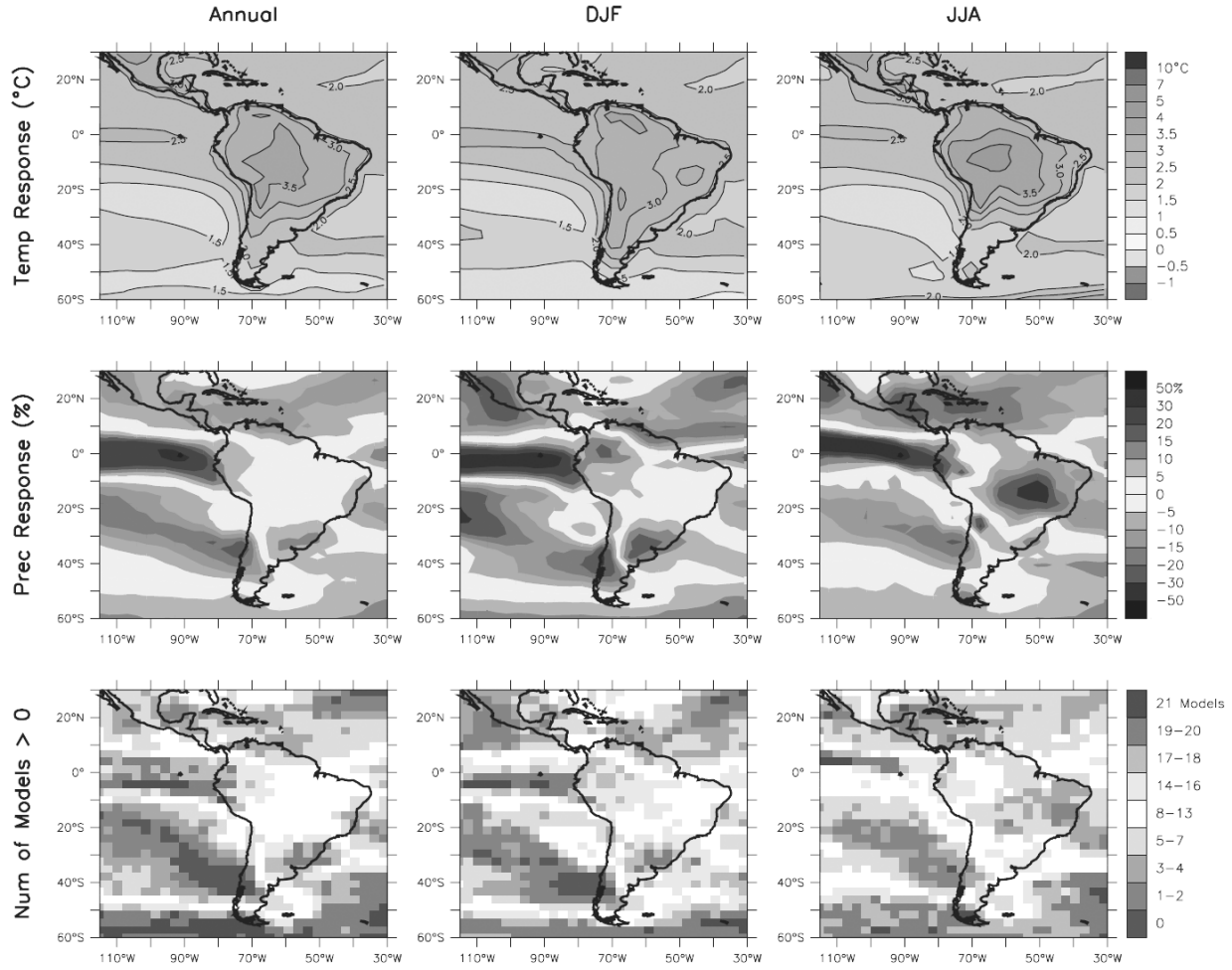


Figure 1. Summarizing temperature and precipitation changes over Central and South America from the MMD-A1B simulations. Top row: Annual mean, DJF and JJA temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Middle row: same as top, but for fractional change in precipitation. Bottom row: number of models out of 21 that project increases in precipitation (Source: Intergovernmental Panel on Climate Change, Figure 11.15, Solomon 2007).

respectively. Temperature increases from 3 °C to 5 °C projected over the coming 70 to 80 years are more pronounced in the summer than winter over much of Mexico. Although with less consensus, precipitation is projected to fall significantly on an annual basis from 5 percent to 15 percent, with winters becoming much drier across most of Mexico (as much as 30 percent in some areas) and summers drying, with a bit less intensity in the north but very significantly in the south. The bottom panel shows the number of GCM models out of the 21 in the assessment that project an increase in precipitation. For Mexico, less than one third of the projections show an increase.

Understanding Climate Change Vulnerability

Climate vulnerability is a concept that expresses the risks and consequences of failure of systems that are both sensitive and exposed to climatic factors and their changes (e.g., temperature and precipitation changes). Easterling et al. (2004) describe how vulnerability is assessed and measured in both physical and economic dimensions, including threats to public health, important economic industries, communities and settlements, economic developments, infrastructure, and environmental and ecological resources and services. Building adaptive capacity can reduce vulnerability, mitigate the adverse effects, and enhance system restoration and resiliency. A useful way to understand and assess climate change vulnerability is through its three interactive components: sensitivity, exposure, and adaptability or adaptive capacity.

Sensitivity. Conceptually similar to the notion of elasticity, sensitivity describes how much a system and its functionality are potentially affected by changes or events. Without some sensitivity, no vulnerability would exist. In agriculture for example, some crops cannot tolerate hotter and drier conditions, and when such conditions occur, crop performance is significantly diminished. One important example for Mexico is corn, which is much more physiologically sensitive to hot and dry conditions than wheat.

Exposure. Though a system may have high sensitivity, if it is not likely to experience or be exposed to such changes or events, then vulnerability is minimal. Exposure is a critical element affecting vulnerability, and is a factor that institutions and policy can often affect. The vulnerability of coastal communities to sea-level rise and storm surges, for example, rises with the size of population and development, as people are drawn to aesthetic and recreational opportunities. In these cases, updating zoning and building codes may be possible mechanisms whereby development occurs in a less vulnerable fashion.

Adaptability. With systems that are both sensitive and exposed to adversity, adaptability becomes relevant. Adaptability refers to changes that can be made to the design, function, or behavior of a system that can strengthen its ability to withstand and/or recover from adversity, for example, through limiting sensitivity or exposure, or by enhancing robustness and resilience.

Vulnerable Populations, Sectors, and Resources. Several sectors in Mexico are potentially vulnerable to climatic changes, including agriculture, water, energy, and even health and tourism to lesser degrees (Ibarrarán et al. 2008).

Agricultural Resources and Food Security. Arable land in Mexico is relatively scarce, amounting to about 11 percent of its land base. Many important growing regions depend on irrigation. In terms of net economic returns, the most important crops include corn, tomatoes, sugar cane, dry beans, and avocados. Livestock is also important, particularly beef, poultry, pork, and dairy. Whereas, agriculture accounts for 3.8 percent of GDP, it provides 15 percent of the jobs. In 2009 Mexico accounted for 15.9 percent of U.S. agricultural imports, valued at nearly $11 billion (U.S. Department of Agriculture Foreign Agriculture Service 2011).

Corn is the foundation for food supply and food security in Mexico. It is the basic staple grain and energy source in the diet of much of the Mexico's population, and more importantly for the most vulnerable populations. Climate change can adversely affect corn production by limiting

growing seasons, grain quality and quantity, and through limited rainfall and irrigation water supplies. Martínez (2007) and Martínez and Adrian (2004) assess the regional effects of climate change on maize production within Mexico, identifying both regions of production increase and decrease. Under the A2 emissions scenario they show net production falling. With the exception of a few small regions in central Chihuahua, maize production in northern Mexico is diminished under the A2 scenario.

Water Resources. Mexico's water resources are also highly vulnerable to changes in both temperature and precipitation. Surface and ground water supplies are often overexploited and stressed by pollution. As in the Western U.S., agriculture accounts for the majority of water use, in 2009 was was nearly 77 percent (Conagua 2011). A recent study along the Arizona and Sonora border, where communities are heavily reliant on a transboundary aquifer for water, indicates that continued population growth in the region will likely require enhanced use of transfers of surface waters and increased use of recycled waters to meet growing demands. Climate change trends, the study indicates, are highly variable in their projected effects on ground water flows and aquifer levels. Under drier climate scenarios, aquifer recharge would add considerably to the water stress faced by the region.

Along the Rio Grande, another recent study shows that even under scenarios where precipitation may significantly increase, the resulting losses from evaporation more than offset any gains, resulting in much lower runoff and streamflows in nearly all scenarios (Hurd and Coonrod 2012). In Mexico's arid north, decreasing runoff and streamflow threaten not only regional irrigation and food production, but also threaten treaty-obligated deliveries to the Rio Grande and to south Texas farms. In particular, the regionally important Rio Conchos basin supplies the majority of the river flow in the lower Rio Grande and to south Texas farms.

Oil and Energy. Mexico is one of the world's largest producers of crude oil and the second-largest supplier of oil to the U.S. Oil and gas revenues provide more than one third of all Mexican Government revenues and are the country's largest source of foreign currency. The nationally-owned oil company, Pemex, is a constitutionally established monopoly controlling the exploration, production, transportation, and marketing of oil. Experts suppose that Mexico's primary known oil reserves are in decline. To avoid declining economic production, decisions about developing deep water reserves might need near-term attention (globalEDGE™ 2011). The energy sector has moderate climate change vulnerability derived primarily from exposure of offshore oil facilities to damaging storms and from the potential loss in hydropower production from low rainfall and resulting storage conditions, primarily in the south. Hydropower produces about 20 percent of Mexico's electricity and is concentrated in the south. The largest hydro plant in Mexico – and fourth-largest in the world – is the 2,400 MW Manuel Moreno Torres Dam in Chicoasén, Chiapas, on the Grijalva river. Additionally, electricity production capacity could be stressed by load strain from higher temperatures and drought.

Tourism. Tourism is an important economic sector, responsible for over 10 percent of Mexico's GDP and foreign currency. Located principally in the resort communities along the Pacific, Gulf and Yucatan Peninsula coastal areas, these regions are vulnerable to both sea-level rise and to damaging storm events. Sustained disruption and loss of these economic areas could exacerbate poverty and employment stress.

Climate Change Adaptation Strategies

Climate adaptation strategies are a challenge to develop and implement successfully, particularly where economic resources are limited as is common within a developing economy. Except for the exceptional "no-cost" or "low-cost" adaptation, most climate adaptations are evaluated within a broader context of need or desirability. For example, a dam may be primarily intended for managing variable water supplies and flood events, but adjustments or adaptations in the design could enhance its performance in the event of climate change. Climate adaptation is generally articulated within a broader context of economic development, and it is often

difficult or impractical to distinguish the two, notwithstanding the need to do so for funding purposes. It is also important to understand the often variable and scalable nature of adaptation. Uncertainty regarding severity and timing of climate change might give rise to alternative strategies regarding the timing of planned investments, or whether or not to make anticipated or planned investments at all.

Understanding Reactive and Proactive Adaptation

In many cases, strategies to build adaptive capacity can include a mixture of activities. Responses and actions that are taken once climate changes are realized (and recognized as such) are commonly referred to as reactive adaptation. In contrast, responses and actions that are enacted in advance or with the anticipation of climate changes are commonly considered proactive adaptations (Easterling et al. 2004; Hurd 2008).

One of the key differences between reactive and proactive adaptation strategies concerns the timing of investments in adaptive capacity building. Reactive adaptation can result from two situations. First, no consideration is given at all to changing conditions or events; simply adapt when and as conditions warrant. Second, a deliberate decision to delay or postpone investment is taken, owing to inherent uncertainty, and results in adaptation actions that were anticipated but otherwise taken too late to do as much good as they otherwise might have. Proactive adaptation tries to anticipate changing conditions and

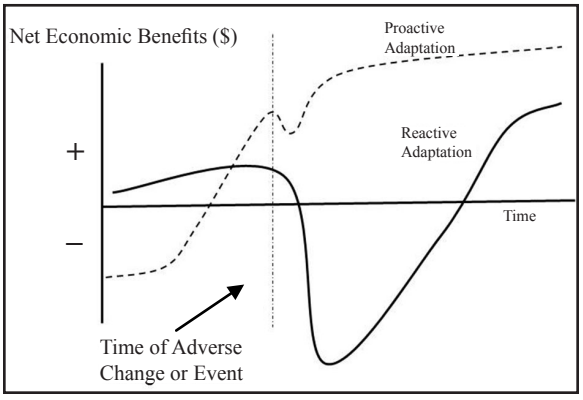


Figure 2. Understanding Reactive and Proactive Adaptation.

prepareing for them well in advance.

Figure 2 compares two hypothetical and stylized time paths depicting the net economic benefits for both cases. In the case of reactive adaptation, net economic benefits are positive and continue to grow until the time of disastrous change. For example, consider a catastrophic hurricane in the Gulf of Mexico that destroys offshore oil facilities and coastal communities. With reactive adaptation, disaster costs are severe and recovery time is long. It is also possible that redevelopment occurs without any change for future defenses. In contrast, proactive adaptation might anticipate the disastrous event and take prudent and appropriate steps to mitigate damages, such as strengthening defenses around facilities and communities prior to disaster. Under proactive adaptation, investments cause an initial drop in economic welfare, after which growth proceeds until the disaster. With successful adaptation, damages still occur but they are much smaller and are recovered from more quickly. Long-run economic welfare can be enhanced by proactive adaptation (Hurd 2008).

Mexico's Intersecretarial Commission on Climate Change published mitigation and adaptation strategies in 2007 (Comisión Intersecretarial de Cambio Climático 2007). This report is Mexico's "National Strategy on Climate Change" in which it a) identifies mitigation measures and estimates of potential for emissions reduction; and b) recognizes the vulnerability of various economic sectors and geographic regions to climate change, and broadly outlines national- and local-level opportunities for building adaptive capacity. Key areas identified in this strategy for building adaptation capacity are:

- Hydro-meteorological risk and water resource management,
- Biodiversity and environmental services,
- Agriculture and farming,
- Coastal developments,
- Human settlements, and
- Energy generation and use.

General principles of Mexico's Climate Adaptation Strategy (Comisión Intersecretarial de Cambio Climático 2007) are shown in

Appendix 1, and identify policy and program initiatives that could be undertaken to strengthen adaptive capacity. Many of the themes refer to improved data and information gathering and other management-related activities.

Confronting Obstacles to Binational Cooperation and Co-Adaptation

Where vulnerabilities and challenges are shared across a common national border, there may arise opportunities for cooperative adaptation or co-adaptation. Although significant challenges to binational cooperation exist along the U.S./Mexico border (including issues of governance, data-sharing, institutional and legal barriers), it may be possible to explore mutually-beneficial strategies that will enhance adaptive capacity for both sides (Granados et al. 2006). Wilder et al. (2010) have identified some promising pathways for adaptation that explore opportunities under models of cooperation, mutualism, and binational integration. Their research explores transboundary approaches "to improve the adaptive capacity to climate change, especially for water resources management." In spite of the difficulties of cross-border collaboration, their research supports the hypothesis that:

> Regional adaptive responses across borders could increase resilience and decrease vulnerability to climatic changes. Such cross-border approaches can emerge through shared social learning and knowledge, by creating binational communities of practice, such as among water managers or disaster-relief planners, and by addressing inequities resulting from uneven development (Wilder et at. 2010).

Upon assessing three distinct efforts at binational cooperation along the Arizona-Sonora border, Wilder et al. (2010) conclude that adaptive potential across the border is promising and likely to show positive impacts. Continued efforts following Wilder et al. in these directions show distinct ways for co-adaptation that not only contributes to building regional adaptive capacity in response to climate change but offers a glimpse toward cooperative strategies that may benefit efforts to manage other binational resources and offer a template to other regions.

Conclusions

With limited opportunities for new water sources along the U.S./Mexico border, continued population growth must necessarily compete with existing water users for available supplies. This competition will intensify as runoff and aquifer recharge rates fall under a projected warmer and drier climate, and likely result in reducing agricultural water uses in favor of domestic and urban. All water users will likely experience the adverse economic consequences that accompany rising water scarcity and costs. The regional vulnerability to climate change and the additional stresses from population growth will increase the struggle and hardship of those communities with limited means. It appears, therefore, all the more prudent to identify and promote strategies that recognize the challenges of changing conditions and contribute to and building adaptive capacity. The potential benefits of proactive adaptation have been highlighted along with the potential synergies of pursuing regional and binational efforts and activities to strengthen adaptive capacity.

Acknowledgments

I would like to thank Laura Mayagoitia, a former student from Mexico who enhanced my appreciation for the perspectives of Mexico and provided assistance upon visiting Ciudad Chihuahua and her home in Cuauhtémoc. I would like also to thank the very helpful comments of an anonymous reviewer and also my colleagues in the Department of Agricultural Economics, particularly Dr. Terry Crawford who has worked hard to develop synergies between NMSU and Universities in Mexico. I would like to recognize and acknowledge the continuing support of New Mexico State University and the Agricultural Experiment Station for providing a nurturing and collaborative working environment and resource support for my research.

Author Bio and Contact Information

Brian Hurd is an Associate Professor of Agricultural Economics and Agricultural Business at New Mexico State University. He earned his MS and Ph.D. from the University of California, Davis, and a BA in both Economics and Environmental Conservation from the University of Colorado, Boulder. With more than 20

years of experience in both private consulting and in academic research, he teaches and conducts research on the economics of natural resources, watersheds, food security and the agro-environment. Through his research he aims to improve the economy and performance of water and agricultural systems, policies and institutions across New Mexico, the region, and globally by better managing weather and climate risk. His research includes cost-benefit assessment and non-market valuation of natural and environmental resources, economics of production agriculture, and the assessment of impacts and adaptation of water and agricultural systems to climate change.

References

Comisión Intersecretarial de Cambio Climático. 2007 Estrategia Nacional de Cambio Climático: México 2007. 1-18. México D.F.

Conagua. 2011. Estadísticas del agua en México, edicion 2011. 1-181. Secretaria de Medio Ambiente y Recursos Naturales (SEMARNAT).

Easterling, W.E., B.H. Hurd, and J.B. Smith. 2004. *Coping With Climatic Change: The Role of Adaptation in the United States*. Arlington, VA, Pew Center on Global Climate Change, 1-40.

globalEDGE™. 2011. International Business Center at Michigan State University. Michigan State University.

Granados-Olivas, A., C. Brown, J. Greenlee, B. Creel, J. Hawley, J. Kennedy, O. Dena-Ornelas, and B. Hurd. 2006. Geographic Information Systems At the Paso Del Norte Region: The Academic Accomplishments and Challenges for a Transboundary Water GIS Cooperation. *New Mexico Journal of Science* 44: 59-70.

Hurd, B. 2008. Coping and adapting to a changing climate: Concepts, issues and challenges. *Annals of Arid Zone* 47.3 & 4: 221-31

Hurd, B. and J. Coonrod. 2012. Hydrological and economic consequences of climate change in the Upper Rio Grande region. *Climate Research* 53:103-118. doi: 10.3354/cr01092.

Ibarrarán, M.E., A.L. Brenkert, and E. L. Malone. 2008. *Climate Change Vulnerability and Resilience: Current Status and Trends for Mexico*, prepared for the U.S. Dept of Energy, Pacific Northwest National Laboratory, Richland, Washington.

Martínez, J. 2007. Efectos del Cambio Climático en México. Mexico City, SEMARNAT. ABC de Cambio Climático: Impactos y Acciones en México. 3-13-2011.

Martínez, J. and F. Adrian. 2004. *Cambio climático: una visión desde México*. Instituto Nacional de Ecología, Secretaría del Medio Ambiente y Recursos Naturales. Mexio City Mexico, 523.

Parry M.L., O.F. Canziani, J.P. Palutikof, P. Linden, and C. E. Hanson. 2007. *Climate change 2007: Impacts, Adaptation and Vulnerability*. University of Cambridge, Cambridge, United Kingdom.

Scott, C.A., S. Megdal, L.A.Oroz, J. Callegary, and P. Vandervoet. 2012. Effects of climate change and population growth on the transboundary Santa Cruz aquifer. *Climate Research* 51: 159-170.

Solomon, S. 2007. Climate Change 2007; the Physical Science Basis; Contribution of Working Group I to the Fourth Assessment Report of the Intergovernamental Panel on Climate Change. Dahe Qin et al. (Ed.) *Cambridge University Press*: Cambridge, United Kingdom.

United States Department of Agriculture Foreign Agriculture Service, Global Agricultural Trade System. 2011. *Selected U.S. agricultural imports from Mexico, 1991-93 versus 2007-09*.

Wilder, M., C.A. Scott, N.P. Pablos, R.G. Varady, G.M. Garfin, and J. McEvoy. 2010. Adapting Across Boundaries: Climate Change, Social Learning, and Resilience in the U.S.- Mexico Border Region. *Annals of the Association of American Geographers* 100: 917-928.

Appendix 1: Key Provisions of Mexico's Climate Adaptation Strategy.

1. Design a program promoting the natural recharging of aquifers.
2. Increase knowledge and deployment of information exchange and early warning systems.
3. Adjust water treatment technology in line with changing climatic conditions.
4. Review and strengthen the implementation of natural resource management instruments such as seasonal bans, marine and coastal Protected Areas, and payment for environmental (hydrological) services, so as to adapt them to changing climatic conditions.
5. Establish biological corridors between Protected Areas, and evaluate the need to adjust the current boundaries of these and of Priority Regions for Conservation, to improve the adaptive capacities of ecosystems and species.
6. Evaluate design adaptation policies based on these evaluations. The experience acquired by vulnerable groups in the face of climate variability and
7. Preserve Mexican agrobiodiversity in situ through programmes jointly implemented by the Ministry of Environment and Natural Resources (SEMARNAT) and the Ministry of Agriculture, Rural Development, Fisheries and Food.
8. Develop and implement a climate information and monitoring system specifically designed for the farming community.
9. Strengthen epidemiological monitoring systems.
10. Plan for an increase in mean sea level of 40 cm between now and the end of the century as a baseline for infrastructure development in coastal zones.
11. Articulate the national policy for marine and coastal sustainable development with the strengthening of national capacities for adapting to climate change.
12. Promote synergies between the tourism, fishing, and water sectors, and with the National System for Civil Protection.
13. Include appropriate environmental design criteria in all aspects of urban planning and development.
14. Include the watershed management approach in schemes for environmental services protection and disaster prevention in peri-urban and rural areas.
15. Design and build decentralised, small-scale, local energy supply systems.

Source: Comisión Intersecretarial de Cambio Climático (2007).

Universities Council on Water Resources
Journal of Contemporary Water Research & Education
Issue 149, Pages 64-75, December 2012

Development of an Army Water Security Strategy: Stateside Component

Paul Koch[1] and Marc Kodack[2]

[1]*Paul Koch Analytics LLC;*
[2] *Office of the Assistant Secretary of the Army for Energy and Sustainability, Washington, DC*

Abstract: In October 2010, the Army Environmental Policy institute initiated the development of an Army water security strategy, which was ultimately published in December 2011. The purpose of this effort was to; (1) provide a complete workable definition for Army water security, (2) conduct the first comprehensive study of water security management in the Army, and (3) identify the key issues on which Army leadership can focus to ensure that the Army has enough water of suitable quality for the foreseeable future. A review of key policy drivers was followed by a series of interviews of personnel inside and outside the Army. The culminating effort identified four major goal areas, three of which apply to stateside military installations: (1) water resources sustainability – preserve sources, protect rights, (2) reduce demand, and (3) maintain infrastructure integrity and security. This paper provides a condensed view of the objectives associated with each of these three goals.

Keywords: *Military, strategic planning, water resources managment*

A recent Army paper concerning water security states:

> The availability of water is of strategic importance to all levels of the Army enterprise. Having continued access to adequate water resources and the ability to deliver treated water efficiently is essential for on-going and future Army missions. However, a widely favorable water supply situation cannot be assumed. Future water security will be directly affected by climate and demographic changes, making continued availability uncertain in many parts of the world where the Army operates (Assistant Secretary of the Army for Installations 2012).

As the U.S. Army protects and advances American security interests around the world, its stateside installations – the focus of this paper – play a vital role in support of global operations, preparing personnel and materiel for deployment overseas.

Figure 1 shows where active Army installations are currently located. Installations that were established in regions where the population density was low, economic activity was limited, and fresh water was relatively plentiful did not initially need to be particularly concerned about the sustainability of their long-term water supply. Regional growth across the country and the significant reduction of fresh water availability in some areas, however, has raised the level of interest in ensuring that every Army installation has the water it needs to fulfill its mission in support of national defense.

But there is no one-size-fits-all approach to providing water security for Army installations. Ensuring water security across the Army enterprise will involve addressing a complex interaction of interests and concerns. Appendix 1 characterizes the types of complexities that complicate water security planning and the attendant consequences for installations.

The Army Water Security Strategy (Department of the Army 2011) identifies a broad set of goals, objectives, and associated actions that can be undertaken at appropriate levels to address key facets of Army water resources management.

These factors provided a conceptual framework:

- Sources: The quantity and quality of natural, raw water (both surface and ground water) available to the region.
- Supply: Rights to water and water infrastructure.
- Sustainable Practices: Water use efficiency concepts.
- Survivability: Preventing and recovering from water supply disruption or contamination.
- Sponsorship: Identification and alignment of Army water management responsibilities.
- Stakeholders: Constructive engagement with regional water users.

Encompassing all of these facets, the Strategy offers this definition:

> Army water security is the assurance that water (potable and non-potable) of suitable quality will be provided at rates sufficient to fully support the Army wherever it has, or anticipates having, a mission in the future (Department of the Army 2011).

To develop water security goals and objectives, the research team supporting the development of the Army Water Security Strategy (Department of the Army 2011) conducted a thorough review of current policy drivers concerning Army water management and completed a series of interviews of personnel inside and outside the Army. The resulting goals and objectives are described below.

Goals and Objectives

Water Resources Sustainability – Preserve Sources, Protect Rights

Rationale: Regional population growth and land development tends to increase demands on regional water sources (Kenny et al. 2009), increase the variability in surface water flow rates (Brun and Band 2000), decrease surface water quality (Urbonas and Roesner 1993), and decrease ground water recharge rates (Viessman et al. 1977). These consequences may affect the availability of water to support current and future Army mission requirements, and diminished water quality may increase Army water treatment costs. Legal and administrative challenges to maintaining Army water rights highlight the importance of exercising diligence in protecting those rights.

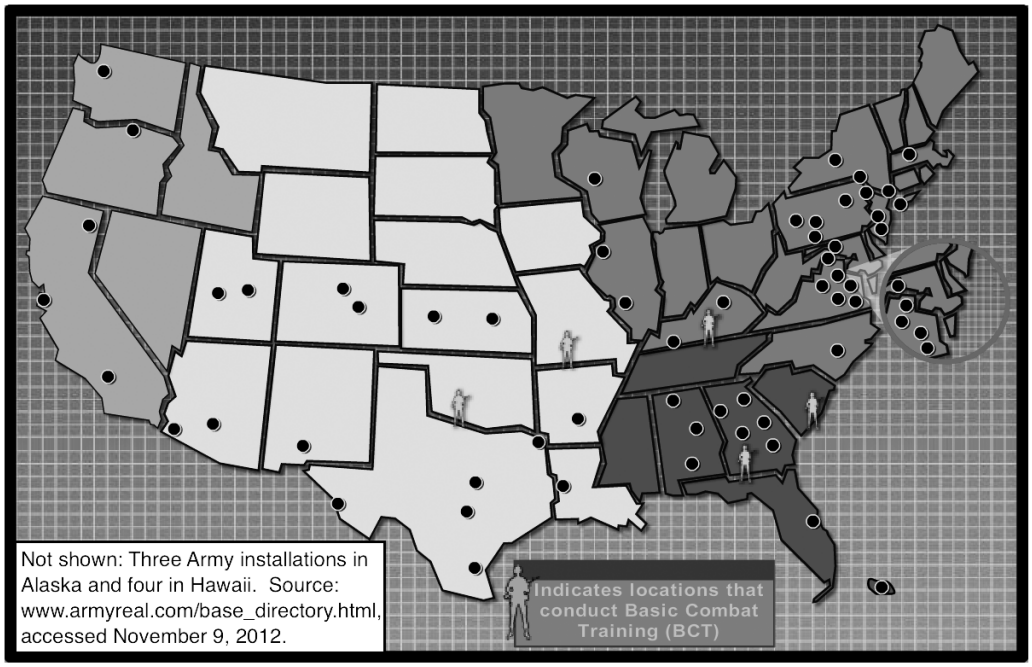


Figure 1. U.S. Army Installations in the United States.

Objectives for Protecting and Preserving Water Sources and Water Rights Include:

Anticipate Long-Term Water Requirements. Anticipating long-term water requirements involves maintaining up-to-date assessments of an installation's current and projected water needs in the context of regional water availability and verifying in advance that adequate water resources are available for future mission requirements as part of both the real property master planning process and the basing decision process for new or realigned functions. This objective can be advanced by:

- Sustaining support for use of water demand forecasting software. As computer technologies change and forecasting methods evolve, sustained support for the use of forecasting software will ensure that they are properly updated and continue to be useful (April and Abran 2008; Billings and Jones 2007).
- Establishing a long-term forecast period for water requirements at each installation that includes a regional water supply and demand analysis. A water demand forecast based on a number of conceivable scenarios (Billings and Jones 2007) provides a useful basis for discussing risks and the consequences of future actions taken by the Army and other regional water users.
- Designating a regular cycle or set of triggers for revising installation and regional forecasts. Diligence in refreshing forecasts, perhaps as part of existing planning requirements, will not only ensure that recent information is available to decision makers, but also provide valuable periodic feedback concerning costs and benefits of selected forecast methods (Walters 1986).

Protect Water Rights. Protecting water rights involves the development of a proactive policy to identify and protect Army water rights nationwide. Legal concerns pertaining to water rights will continue to encompass a variety of complex issues, including water rights associated with federal lands reserved out of the public domain, water rights associated with land transactions, benefits and consequences of participating in state permitting programs, and opportunities for banking and monetizing water rights. Issues are further complicated by the differences in water law among the states (Jungreis 2005; Sherk 2003). As the frequency and intensity of water rights issues may increase in the foreseeable future, Army water security will benefit from maintaining appropriate levels of vigilance concerning the protection of water rights for all Army installations.

Integrate Water Assessments into Strategic Decisions. Integrating water assessments into strategic decisions involves evaluating water resource requirements and the effects of installation water use early in all strategic planning actions. This includes base closure and realignment actions as well as designs, program basing, renewable energy siting, and procurement and acquisition decisions. Water availability is best evaluated ahead of basing decisions and associated environmental assessments. An early assessment of the availability of water to support each of several alternative courses of action being considered will shed light on any water security concerns that may affect the cost and consequences associated with each option. The time frame for Military Construction decisions is too slow to adapt to changing water needs and constraints. As the Army advances its capabilities in cyberspace (Department of the Army 2012a), the amount of water required for cooling new data centers makes the evaluation of water availability ahead of siting decisions even more critical. This objective can be advanced by:

1. Using water footprint analysis (Hoekstra et al. 2011) to make resource and mission decisions for different types of installation activity. Based on known measures, including recent metering data, the Army can establish reasonable ranges of water use for different missions and specialized sectors, such as renewable energy projects.
2. Amending Army facilities management and real property planning guidance. This guidance can include mission-based water planning requirements and community participation in water source protection and water supply planning activities, in a manner that is similar to the Joint Land Use Study process (Office of Economic Adjustment 2006).

3. Assessing and tracking embedded water risks for critical items in the Army supply chain. This requires:
    - Compiling a master list of all the Army's suppliers;
    - Determining which supplies are critical; where criticality is based on the importance of what a supplier produces to a final product or service that cannot be obtained by any other suppliers;
    - Ranking all the critical supplies against one another with respect to the amount of risk of these suppliers' not being able to produce their product or service;
    - Using geo-spatial tools to physically locate the manufacturing location of each critical supplier; and
    - Determining what the current and future water availability is for that supplier.

Alternatively, suppliers of critical equipment can be required to report on the sustainability of the water supplies on which they depend to support their processing as a contract requirement. The supply chain contains an un-assessed amount of risk that cannot be determined and addressed in the absence of such data and analysis.

Influence Long-Term Water Management outside the Fence Line. Long-term water management of water outside of Army installations involves proactively engaging external stakeholders who have a role in the protection, use, and long-term availability of water in the watersheds and aquifers on which these installations also depend. Proactive engagement can:

- Provide installations with a situational awareness of trends that may affect regional water resources;
- Give installations the opportunity to make their water resources interests better understood; and
- Encourage collaborative efforts to address water issues that affect all the communities relying on a shared water source. Collaborative efforts may include, for example, the Army Compatible Use Buffer Program (Department of the Army 2008) to protect watersheds.

Coordinate, Refine, and Exercise Emergency Response Plans and Preparations. Emergency response involves robust planning and preparation for extreme events and supply disruptions that may affect water availability. This objective can be advanced by:

- Ensuring proper function of back-up water supply systems, and increasing emergency storage volumes within distribution systems.
- Developing strategies for sourcing, pre-placement and rotation of contingency drinking water drinking and material stockpiles and establishing procurement relationships with other sources that can be activated in times of acute shortage.
- Reviewing and updating installation and community Water System Emergency Response Plans and installation contingency water plans. The feasibility of implementing water contingency operations plans under actual emergency scenarios should be clear.
- Promoting favorable state policies concerning defense water requirements during drought. Research undertaken to support the Army Water Security Strategy found that only two states had established priorities concerning defense requirements for water during times of water scarcity.
- Ensuring that privatization contracts are sufficiently flexible to allow for facility operation adjustments and investments in a timely manner in an emergency or contingency response situation.

Eliminate Water Planning Inefficiencies. Eliminating inefficiencies involves consolidating and clarifying water information requirements so that different planning instruments developed at any one Army installation provide a consistent view of the water situation. Incorporating water planning consistently into installation master plans (Department of the Army 2005) can further enhance the planning process.

Provide Comprehensive Water Security Guidance for Installations. This involves developing Army water security guidance materials that include sections focused on:

- Water rights protection;
- Water security responsibilities for garrison command and staff;
- Stakeholder engagement considerations regarding water;
- Water demand forecast methods;
- Investment priorities; and
- Water management support resources within the Army, Department of Defense, and other branches of government.

The USACE approach to Integrated Water Resources Management (U.S. Army Corps of Engineers 2012b) can be further adapted to this end.

Water Resources Sustainability – Reduce Demand

Rationale: Among current policy drivers pertaining to Army sustainability generally, water conservation is a recurring emphasis. Pursuing opportunities to manage demand should continue as a key water security goal, and it will be of particular importance where unilateral Army water management decisions can have a major influence on the sustainability of the Army's water supply.

Objectives for Reducing Demand Include

Reduce Water Withdrawal and Consumption Rates. Diminishing water consumption will minimize the net effect of Army water use on regional surface and ground water resources. Also, reducing rates of water use will reduce the costs associated with water treatment, storage, distribution, and heating, and wastewater collection and treatment. By setting a high standard for conservation and responsible water use, Army installations can serve as a model for surrounding communities to follow in preserving and protecting shared water sources. The Army's Net Zero Water initiative, begun in 2011 (Department of the Army 2012b; U.S. Army Corps of Engineers 2012a), will help to reduce water use, increase installation security, and increase the Army's sustainability of regional water sources of supply.

Match Water Quality to Water Use. Where feasible, potable water can be replaced with lower quality rainwater, ground water, or gray water (U.S. Department of Energy 2012). Given the expense of treating water to meet fresh water standards, those costs can be saved where fresh water can be replaced by alternative sources for such uses as irrigation and toilet flushing. Some water security advantages, such as the use of gray water and treated wastewater, however, will come at the cost of constructing and maintaining separate distribution systems, which may not be affordable or feasible to operate in some locations.

Sustain a Culture of Efficiency and Conservation. The Army's success in using water efficiently will be influenced by the choices made by individuals at all levels across the organization. Perpetuating an awareness of the importance of using water efficiently will encourage choices that collectively make a difference in how water is used across the enterprise. Sustaining a culture of efficiency and conservation will encourage the adoption of standard operating procedures, building standards, best management practices, procurement decisions, training practices, and individual behaviors that result in water savings. Programs that highlight and return benefits of efficiencies at the points of water consumption and, on the other hand, amplify negative consequences of wasting water will service as incentives to advance beyond awareness to higher levels of unit and individual commitment.

Tailor Expectations to Differences Among Installations. Adapting water conservation targets and conservation strategies among installations is important, in order to recognize variations in geographic settings and in water consumption reductions already achieved. Executive Order No. 13514 (2009) specifies water use reductions relative to a 2007 baseline for federal agencies, each agency evaluated as a whole. Using a 2007 baseline for setting individual installation goals, however, creates challenges for installations whose 2007 water use intensity was already low, either because of sizable deployments that year, or because of water consumption reductions already achieved. Identifying where the greatest additional decreases in water use intensity can be achieved and prioritizing water conservation efforts accordingly may yield greater conservation reductions for the Army as a whole.

Mitigate Adverse Consequences of Aggressive Conservation. Infrastructure design and operation must be adapted to ensure that substantially reduced flows do not pose health hazards. Since residual chlorine levels in treated water diminish over time, low flow rates in water distribution systems can result in increased health risk from reduced disinfection at points of consumption. Low flow rates in pipes that carry wastewater can result in insufficient movement of waste through the system and, consequently, exceptionally high concentrations of contaminants entering a receiving wastewater treatment plant. High nitrogen concentrations in wastewater are particularly problematic, as inadequate treatment may result in National Pollutant Discharge Elimination System violations (Environmental Protection Agency 2010).

Strategic Investment – Maintain Infrastructure Integrity and Security

Rationale: Army water security requires robust funding to ensure that water and wastewater systems do not deteriorate or become obsolete. With the annual sustainment, restoration, modernization, and military construction funding levels routinely less than the amount required to fully revitalize and maintain these utilities, there is a systematic underfunding of Army-owned water and wastewater systems.

Utilities privatization projects, where implemented, have been largely successful in recapitalizing and upgrading Army water systems. Utilities privatization provides a stabilized utility rate platform by amortization of project costs and the accumulation of Repair and Restoration reinvestment funds. The Army Energy and Water Campaign Plan (Department of the Army 2007) cites utilities privatization as the Army's preferred strategy for upgrading identified deficiencies in existing utility infrastructure. The Army utilities privatization Program was reviewed and reauthorized on 28 January 2011 by the 3-star Budget, Requirements, and Programs Board and was subsequently validated for funding.

Privatizing infrastructure assets has raised questions about how to ensure that those assets are protected from accidents and malicious tampering. Relying on connections to external utilities exposes the installation to external vulnerabilities and introduces concerns about how an installation will function in a situation that requires it to be self-sufficient for an extended length of time.

Army research and development has a significant ongoing role ensuring that the Army uses the most efficient and effective water infrastructure technology. Research and development in the areas of contaminant sensing, control systems, water purification, and water quality analysis generates tools, techniques and internal knowledge specifically suited to Army water security concerns.

Objectives for Strategic Investment Include:

Develop Funding Baseline. Developing a baseline of all water system funding requirements for retained and privatized water systems is fundamentally important to the maintenance of infrastructure integrity and security. A baseline of funding requirements will indicate where the greatest water security needs and risks are, not only in terms of infrastructure condition, but also in terms of the criticality of the missions that the infrastructure supports.

Recapitalize. Recapitalization means funding sustainment, restoration, and modernization sufficiently to provide for water utilities recapitalization among installations whose water infrastructure assets have not been privatized. Chronic underfunding of Army-owned infrastructure perpetuates inefficiencies that exacerbate the scarcity of funds and introduces unnecessary risks to Army missions. Funding with a long-term view of costs and benefits will reduce waste and mitigate risk of infrastructure failure.

Anticipate Costs. This means estimating ahead of time the increased costs of water projects resulting from privatization, and budgeting funds accordingly. Under privatization contracts, addressing years of previously deferred infrastructure maintenance can result in substantial increases in the cost of water.

Provide Advance Planning, Contractual Flexibility, and Adequate Staff Support to Implement and Administer Army Water Privatization Contracts. Adequate support involves ensuring that all Army water privatization contracts include advance planning that identifies and prioritizes initial water system improvement projects, with sufficient flexibility to accommodate future increases in installation missions and water consumption. The period of performance for privatization contracts may extend over several decades. Including planning services in these contracts, providing contractual flexibility, and maintaining robust staff support will help ensure that long-term privatization commitments deliver the greatest value to the Army and ensure the greatest level of security. Contracts should be explicit in granting full infrastructure access to Army Anti-Terrorism/ Force Protection personnel and to Public Health officials. Anti-Terrorism/Force Protection personnel and health personnel should be able to inspect the entire water system, review operational logs and laboratory procedures, collect and test water samples, ensure compliance with the National Primary Drinking Water Regulations, and make recommendations where improvements are needed. Contract language should be clear and specific concerning responsibilities for water infrastructure security. Security concerns should include how well a contractor will respond to a crisis situation and the degree to which installations have the flexibility and means to operate self-sufficiently, for a sufficient period of time.

Provide Internal/External Infrastructure Compatibility. This objective entails ensuring that Army installation infrastructure and external, privately owned infrastructure function together with a high degree of effectiveness and efficiency. Water and wastewater systems that were designed to serve separate communities face different performance requirements when they are expected to function together. Resolving these differences will increase operational efficiency and security.

Install Robust Contamination Risk Reduction Technologies. Deliberate or accidental contamination of critical infrastructure pipelines can disrupt installation operations, affect human health, and result in high economic costs associated with infrastructure downtime and recovery. A security system that provides ongoing monitoring, generates prompt alerts, and facilitates contaminant isolation within a water distribution system will reduce the risk of serious disruptions on Army installations should contamination occur (Ginsberg and Smith 2011).

Assess the Vulnerability of Water and Wastewater Infrastructure to Natural Mishaps. While installations have been required to complete a Water System Vulnerability Assessment (U.S. Army Environmental Command 2011) concerning risk of deliberate disruption or contamination of water supplies, there is not currently a requirement to assess vulnerabilities to natural mishaps. Flooding events in particular may disrupt the function of pumping stations and treatment plants. Climate change is widely expected to increase the severity of flooding inland and result in sea level rise along coastlines. The EPA Climate Ready Water Utilities initiative (Environmental Protection Agency 2012) offers tools that can be adapted to the assessment of flood risk.

Conclusion

Army water security is strengthened when focused attention is given to each of several different key facets of the water resources management challenge. These facets include regional water availability, water rights, water infrastructure, water use, and water consumption for production of materiel. The issues are complex and interrelated, the situation at each installation is different, funds are limited, and effective action will require strong leadership. The Army Water Security Strategy offers a way forward by highlighting the work that can be done to ensure best management of water resources in the interest of national defense.

Acknowledgments

The project was led by Dr. Marc Kodack who was a Senior Fellow at Army Environmental Policy Institute at the start of the project and transitioned to the Office of the Deputy Assistant Secretary of the Army for Energy and Sustainability in June 2011. Representatives

from a wide range of U.S. Army stakeholders who hold water management responsibilities contributed to the development of the water security strategy. The project was managed by Juli MacDonald-Wimbush of Marstel-Day, LLC. The project team included Lauren Birney, Richard Engel, Paul Koch, and Sylvia Lam. Other contributors included Lee Halterman, Phil Huber, Rebecca Rubin, Erika Wettergreen, and Harry Zimmerman.

Author Bios and Contact Information

Paul Koch is an independent water resources consultant. Over the past five years he has supported the development of environmental and water resources management actions for the U.S. Army, Air Force, and Marine Corps. Previously he developed computer models for irrigated agriculture and stormwater management, and has managed large-scale hydrologic and hydraulic analysis for floodplain mapping. As an adjunct professor with the University of Maryland University College, Dr. Koch has taught hydrology, environmental science, environmental economics and land use planning. He can be contacted at, 14915 Nashua Lane, Bowie, Maryland, 20716, or prkoch@gmail.com.

Marc Kodack is a project manager in the Office of the Deputy Assistant Secretary of the Army for Energy and Sustainability. He is responsible for assisting the Army Secretariat in the development of proactive policies and strategies to address water, operational energy, contingency bases, electric vehicles, and metrics. Dr. Kodack can be contacted at, Office of the Assistant Secretary of the Army for Energy and Sustainability, 110 Army Pentagon, RM 3D453, Washington, D.C. 20310, 571-256-4197, BB: 703-342-7355, marc.d.kodack.civ@mail.mil.

References

April, A. and A. Abran. 2008. *Software Maintenance Management: Evaluation and Continuous Improvement*. John Wiley & Sons Inc., Hoboken, New Jersey.

Assistant Secretary of the Army for Installations, Energy and Environment. 2012. Army Posture Statement, Addendum A. Available at: https://secureweb2.hqda.pentagon.mil/VDAS_ArmyPostureStatement/2012/InformationPapers/PapersIndex.aspx.

Billings, R.B. and C.W. Jones. 2007. *Forecasting Urban Water Demand, 2nd ed.* American Water Works Association, Denver, Colorado.

Brun, S.E. and L.E. Band. 2000. Simulating runoff behavior in an urbanizing watershed. *Computers, Environment and Urban Systems* 24(1): 5-22.

Department of the Army. 2005. *Real Property Master Planning for Army Installations*, AR 210-20.

Department of the Army. 2007. *Army Energy and Water Campaign Plan for Installations*. Available at: http://army-energy.hqda.pentagon.mil/docs/AEWCampaignPlan.pdf.

Department of the Army. 2008. *Army Compatible Use Buffer Program*. Available at: http://www.sustainability.army.mil/tools/programtools_acub.cfm.

Department of the Army. 2011. *Army Water Security Strategy*. Available at: http://www.aepi.army.mil/docs/whatsnew/ArmyWaterStrategy.pdf.

Department of the Army. 2012a. *Army Posture Statement*. Available at: http://www.bctmod.army.mil/downloads/pdf/2012%20APS.pdf.

Department of the Army. 2012b. *Army Vision for Net Zero*. Available at: http://army-energy.hqda.pentagon.mil/netzero/.

Environmental Protection Agency. 2010. *National Pollutant Discharge Elimination System Permit Writers' Manual*, EPA-833-K-10-001.

Environmental Protection Agency. 2012. *Climate Ready Water Utilities*. Available at: http://water.epa.gov/infrastructure/watersecurity/climate/.

Executive Order No. 13514, 3 C.F.R. 13514. 2009. Available at: http://www.gpo.gov/fdsys/pkg/CFR-2010-title3-vol1/xml/CFR-2010-title3-vol1-eo13514.xml.

Ginsberg, M. and E. Smith. 2011. USACERL's Water Infrastructure Security Program (WISP) for contamination prevention, detection, containment, and recovery on Army installations: Considerations for policy and technology. *Proceedings of the Integrated Water Security Summit Dedicated to Defense-in-Depth: Innovation and Technology Implementation Conference*. San Francisco California.

Hoekstra, A.Y., A.K. Chapagain, M.M. Aldaya, and M.M. Mekonnen, 2011. *Water Footprint Assessment Manual*. Available at: http://www.waterfootprint.org/ downloads/ TheWaterFootprintAssessmentManual.pdf. Earthscan, New York.

Jungreis, J.N. 2005. Permit me another drink: A proposal for safeguarding the water rights of federal lands in the regulated riparian East. *Harvard Environmental Law Review*, 29.

Kenny, J.F., N.L. Barber, S.S. Hutson, K.S. Linsey, J.K. Lovelace, and M.A. Maupin. 2009. Estimated Use of Water in the United States in 2005. *United States Department of the Interior, circular 1344*.

Office of Economic Adjustment. 2006. Joint Land Use Study Program Guidance Manual. Available at:http://oea.gov/index.php/resource-library/resource-library/doc_download/64-joint-land-use-study-program-guidance-manual.

Sherk, G. 2003. East meets West: The tale of two water doctrines. *Water Resources Impact* 5(2): 5-8.

U.S. Army Corps of Engineers. 2012a. Net Zero Installations. Available at: https://eko.usace.army.mil/public/fa/netzero.

U.S. Army Corps of Engineers. 2012b. Towards Integrated Water Resources Management: A Conceptual Framework for U.S. Army Corps of Engineers Water and Related Land Resources Implementation Studies. *Report 2012-VSP-01*. Available at: http://www.iwr.usace.army.mil/docs/iwrreports/2012-VSP-01.pdf.

U.S. Army Environmental Command. 2011. *Water System Vulnerability Assessments. Fact sheet*. Available at: http://aec.army.mil/usaec/newsroom/wsva01.pdf.

U.S. Department of Energy. 2012. Best *Management Practice: Alternate Water Sources*. Available at: http://www1.eere.energy.gov/femp/program/waterefficiency_bmp14.html.

Urbonas, B.R, and L.A. Roesner. 1993. Hydrologic design for uban drainage and flood control. In D. Maidment (Ed.) *Handbook of Hydrology*. McGraw-Hill, New York, 28.1-28.52.

Viessman, W., Jr., J.W. Knapp, G.L. Lewis, and T.E. Harbaugh. 1977. *Introduction to Hydrology*, New York, NY: Harper and Row.

Walters, C.J. 1986. *Adaptive Management of Renewable Resources*. New York, NY: McGraw Hill.

Appendix 1. Overview of Complexities of Army Water Security.

Complexity	Situation	Consequence
Diverse Missions	Every Army mission is different, some missions are joint, and missions change.	Rational allocation of resources among water security concerns will not simply rely on measures of water use intensity or per capita consumption, but will also consider the value of the military capabilities supported.
Diverse Leadership History Among Installations	The differences in the focus of various commanders over time, and changes in the leadership at any one location have led to different results. Some installations have established a tradition of thought leadership in water management and conservation.	The need for information, policy, guidance, and assistance in matters of water security varies greatly, and overall Army progress in this area would improve with wide-ranging leadership and commitments above the installation level. Practical solutions developed at one location may be of benefit at other locations.
Multiple Levels and Types of Responsibilities Across the Army Enterprise	Stakeholders across the Army enterprise have responsibility for different aspects of ensuring that water of suitable quality is provided. Water security encompasses medical, technical, financial, legal, doctrinal, logistic, managerial, research and community relations concerns among fixed facilities and contingency operations. Having many disparate stakeholders reporting to different commands and bill payers tends to weaken communications, management, and oversight of the overall water mission. Different key organization units include Logistics, Public Health, Assistant Chief of Staff for Installation Management/ Installation Managment Command, U.S. Army Corps of Engineers, research development test and evelualuation communities, and Antiterrorism/Force Protection interests.	A comprehensive approach to ensuring water security will involve coordination among Army offices with diverse and overlapping mandates. Leadership needs to encourage ongoing communication and cooperation among all stakeholders to prevent redundant effort and ensure that all stakeholders share a common goal and align their initiatives in support of that goal.
Multiple Resource Inputs to Army Missions	Water, while absolutely vital, is not the only essential resource that the Army has an interest in securing to meet mission needs.	In the context of ever-pressing funding constraints, proposed investments in water security solutions will always need to be weighed against other investment needs and opportunities.
Multiple Water Security Components	Water must typically be obtained from a natural water body, treated, distributed, and, following consumption, discharged. Upstream levels of land development, industrialization, and agriculture affect the quantity and quality of water running off into surface water bodies and percolating down into aquifers. Between the raw water source and consumer, the infrastructure and equipment needed for water treatment, storage, and delivery	Since water security can be affected at multiple points, a robust water security strategy will need to address the vulnerabilities at each of those points. An effective monitoring, surveillance, and protection program must be developed and incorporated into the installation of a water security plan to protect these components and to allow early detection of problems and rapid response to identified problems. Higher levels of security must be provided for infrastructure designated as critical.

Appendix 1. Overview of Complexities of Army Water Security (cont.)

Complexity	Situation	Consequence
	may lie both inside and outside installation boundaries. Each of these components is vulnerable to accidental and intentional compromise. Computerized control systems are vulnerable to cyber attack. For contingency bases, meeting water requirements presents more complex technical and logistics challenges. The mix of consumptive and non-consumptive uses by the Army determines the availability of water for other users downstream.	
Energy Requirements for Water	Without energy, water systems do not function. From source to tap, every aspect of water collection, transference, treatment, and distribution requires pumps and other equipment that require power. The energy delivery systems may be compromised by overload, natural, accidental, and intentional events, and may be local or widespread in nature.	Robust and redundant or backup energy delivery systems must be considered to be of paramount importance in developing a water security strategy. Employing gravity to the extent possible to move water through the water system can reduce the need to purchase energy, and should be considered when designing new systems.
Differences Among Freshwater Sources	Water sources include surface and ground water with different characteristics. Surface and ground water are connected. Water may be moved in substantial amounts across watershed boundaries. Watersheds, rivers and aquifers vary in size and water quality.	Evaluating water resource characteristics only within the watershed in which an installation lies will not necessarily be sufficient as a basis for identifying factors that influence water availability at an installation. Looking upstream of an installation may lead through external infrastructure to surface and ground water sources that originate many miles away. From one installation to the next, the scale of this kind of analysis may vary substantially.
Geographic Variability	The geographic conditions affecting water security vary considerably among Army locations. Climate differences are well known. The quality of raw water can be variously influenced by natural chemicals, agriculture, industry, and urbanization. Regional growth rates and patterns are different from one location to the next. Legal constraints on water rights vary across the United States and internationally.	An enterprise-wide Army water security strategy must encompass diverse solutions that are tailored to the specific conditions in and around the installation or contingency base. Programmatic goals and objectives that are tailored to regional and installation-specific circumstances will ensure maximum benefit for dollars invested
Vagaries of Weather and Climate	Weather will always vary naturally. The effects of climate change cannot be precisely predicted.	The consequences of Army action (or inaction) cannot be determined precisely. Addressing water security issues will necessarily require some judgment concerning the probability that adverse situations develop.

Appendix 1. Overview of Complexities of Army Water Security (cont.)

Complexity	Situation	Consequence
Multiple Water Users	The Army is one water user among many. The amount of raw water available from regional water sources is influenced by the behavior not only of the Army, but also of many other water users. Water is also needed to support ecosystem services.	Unilateral Army action with regard to its own water use may or may not have a significant effect on the sustainability of the supplies upon which the Army is relying. Army water conservation efforts alone will not necessarily result in substantial increases to water security.
Size and Extent of Army Water Systems	Individuals or groups who have issues with the government or the military, be they terrorists, disgruntled or former employees, angry citizens or student organizations recognize that threats and actions against military facilities or personnel get attention, and large water distribution systems can be vulnerable at many points.	Surveillance and vigilance, including education programs, detection equipment, and water system vulnerability assessments, need to be improved and increased to deter, delay, and respond rapidly to water system attacks of any kind.
Multiple Levels of Government Interest	States administer water rights and federal interests participate in state water rights adjudications. Army water use may involve government interests as close as the local public water utility, as broad as interstate water commissions, and as distant as host nations overseas. Host nation agreements would further involve allied/friendly governments.	States administer water rights and federal interests participate in state water rights adjudications. Army water use may involve government interests as close as the local public water utility, as broad as interstate water commissions, and as distant as host nations overseas. Host nation agreements would further involve allied/friendly governments.
Multiple Drivers for Water Conservation	Beyond the mandates of Executive Order No. 13514 (2009), conservation action may also be driven by cost savings opportunities, by legal constraints due to legislation such as the Endangered Species Act, by applicable state water law, and by limitations on the quantity and quality of raw water available.	A robust evaluation of the success of conservation efforts will examine more than progress toward consumption reduction goals relative to a baseline consumption rate. At any given allocation, a variety of factors will affect how much water use intensity can be reduced from prior years.
Differences in Arrangements Involving Non-Military Organizations	Water and wastewater utilities may be Army owned and operated, Army owned and privately operated, or privately owned and privately operated. External public utilities may supply all or part of the water needed.	Policies and procedures encompassing Army water and wastewater infrastructure will have implications for commercial and public organizations supplying these services.

Universities Council on Water Resources
Journal of Contemporary Water Research & Education
Issue 149, Pages 76-87, December 2012

Sustained Dialogue for Ground Water and Energy Resources in Chile

Suzanne A. Pierce[1], Reed A. Malin[1], and Eugenio Figueroa[2]

[1]The University of Texas, Austin, TX; [2]Universidad de Chile, Santiago, Chile

Abstract: Water conflict arises in interconnected ways. As demand increases in one region or industrial sector, the accompanying shifts in water resource management regimes have impacts at the local level and may carry international implications. Insecure water resources are often the root cause of resistance or social conflict across many political and economic sectors. Integrated Water Resources Management is an emerging transdisciplinary approach to science-based water management that attempts to account for these cross sector effects. This paper presents a case study of Integrated Water Resources Managment methods applied in the El Tatio Geothermal Field basin of northern Chile where tensions from the competing needs of metals mining, tourism, energy development, scientific research, and environmental conservation have created social and political tension. Participatory engagement was conducted with stakeholders in the field through elicitation and group dialogue process. This was combined with design of a cyberinfrastructure system for managing and presenting data. Results suggest that sustained facilitated dialogue and socio-technical systems approaches provide a framework to implement Integrated Water Resources Managment, improve science communication, and engage stakeholders at the center of resource conflict. In the case study, early results are informing the framing of data collection plans, microentrepreneurial ventures, and spurring communication across sectors.

Keywords: *Participatory modeling, ground water management, energy-water dialogue*

Available sources of freshwater and energy are critical to human and economic development. Frequently the benefits of economic development are experienced at a national scale while the impacts are focused at the local and regional levels, particularly in cases with energy-water tradeoffs (e.g., Scott et al. 2011). Global development and population growth are spurring demand for resources, such as copper and other metals, that require secure, stable sources of water and energy. In the Atacama Desert of northern Chile, regions of extreme water scarcity are also experiencing intense economic growth from mining, causing concern for the security of long-term water and energy supplies in that region (Figueroa et al. 1996; Lloyd 1976; Madaleno and Gurovich 2007). Sustainability describes the rates of use for a resource that are considered appropriate for the current generation's benefit, offset by preserving the viability of that same resource for future generations (United Nations 1987). Global demand is driving the mining industry in northern Chile to expand with an increasing reliance on already unsustainable uses of energy and water in the region. Mining has been present in the region since pre-Incan times (Salazar 2010) and the industry is tightly enmeshed with the national Chilean identity. Yet relationships be-tween regional indigenous communities and the mining industry have been strained due to the environmental (particularly water resource related) impacts of mining (Larrain and Schaeffer 2010). In recent times, tensions over these resources have been exacerbated by the need to develop reliable energy generation to support mining. Contemporary events, such as the "Water War" of Bolivia in 2000 and the "Gas War" of northern Chile in 2004 are concrete examples of tensions among industrial, government, and indigenous entities in the Altiplano zones of South America. These have resulted in active conflict

and resistance to water and energy infrastructure development (Orihuela and Thorp 2012).

Science can contribute to the topic of water and energy resource allocation by providing information about the workings of these Integrated Water Resources Managment systems and by creating tools to quantify impacts or beneficial aspects of development. Yet, tools alone cannot deliver adequate decision support for complex, ill-structured, and dynamic problems. To address the needs for the application of science and planning, decision-makers and community stakeholders need both computational tools, or models, and soft system methodologies to support dialogue, and deliberative processes to assist with the design, presentation, and evaluation of water management alternatives.

This paper presents a methodological framework to link decision analysis tools with a sustained and facilitated dialogue process in order to establish the basis for transforming relationships across stakeholder groups and enable systematic evaluation of resource management and development alternatives. The decision pathways framework (Pierce 2008) presented in Figure 1 shows the process flow between scientific data analysis, economic valuation, and policy development procedures. Dialogue processes are especially useful during the "Identification" stage, while deliberative process is well-suited to "Evaluation & Choice Routines" as shown in Figure 1.

There are deep-seated conflicts and interdependencies in many water and energy resource cases. Disputes can be compounded by social and political misunderstandings among the various interest groups in a basin, as well as by misconceptions about the meaning of scientific models at how water resources interact and respond to management actions within a basin. The need to identify tough decisions and necessary tradeoffs makes it difficult to gain clarity on both the system behavior and interest group concerns that are critical to identifying possible solutions within a reasonable timeframe.

The El Tatio Geothermal Field presents a case example that exemplifies common relational dynamics and the role of scientific information common to resource issues. The overarching motivation for this work is to develop replicable Integrated Water Resources Managment approaches for this and other systems. These approaches should be capable of improving links between water resource problems and community concerns so that science based information can be communicated in ways that are both meaningful and accurate. Research focuses actively on the use of Sustained Dialogue in the El Tatio Geothermal Field case study to bridge the diagnosis phase of a problem from naming and framing the problem and analysis of cross communication among different stakeholder groups.

The El Tatio Case Study

The El Tatio Geothermal Field in the Atacama region of Northern Chile is the largest geyser basin in the southern hemisphere, and is located in one of the driest places on Earth (Figure 2). Often labeled the Yellowstone of

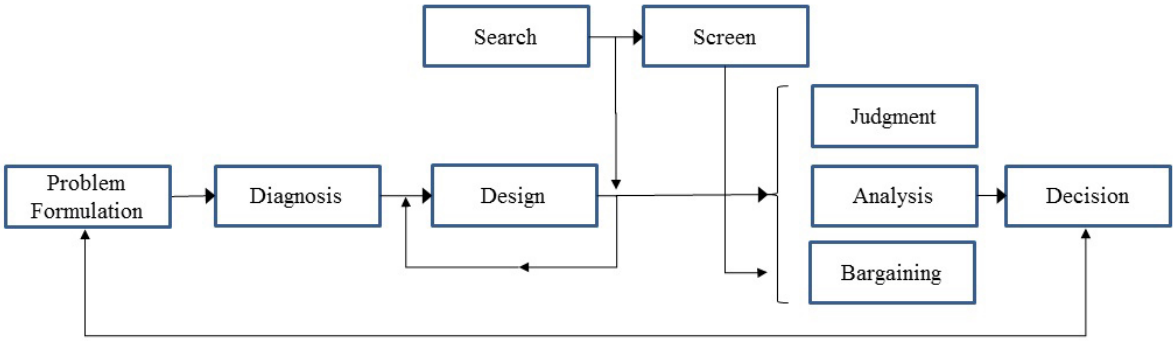


Figure 1. Decision Pathway framework identifies common decision-making stages (from Pierce 2008; modified from Mintzberg et al. 1976).

South America, this unique geyser basin is a rare natural resource that sees heavy visitation by Chilean and international tourists, and it is an important economic resource for the local towns and indigenous peoples. The geothermal springs create an extremophile environment that supports a microbiological community of organisms tolerant to arsenic and ultraviolet light. While the spring features have dynamic microbial ecosystems very similar to Yellowstone, El Tatio Geothermal Field is unlike Yellowstone National Park in that it has limited protection by the Chilean government, and is open to economic development, including for geothermal energy. In the latter half of 2008 the Chilean government issued leases to an international consortium of developers to develop a 100 MW power plant 4 km from the geysers, a plan vehemently opposed by the local indigenous population. Drilling started early in 2009, and included completion of initial production wells, together with retrofitting a set of old test wells from the 1970's, for use as reinjection wells. El Tatio Geothermal Field is now at the center of an international debate centered on the conflict between energy development and water resource preservation. The event driving the current conflict occurred in September 2009 when one of the older wells being retrofitted for reinjection blew out, leaving an open hole to more than 4500 m depth. Steam was venting to a height of 60 m, releasing ground water fluids that are extremely high in naturally occurring arsenic and antimony, and depositing a blanket of arsenic rich salts around the well. This is one of the worst-case scenarios feared by various interest groups in Chile, where an uncontrolled release would contaminate the surface environment while upsetting the thermal and hydraulic balance in the basin itself, possibly drying up unique geyser features.

The wellhead release created localized impacts to the environment, perceived health risks due to arsenic precipitates from the release, and concerns regarding the relative impacts to basin fluxes due to depressurization of the geothermal complex. Impacts from shifts in the geochemical, hydrological, and thermal fluxes in the basin may result in negative impacts for a range of industries and interests for use of the basin, such as geothermal energy development and international tourism.

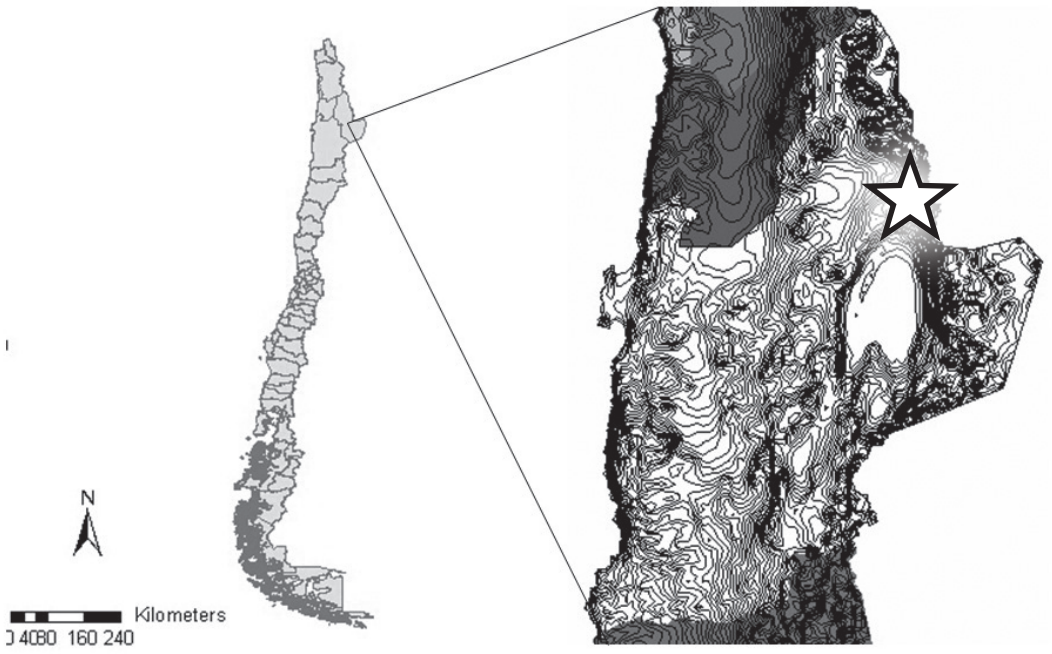


Figure 2. Map of Tatio and Calama basins, Loa Province, Chile with regional and local inset satellite image (modified from Markovich 2012; Direccion General de Aguas 2003).

Physiographic and Geologic Characteristics of the Setting

El Tatio Geothermal Field is situated within the physiographic province of the Cordillera de Los Andes (or Andean Mountain Belt). The geyser complex is located within the larger altiplano volcanic region of northern Chile at approximately latitude of -68.0168 and longitude of -22.3372 (Hauser 1997). The high altitude, approximately 4,250 meters above sea level, and relatively high temperatures at the geysers, between 78-86 ^{o}C (Malin et al. 2011; Lahsen 1988; Lahsen and Trujillo 1976) make this geyser field an extreme environment. In addition, El Tatio Geothermal Field is one of the largest reported in the world with approximate 67 reported geyser features (and potentially many more, unreported) and a total estimated area of 30 km^2 (Glennon and Pfaff 2003; Jones and Renaut 1997).

At the same time, the geyser basin discharges and contributes to the Rio Loa Depression making it an important water resource for the downstream agricultural activities. El Tatio and El Loa (or Calama) hydrologic basins are located within the greater Antofagasta region, or administratively the Second Region of Chile. Surface water and ground water flows from high altitude precipitation and eventually recharge the Loa river which is a major river basin within the country that provides a significant portion of the water demanded by industries, as well as potable water for the more than 400,000 inhabitants of the region (Salazar et al. 2003).

The Cordillera de Los Andes (The Cordillera) is made up of a north-south trending series of volcanic cones with intermontane basins that constitute the altiplano (or high plains of Chile) (Marinovic and Lahsen 1984). The Cordillera is characterized by Cenozoic volcanics with Cretaceous and Tertiary intrusives. The Tatio geyser complex is located within a graben that is part of a larger regional system of normal faults (Marinovic and Lahsen 1984).

The downgradient Rio Loa Depression is covered primarily by sedimentary sequences of Miocene and Pliocene age, overlain in some locations by unconsolidated Quaternary age sediments (Marinovic and Lahsen 1984). The arid climate limits recharge from seasonal precipitation largely to the upper elevations of the Cordillera (Salazar 2003). Surface water occurrences within the Tatio Basin are generally limited to a 10 km^2 area subject to superficial thermal activity. The central portion of the basin demonstrates anomalous resistivities of less than 10 Ohm/m (Marinovic and Lahsen 1984). Additionally, surface water temperatures at the geyser expressions are generally greater than 70^{o}C and do not tend to exceed the 86 ^{o}C boiling point for the altitude, yet geothermal exploration conducted in the mid-1970's demonstrated that subsurface temperatures ranged between 160 ^{o}C and 265 ^{o}C (Lahsen 1988).

Socioeconomic Demands for the Region

Geothermal Development

Geothermal development of El Tatio Geothermal Field geyser complex has been considered by Chilean government agencies since the mid-1960's. Early estimates of thermal energy production for three exploratory geothermal wells were capable of producing 18 MW of power (Marinovic and Lahsen 1984) and reportedly 10 L/s of freshwater could be produced from each MW of potential power in the basin (Lahsen 1988). Today, the Second Region has developed several power sources, including coal powered and natural gas imported from Argentina, but neither is secure and can be disrupted from international conflicts or transport issues. As the region's population continues to grow, a safe, secure, efficient power source is desirable for continued economic success mostly rooted in mining activities.

Most recently, geothermal exploration and development throughout Chile has become a focal point for conflict with indigenous communities along the Andes. Similar conflicts are emerging throughout the region, particularly in the altiplano regions of Chile and Bolivia (Orihuela and Thorp 2012).

Agricultural Production

An estimated 1,503 hectares were under production within the Loa basin in 2002 with

primary crops of alfalfa and carrots. Between both surface and ground water rights, approximately 5,861 L/s are used on average (Direccion General de Aguas 2003). Unfortunately, severe economic restrictions are placed on all agricultural goods produced in the region due to the high levels of arsenic in irrigation waters. Improved water quality discharge from the Tatio basin could have far reaching economic implications for the agricultural industry in the region if produce could be marketed outside the Second Region.

Mining Industry

The mining industry is recognized as the largest water resource demand component in the Second Region, yet the water ministry reports that it does not have complete information regarding the total water usage for mines in the area. Mining stands to benefit from geothermal development due to decreased energy costs for production, but the industry must also consider as yet undetermined benefits from conserving the geyser complex for international tourism, scientific discoveries in the extreme environment, or other sectors. The benefits of energy costs are directly quantifiable, but the unknown value of future research discoveries, which can only be developed if the primary geyser site is preserved, are difficult to predict.

Tourism Industry

The international tourism industry is thriving in the Second Region with El Tatio Geothermal Field providing a site for destination travelers. Protection of the geyser field is important to the retention of the current tourist industry that has developed in the San Pedro de Atacama area and is now expanding into other altiplano pueblos, such as Chiu Chiu, Toconce, and Caspana. Tourism is mentioned among regional stakeholders as a strong offset to the economic drivers urging geothermal development.

Local/Regional/International Industries

Small enterprises, support industries for the larger mining sector, and international import/export activities in the Second Region are driven by the availability of both energy and water. Therefore geothermal development paired with water treatment could potentially result in positive benefits for most organizations within this category. Local indigenous cottage industries, such as an existing Ayquina Goat Cheese Factory, could be expected to increase with improved water resources. Regionally, a decrease in energy costs might encourage entrepreneurial investment and the existing port facilities in Antofagasta could also see increased business if the existing mine operations augmented production.

Domestic Demand

Demand for potable water for use in domestic residences is inevitable. Current potable water demands of approximately 1,600 L/s within the Loa basin are met using surface water only (Direccion General de Aguas 2003). Anecdotal information indicates that demands from the larger city of Antofagasta are augmented with approximately 850 L/s from the altiplano. As the economy of the Second Region and areas near Calama expands, domestic use will also continue to grow. While domestic use rates seem relatively small when compared with industry, when the demand of all populations is aggregated, a significant component of the overall water budget is attributable to this category. In terms of driving economics, the costs for treatment of water to potable standards can be relatively high, while the benefits are extremely difficult to monetize. In relation to the microbial dynamics of the Tatio Basin, if geothermal development incorporated water treatment and arsenic removal (potentially mediated by the very same microbial denizens of the geyser basin) the associated costs and benefits would provide a positive motivation for development.

Methods

This research develops an integrated approach to link science-based information to local knowledge for sense-making stages after a surprise event. Methods begin with elicitive interviews across stakeholder groups using open-ended elicitation and previously successful narrative analysis approaches (Pierce et al., in press) followed by focus group interactions based

on sustained dialogue techniques (Saunders 2011). Decisions about how to protect and/or use El Tatio Geothermal Field will pit a myriad of interests (economic, environmental, scientific, cultural) against another. The conflict has intensified because of recent events creating conditions to observe how different stakeholder groups name and frame their concerns and understanding about potential consequences for the resource.

Initial Interviews

Initial socio-technical research for this case began with interviews conducted after the geothermal incident. These interviews were conducted with representatives from municipal governments, environmental interests, energy development, the tourism industry, national government ministries, local pueblo community members, research scientists, and tourists about the perceived impact of the event and the impacts of future development on tourism and the local economy. Two field visits were completed in October and December of 2009 immediately following the uncontrolled release from the 4500 m deep exploration well.

Interview results were used to collect preliminary data on how stakeholders perceive vulnerability and frame the possible consequences and solutions for the management of the El Tatio Geothermal Field. Stakeholder perceptions of the event were then compared with results of direct measurements of the hydraulic and thermal balance of the El Tatio Geothermal Field in October and December 2009. Post event recovery measurements provided a scientific basis for evaluating the actual impact to the basin (flow, temperature, chemistry, heat flux) and interviews captured perceptions (varying from catastrophic impact to no impact across stakeholders).

Qualitative data were collected using open-ended elicitation with a set of participants from interested parties. Preliminary data were evaluated using Value Focused Thinking Techniques (Keeney 1992), sustained dialogue stages (Saunders 2011), and combined evaluation of collective sense-making (Weick et al. 2005) to describe possible science-based uncertainties that are integral to the dialogue surrounding long-term management and decision-making for managing the geothermal basin. Results from interviews were captured with either hand written notes and/or capturing comments using word processing tools on a portable laptop computer. Human subject involvement began October 26, 2009 and participants were asked to self-identify with an interest group category and then selected for inclusion or exclusion using the following criteria:

- Knowledgeable about the situation and/or geothermal basin,
- Willing to participate and give verbal consent,
- Available at the time of the field study and/or willing to participate via teleconference after the field visit is complete, and
- A member of one of the interest groups named above and/or another group with an interest in management of the geothermal basin.

Open-ended elicitation interviews lasted 20-60 minutes depending on the length of participant responses to questions. Questions during non-structured elicitation using open-ended questions related to:

- Historic connection with the geothermal basin;
- Perceived level of vulnerability in the basin to use and/or management options;
- Description of primary concerns or objectives for resource management;
- Description of primary controls for management;
- Description of possible best and worst case outcomes or consequences for the basin;
- Identification of the highest perceived values to society from the basin; and
- Perception of the impacts specifically related to the September 21, 2009 well release incident.

Interview results supported the research design for a follow on group dialogue forum as described in the next section.

Sustained Dialogue and Group Forum with Indigenous Stakeholders

Values that consider non-market aspects of resource problems, such as environmental and long-term sustainability (or intergenerational

equity) values and economic forces associated with a problem are difficult to measure. Initial interview processes provide insight into the key concerns, objectives, and social constraints for any resource problem, but moving from identification to transformation of group dynamics is a challenging process. Sustained Dialogue is a descriptive framework that recognizes the phases that every group goes through to resolve a conflictive issue and it also sets out a set of principles and tenets that mediators or facilitators can use to inform group engagement (Saunders 2011; Stewart and Saunders 2009). Sustained Dialogue formed through decades long processes of conflict resolution conflict negotiation teams working on behalf of the US Department of State to broker peace in many of the most volatile situations around the world. Although readers are referred to publications by Saunders (2011) for more detailed information on this complex process, key elements include five general stages (shown in Figure 4) that reflect the topics that groups need to address during any conflict resolution process. The discussion is not a linear process, it is iterative, but any group seeking to achieve resolution must address each of the five stages. The case reported here is in the Stage I and II framing and early problem identification stages of dialogue. One tenet that Sustained Dialogue practitioners are urged to follow, is disallowing the group to discuss alternatives or solutions until they have addressed the first stages of any problem. These early stages are also the starting point to bridge science and society knowledge, because Stages I and II provide for sound problem diagnosis for a scientist interested in constructing an Integrated Water Resources Managment model.

Results

The results reported in this research present initial steps for creating a long-term engagement strategy with a community group. Initial problem formulation and fact-finding were completed through individual interviews across stakeholder groups. The results of interviews informed the design of a participatory process to engage with a target stakeholder interest group, in this case the indigenous community members of northern Chile. These initial steps provide early problem formulation and social learning opportunities in the broader process of decision support to long term Integrated Water Resources Managment in the Second Region. As the process continues, additional stakeholder groups will be engaged and dialogue processes are expected to continue. The following sections discuss specific results of early engagement processes.

Interview and Scientific Results

Results of the stakeholder interviews demonstrated several important considerations about the perceptions of scientific knowledge and conditions in the El Tatio and El Loa basins. This section focuses on perceptions reported by indigenous community members and government agency representatives, because analysis indicated that the greatest levels of misunderstanding and miscommunication exist between these two groups.

Results of interviews with indigenous community members highlighted their perception of severe impacts to the El Tatio Geothermal Field basin during and after the geothermal blowout event, which is directly at odds with results of scientific measurements after the event (Malin et al. 2011). Core concerns raised by indigenous community members demonstrated that they are firmly locked in the Stage I aspects of a Sustained Dialogue that represents a sense of direct threat to identity and power imbalances with all other sectors in the region. In relation to scientific information, participants reported that they see science as a "weapon" that can be used against them locally, while international scientists are viewed as allies to help the group advocate for their case. Importantly, the indigenous community members indicate that they reject all government authority over environmental, water, or energy resources in the region. Community members led a protest march against government control of El Tatio Geothermal Field. In response to the protest, the Chilean Senate passed a moratorium on leases for geothermal exploration for several months.

Government representatives reported perceptions that are directly connected to Stage II aspects of Sustained Dialogue demonstrating that they feel they are in a top-down environment with control over activities and events in the El

Table 1. Stages of Sustained Dialogue process and showing primary concerns addressed in these stages of a process (Saunders and Stewart 2009).

Stage I	Stage II	Stage III	Stage IV	Stage V
Define	Identity interests	I to We	Collaborate	Communicate
Who	Power	Alternatives	Transform the Problem	Implememnt
Engage	Misperceptions -Interaction		ID Actions	

Tatio Geothermal Field basin. Participants in this stakeholder category indicated that they needed more hydrologic information to make sound decisions and that from more technical information they would be able to craft a limited communication plan and control outcomes for El Tatio Geothermal Field. This planned change perspective is at odds with the indigenous community's rejection of government authority.

Notably, the physical measurements and comparisons using forward-looking infrared, geochemical, and flow datasets indicate that the El Tatio Geothermal Field system recovered rapidly from the exploration incident in 2009 (Malin et al. 2011) and this corroborates the findings of the official report by the United Nations Development Program's panel of experts (UNDP Chile 2010).

These results provided important information to guide the next elements of the research so that sustained dialogue sessions could be initiated to bridge between science, policy, and communities. Because the indigenous group is squarely situated in Stage I phase, the research team decided to initiate a group dialogue using the Sustained Dialogue techniques to initiate and inform an early framing and problem diagnosis process and open opportunities to bridge a dialogue process with government representatives in the future.

Forum Results

The initial group dialogue session was hosted as a "Seminario Cientifico-Etnico" (Ethnic Science Seminar) with 19 participants from four northern regions in Chile over the course of 12 hours (See Figure 5 for a photo of participants during the forum).

The process combined narrative and deliberative approaches to generate substantive discussions among participants. Scientific participants provided brief capacity-building lectures about available information sources for water data through the Chilean government, GIS and mapping resources, and the macroscopic context of water resources in the north of Chile.

At the conclusion of the meeting, participants defined three initiatives to:

1. Create an indigenous management environmental and water resource monitoring network;
2. Develop a science-based training program for indigenous tour guides using water topics initially; and
3. Explore potential for an indigenous-led alternative energy cooperative.

Each of these initiatives is underway since the culmination of the group forum. Some important constraints were placed on topics by the participants, who refused to discuss geothermal energy and only allowed presentation of water resource information, which may indicate that water is an entry point for dialogue on more divisive topics for this region. Additionally, the group agreed to clear actions in relation to the three initiatives and also requested a future seminar to discuss geothermal energy and ground water.

The group forum supports scientists with an improved understanding of the level of knowledge about water resources in the region and the primary concerns of the indigenous community members. This new understanding can support the development of educational materials for future interactions and inform development of decision support models for Integrated Water Resources Managment efforts.

Conclusions

Truly sustainable water and energy resource management will not optimize a single indicator to define a long-term management regime. Rather, integrated water resources management that takes into account the various biophysical, hydrologic, environmental, economic, cultural, and legal factors can be expected to generate the most appropriate strategies for all parties concerned. Energy and ground water management is a significant, complex real world challenge that requires thoughtful consideration of scientific and social aspects before selecting a recommended course of action.

English and Dale (1999) recognized that future research and work in the area of decision support development can be expected to flourish in areas that:

1. Develop new tools that are increasingly transparent to the user groups;
2. Improve the integration of tools into daily use by decision-makers (i.e., keeping the tools off the shelf and in use); and
3. Continue collection of input parameter data and improve data measurement.

This study presents a replicable process for the early stages of decision problem formulation that may provide an avenue for addressing the areas identified by English and Dale (1999) and improve com-munication with regard to water resource conflicts, as demonstrated by El Tatio geyser complex. At the same time community conflicts that involve complex systems with critical scientific information, are unlikely to be resolved without clarity in the naming and framing of issues to be addressed during a dialogic or deliberative process.

Socio-technical tools and methods are capable of systematically bridging the boundaries between science and social regimes. It is necessary for professionals across the range of water and energy resource management and research to create a common understanding and level of communication in order to improve the outcomes of planning and policy implementation.

Acknowledgements

This research was funded by the inaugural Fulbright Nexus program of the U.S. Department of State, the Longhorn Innovation Fund for Technology of The University of Texas at Austin, and the Jackson School of Geosciences Geology Foundation Rapid Response Program. The research team would



Figure 5. Photo of sustained dialogue participants during January 2013 Seminario Cientifico-Etnico.

like to thank support from Ms. Carolina Yufla and Ms. Sonia Ramos of the Second Region of Chile for their long-term support and commitment to this research. Additional support from fellow researchers, Ms. Sofia Otero and Dr. Diego Morata, at the Geothermal Center for Excellence of Universidad de Chile along with Mr. Benjamin Bass, Ms. Katie Markovich, Mr. Luciano Correa, and Dr. Megan Franks of The University of Texas at Austin has been greatly appreciated. Insights and training for dialectic aspects of this research were provided by Dr. Harold Saunders, Dr. Philip D. Stewart, and Dr. Ramon Daubon of the International Institute of Sustained Dialog. Research activities were supported also by the Universidad de Chile's Center of Environmental and Natural Resource Economics and the Biodiversity Domeyko Project. All research activities have been completed under exemption status through the Human Studies Review Board at The University of Texas at Austin (IRB Exemption 2009-10-0054). We would also like to thank the El Tatio Makalu management group.

Author Bios and Contact Information

Suzanne A. Pierce is a Research Assistant Professor with the Center for International Energy and Environmental Policy in the Jackson School of Geosciences and Assistant Director of the Digital Media Collaboratory in the Center for Agile Technology at The University of Texas at Austin. A trained hydrogeologist adopts a scholar-practitioner approach to integrate science-based information with human organizational systems for application to ground water management and energy-water problems. Professional honors include selection as a Fulbright Nexus Scholar for the U.S. Department of State, and an ICE WaRM Liaison to the Australian Centre for National Groundwater Research and Training. She can be reached at suzpierce@jsg.utexas.edu.

Reed Malin is a dual degree Master's student in Energy and Earth Resources and Public Affairs. His research focuses on how to integrate geoscientific data into public policy using decision support tools. He is currently writing his thesis on the geothermal development of the El Tatio geothermal field in northern Chile. Prior to coming to UT-Austin, Reed worked as a scientific project manager at the Institute of Earth Science and Engineering at the University of Auckland, New Zealand. He has been involved in geothermal explorations campaigns in the USA, Kenya, New Zealand, Australia, Iceland, and the Caribbean. He can be reached at malinman@gmail.com.

Eugenio Figueroa B. is a professor of Economics in the School of Economics and Business at Universidad de Chile in Santiago. He has published twelve books and more than two hundred papers in scientific, technical and professional journals and magazines. As the Director of the Center for Natural Resource and Environmental Economics, Dr. Figueroa has provided scientific and professional advising and consulting for more than twenty years to the government of Chile, foreign governments, national, international and multilateral organizations and institutions such as World Bank and Inter-American Development Bank, and Chilean and foreign firms and companies. Figueroa can be reached at efiguero@econ.uchile.cl.

References

Direccion General de Aguas. 2003. Informe Tecnico: *Determinacion de los derechos de aprovechamiento de agua sub-terranea factibles de constituir en los sectores de Calama y Llalqui, Cuenca del Rio Loa, II Region*: Santiago, Direccion General de Aguas, Departamento de Administracion de Recursos Hidricos, Ministerio de Obras Publicas, 38.

English, M.R., and V.H. Dale. 1999. Next steps for tools to aid environmental decision making. In English M.R. (Ed.) *Tools to Aid Environmental Decision Making*. New York, Springer-Verlag New York Inc., 317-328.

Figueroa, E., R. Alvarez. G. Donoso, J. Muñoz, and G. Lagos. 1996. *La Sustentabilidad del Sector Exportador como una Restricción al Desarrollo Futuro de Chil*e, O. Sunkel (Eds.) Sustentabilidad Ambiental del Crecimiento Económico en Chile. Universidad de Chile. Santiago, Chile. 47-86.

Glennon, J.A., R.M. Pfaff. 2003. The extraordinary thermal activity of El Tatio Geyser Field, Antofagasta Region, Chile. *Geyser Observation and Study Association Transactions* 8: 31-78.

Hauser, A. 1997. *Catastro y caracterizacion de las fuentes de aguas minerales y termales de Chile.* Santiago, Chile, Servicio Nacional de Geologia y Mineria, 90.

Jones, B. and R.W. Renaut. 1997. Formation of silica oncoids around geysers and hot springs at El Tatio, northern Chile: *Sedimentology* 44: 287-304.

Keeney, R.L. 1992. *Value-focused thinking: A path to creative decisionmaking.* Cambridge, Massachusetts, Harvard University Press, 416.

Lahsen, A. and P. Trujillo. 1976. *El campo geotermico El Taito*, Chile. Unpubl report CORFO, 21.

Lahsen, A. 1988. Chilean geothermal resources and their possible utilization. *Geothermics* 17: 401-410.

Larrain, S. and C. Schaeffer (Eds.) 2010. *Conflicts over Water in Chile: Between Human Rights and Markets Rules*. Chile Sustentable. Santiago, Chile, 57.

Lloyd. J.W. 1976. The hydrogeology and water supply problems in north-central Chile. *Pacific Science* 30(1): 91-100.

Madaleno, I. M. and A. Gurovich. 2007. Usos conflictivos del agua en el Norte de Chile. *Boletín de la A.G.E. N.º* 45, 353-372.

Malin, R.A., M. Franks, and S. A. Pierce. 2011. *Using Forward Looking Infrared Imagery to Gauge Thermal Flux: Preliminary Method Development and Evaluation Applied to the El Tatio Geothermal Field. 11th Biennial Meeting of the SGA*, 26-29 September 2011, Antofagasta, Chile. Abstract #308.

Markovich, K. 2012. *Integrated remote sensing and hydrochemical analysis of a playa lake-groundwater system in northern Chile*, unpublished undergraduate honors thesis, The University of Texas at Austin, 42.

Marinovic, N. and A. Lahsen. 1984. *Hoja Calama, Carta Geologica* No. 58: Santiago, Chile, Servicio Nacional Geoogico Mineral.

Mintzberg, H., D. Raisinghani, and A. Theoret. 1976. The Structure of "Unstructured" Decision Processes. *Administrative Science Quarterly* 21(2): 246-275.

Orihuela, J.C. and R. Thorp. 2012. *Social conflict, economic development, and extractive industry: Evidence from South America*. (Eds.) Bebbington, A. Routledge ISS studies in rural livelihoods, London, 256.

Pierce, S.A. 2006. *Groundwater Decision Support: Linking Causal Narratives, Numerical Mod-els, and Combinatorial Search Techniques to Determine Available Yield for an Aquifer System:* unpub. Ph.D. dissertation, University of Texas. Austin, TX, 313.

Pierce, S.A., M. Dulay, D.E. Eaton, and J.M. Sharp. In press. Calculating consensus yield: Narrative analysis for incorporating stakeholder values to determine available yield for an urbanizing groundwater system. *Journal of Hydrogeology*.

Pierce, S.A. 2008. Pieces of a puzzle: Why transdisciplinary socio-technical tools are necessary to address water resources policy, presented at the 2008 Meeting of the American Institute of Professional Geologists, Arizona Hydrological Society, and 3rd International Professional Geology Conference, Flagstaff, Arizona, USA, September 20-24, 2008. Published by American Institute of Professional Geologists.

Salazar, M.C., A.M. Gangas, M.R. Rojas, and B.L. Rojas. 2003. Informe tecnico: *Evaluacion de los recursos hidricos sectores Calama y Llalqui, Cuenca del Rio Loa*, Santiago, Chile, Departamento de Estudios y Planificacion, Direccion General de Aguas, Ministerio de Obras Publicas, 135.

Salazar, D. 2010. *Tras la Senda del Cobre Atacameño. La Historia Minera de San José de El Abra*. SCM El Abra, 90.

Saunders, H. H. 2011. *Sustained Dialogue in Conflicts: Tranformation and Change*. Palgrave Macmillan, New York, 297.

Scott, C.A., S.A. Pierce, M.J. Pasqualetti, A.L. Jones, B.E. Montz, J.H. Hoover. 2011. Policy and Institutional Dimensions of the Water-Energy Nexus. *Energy Policy* 39(10): 6622-6630.

Stewart, P., and H.A. Saunders 2009. *The Heart of Sustained Dialogue's Power.* International Institute for Sustained Dialogue.

UN General Assembly. 1987. Forty-Second Session, Official Records, Supplement 25, *Our Common Future*, prepared by the World Commission on Environment and Development.

UNDP Chile. 2010. *Revisión de la Ejecución del Proyecto Perforación Geotérmica Profunda El Tatio, Fase I: Informe Preliminar. Informe Técnico*. Rev. 2010-06-24Y. Ca-tastro y caracterizacion de las fuentes de aguas minerales y termales de Chile: Santiago, Chile, Servicio Nacional de Geologia y Mineria, 90.

Weick, K., K. Sutcliffe, and D. Obstfeld. 2005. Organizing and the Process of Sensemaking. *Organization Science* 16(4): 409-421.

Universities Council on Water Resources
Journal of Contemporary Water Research & Education
Issue 149, Pages 88-96, December 2012

The Past, Present, and Future of Water Conflict and International Security

David K. Kreamer

University of Nevada, Las Vegas, NV

Abstract: Water stress and scarcity has affected, and will continue to affect, the stability of communities. An overview of global water security challenges indicates profound difficulties and potential flashpoints. There are many examples of struggles in supplying clean water throughout the world, and how water has been both a strategic tool and object of conflict in the past. Water has been an instrument of ethnic and religious conflict, and has recently been used in regional and local clashes. Transboundary water disputes are also potentially dangerous in several regions of the world and stresses from climate change and variability increase the uncertainty of clean water supplies. Potential ways to move positively forward and increase international security include: anticipating future regions of conflict over water, cooperation among water users, proper policy and regulatory structures, and infrastructure solutions.

Keywords: *Water security, transboundary water, water conflict*

On March 22, 2012, World Water Day, an unclassified version of a U.S. National Intelligence Council report on Global Water Security was released which stated that, without more effective water resources management, between now and 2040, worldwide fresh water availability will not keep up with demand (National Intelligence Council 2012). U.S. Secretary of State Hillary Rodham Clinton called the report "sobering" (Environmental News Service 2012). The report stated that "While wars over water are unlikely within the next 10 years, water challenges – shortages, poor water quality, floods – will likely increase the risk of instability and state failure, exacerbate regional tensions, and distract countries from working with the United States on important policy objectives." The report goes on, "Water problems will hinder the ability of key countries to produce food and generate energy, posing a risk to global food markets and hobbling economic growth," and concludes, "As a result of demographic and economic development pressures, North Africa, the Middle East, and South Asia will face major challenges coping with water problems."

Concern over the effects of world water shortages on global political stability are not new. In 1998, the member organizations of UN-Water (known then as the United Nations Administrative Committee on Coordination, Subcommittee on Water Resources) stated that there was a need for regular, global assessments on the status of freshwater resources. As a result, the Committee decided to create a United Nations World Water Development Report every three years, beginning in 2003, with a goal of reporting on the status of global freshwater resources and any advancement in reaching the Millennium Development Goals for water (Medina et al. 2007). In March 2009, the third UN World Water Development Report warned that water scarcity, including that produced by climate change, has the potential to produce major conflicts over water (United Nations World Water Assessment Programme 2009), and quoted UN Secretary-General Ban Ki-moon as recognizing that, as surface water supplies diminish, more competition is placed on ground water resources.

Scope of the Challenge

Water problems affect about half of humanity and a large number of the world's ecosystems. These stresses affect the stability of communities and have the potential to enflame simmering antagonisms

and disputes. Recent findings of the United Nations - Global Annual Assessment of Sanitation and Drinking Water, state that nearly 900 million people have no access to improved sources of clean drinking water and note that over 2.6 billion people (approximately 40 percent of the world) presently do not have access to improved sanitation (World Health Organization 2010). Part of the problem in the Developing World is rapid urban development which has resulted in many informal settlements. These lack domestic waste disposal, sanitation and sewerage/effluent systems, and force people to inhabit, provide sanitation, and obtain water from very limited areas. In some of these areas, surface water bodies are highly impacted, and shallow wells (widely used as the source of water in the absence of nearby surface sources), are often in close proximity to pit latrines. According to some researchers, "Over 80 percent of sewage in developing countries is discharged untreated in receiving water bodies" (United Nations World Water Assessment Programme 2009), affecting not only drinking water, but ecosystems that cannot subsist in eutrophic conditions (Palaniappan et al. 2010). The poor, and particularly children, are hurt by unhygienic, insufficient water. Dr. Maria Neria, World Health Organization Director of Public Health and the Environment, is quoted by the Huffington Post as asserting, "Unsafe water, inadequate sanitation and the lack of hygiene claim the lives of an estimated 2.2 million children under the age of five every year," and "the impact of diarrheal diseases [alone] in children under 15 is greater than the combined impact of HIV and AIDS, malaria, and tuberculosis" (Sauer 2010). Child deaths of 2.2 million annually are equivalent to over 6,000 deaths per day, or about one death every 14.5 seconds. In communities where there is competition for an inadequate supply of clean water, public and private discord can be exacerbated.

There are other costs of lack of clean, reliable water. Food security is intimately linked with water, as worldwide agriculture accounts for 70 percent of all water consumption compared to 20 percent for industry and 10 percent for domestic use (Food and Agricultural Organization 2012), and many forms of energy production require reliable water resources. Just as importantly, the impact of scarce water resources exacts a day-to-day cost on a personal human level. Millions of children and particularly girls spend several hours a day collecting water and are unable to attend school, and there are estimated additional losses of 443 million school days each year from water related illnesses (United Nations 2006). Economic losses associated with water related disease are linked with health expenditures, absenteeism, and productivity decline, which are greatest in some of the poorest countries. Sub-Saharan Africa is estimated to have lost about 5 percent of gross domestic product in 2003, or about $28.4 billion annually to water-related disease, which is more than the total debt relief and aid to the region that year (United Nations 2006). Furthermore, serious problems that arise from inadequate water can last for generations. For example, an estimated 100,000 to 250,000 died in the Sub-Sahelian African drought of 1968-1975, and millions of herd animals perished. As a result, there was major societal upheaval, large shifts in population (5.5 million people displaced), many thousands of children were brain damaged from inadequate nutrition, and the economy of the region (8 countries) was devastated for decades (Abbott 2004). These types of externally imposed stresses can lead to social unrest, political instability, and, in some cases, may presage armed conflict.

The role of water creating unrest and in military conflict has shifted in human history. In times of major global conflicts, clean water supplies have served as direct military tools or military targets. In times lacking all-out global war, particularly in modern times, local or regional water battles for economic and social development dominate, along with terrorist activities that center on attacking or controlling local water supplies to promote ideological religious or ethnic factions (Pacific Institute 2012).

Water as an Instrument of Conflict

Water has been a historical tool of military conflict, and while future large-scale wars over water are not anticipated (National Intelligence Council 2012), water scarcity can foment regional tension and conflict, encourage border disputes, and can be the focus of terrorism, local tribal and ethnic

warfare, and political contention in the context of competing economic development (Pacific Institute 2012). In the past, depriving advancing armies and communities under besiegement of water has been a key military tactic for millennia, and water has been used directly as a weapon.

There is a long history and many examples of armies denying clean water to military opponents (Pacific Institute 2012). As early as 2450 to 2400 BC, surface water was diverted by Urlama, King of Lagash and his son, to deprive the neighboring land of Umma and its city of Girsu of water (Hatami and Gleick 1994). This border region, also known as Gu'edena (edge of paradise) which was the scene of conflict for centuries, is located in what is now southern Iraq. Several thousand years later, World War II exemplified the manipulation of surface water for military objectives. Dams and water supplies were one primary target of aerial bombing, with the British Royal Airforce bombing dams on the Eder, Mohne, and Sorpe Rivers in Germany on the 16th and 17th of May 1943 (London Gazette 1943) as part of "Operation Chastise." Human-created floods were also used by both sides to slow enemy advances. In one example, at the suggestion of the Chinese politician Chen Guofu and on the orders of Chiang Kai-shek, the dikes on the Yellow River near Zhengzhou, China were opened in 1938 during the Second Sino-Japanese War, flooding thousands of hectares in order to slow the advance of the Imperial Japanese Army (Dutch 2009). Likewise, the Dutch flooded the Gelderese Vallei in 1940 to slow the Nazi advance through the Netherlands, and the Germans flooded the Liri, Garigiliano, Rapido, Ay and the Ill Rivers, and the Pontine Marshes to slow Allied advances in 1944 (Pacific Institute 2012).

In addition to surface water being manipulated to achieve political ambitions, ground water also is prominent in military history. As recounted in the King James Bible, in 701 BC springs outside the walls of Jerusalem, including Gihon Spring, were stopped to keep water from Assyrians who were advancing on the city (Scofield 1967). In the siege of the iron-age fort of Uxellodunum, which sat on a craggy hilltop in France's Dordogne Valley, Julius Caesar subverted water supplies by undermining local springs and placing troops near others and a nearby river, eventually leading to the heraldic surrender of the Gauls in 51 BC (McDevitte and Bohn 1869). In 1187 AD, as the Crusaders approached the Horns of Hattin (near Tiberias in present day Israel), Saladin ordered the Muslim forces of the Ayyubid dynasty to sand up wells and destroy villages that could supply water to the advancing army. Saladin's armies captured or killed the large majority of the Crusaders, making Islamic forces the foremost military power in the Holy Land and prompting a Third Crusade.

Poisoning and polluting water sources has also been a military tool. In the sixth century BC, Assyrians poisoned enemy wells with ergot (Claviceps purpurea), a fungus, which grows on rye and related plants and whose kernel (sclerotium) produces the alkaloid ergotamine, effecting the nervous and circulatory systems resulting in nausea, hallucinations, and/or death (Eitzen and Takafuji 1997). Carcasses have often been thrown in water supplies in wartime; for example during the Civil War (Catton 1984), in East Timor by militia killing pro-independence supporters and disposing of bodies in water wells (Al-Rodham 2007), and in 1999 where 100 bodies were found in drinking water wells in central Angola (Al-Rodhan 2007). Other examples of water system poisoning includes the 1915 wartime actions of German troops retreating from the Union of South African troops at Windhoek (Daniel 1995; Totten et al. 2004) and the lacing of wells and reservoirs with typhoid and other pathogens by the Japanese "Unit 731" during World War II (Harris 1994).

Water as a Tool in Ethnic Violence

Water has been used both as an excuse and a vehicle for ethnic violence. Even erroneous claims of well poisoning have sparked past ethnic and religious violence, a precursor to contemporary ethnic water conflict. As Black Death epidemics annihilated approximately half the population in mid-14th century Europe, rumors spread that the disease was caused by Jews deliberately poisoning wells. (The pathogen responsible is actually the Yersinia pestis bacterium, carried by the fleas of black rats likely carried to Europe on merchant ships). Pope Clement VI condemned the subsequent violence and forced "confessions" resulting from torture. Hundreds of Jewish

communities were destroyed by violence, in particular in the Iberian Peninsula and in the Germanic Empire. In Toulon, Provence 40 Jews were burnt alive in April 1348 as were 900 Jews of Strasbourg on February 14, 1349 (Marcus 1938). In modern-day echoes of past and religious and ethnic violence, Serbs disposed of bodies of Kosovar Albanians in local wells and Yugoslav federal forces poisoned wells with carcasses and hazardous materials in the 1990's (Hickman 1999; Pacific Institute 2012), and more recently, more than 150 Muslim bodies were dumped in village wells Nigeria during the miasma of the post-election 2010 riots (BBC 2010).

There are other contemporary examples of the water supplies of ethnic or religious groups being targeted by political leaders. In Botswana in 2002, President Festus Mogae was condemned by international observers for sending forces to the Kalahari Desert to destroy water holes and wells of indigenous Bushman (Khoisan), presumably in an attempt to move them from their familial lands (in favor of mining interests) and absorb them into the modern Botswanian social order. The Bushmen withdrew into the desert and managed to survive in harsh conditions, against most predictions (Workman 2009). Between 1951 and 1990, the Mesopotamian Marshes (Central, Hammar and Hawizeh) in Iraq and to a smaller extent Iran, were partially drained for mosquito control, to open up land for oil exploration, and for agriculture. However in 1991 after the first Gulf War, an insouciant Saddam Hussein ordered that the waters of the Tigris and Euphrates Rivers be diverted away from the marshes. Particular impact was seen in the Central Marshes, which stretched between An Nasiriyah, Al-'Uzair (Ezra's Tomb) and Al-Qurnah. That area completely dried up, with 90 percent of the overall remaining marshland, and associated ecosystems disappearing. This was done in retribution for an unsuccessful Shia uprising and targeted the Ma'dan or "Marsh" people whose numbers dwindled from about 500,000 in the 1950's to an estimated 20,000 by 2003, with an estimated 80,000 to 120,000 moving to refugee camps in Iran. Many international organizations such as the UN Human Rights Commission, the Supreme Council of the Islamic Revolution in Iraq, the Middle East Watch and the International Wildfowl and Wetlands Research Bureau have concluded that the draining of the marshes was a political move with severe social and environmental consequences (Pearce 1993; TED 2012).

The Recent Trend Toward Local and Regional Water Conflict

In the past decade, water disputes have not produced large-scale global war, but regional fights and local wars often have used water as a part of a stratagem to advance political goals. In the Sudan, years of civil unrest saw wells being intentionally bombed around the village of Tina and contaminated in Khasan Basao in 2003 and 2004. In this Darfur region of the Sudan, disputes have traditionally been solved by "tribal" conferences but the influx of small arms have fueled anti-government efforts of ethnic groups such as the Sudan Liberation Movement/Army and the Justice and Equality Movement (Amnesty International 2004).

On the contrary, water has not always been the target of conflict, but sometimes the cause. The perceived misallocation and unavailability of water itself has instigated clashes in what has been labeled "development disputes" (Pacific Institute 2012). In October and November of 2004, 4 people were killed and over 30 injured in the Sriganganagar District of India near the Pakistan border during protests over the allotment of water from the Indira Ghandi Canal (Indo-Asian News Service 2004). Additionally, between 2004 and 2006 a drought affected an estimated 11 million people across East Africa, killing large numbers of livestock and forcing the governments of Kenya and Ethiopia to intercede in scores of skirmishes over water in their countries, even sending military forces and police to pacify battles around wells. In Ethiopia, during that time, there was significant fighting over ground water resources between two clans, with the rise of what local pastoral farmers and herders called "well warlords" and "well warriors" (Pacific Institute 2012). The extensive violence, referred to as the "war of the well," left over 250 dead and many injured, and one villager quoted by the Washington Post said "Thirst forces men to this horror of war" (Wax 2006). In northwestern Kenya, over 90 people had died

by July 2005 in fighting over water between the nomadic and settled communities of the Maasai and Kikuyu (Pacific Institute 2012).

The Threat of Transboundary Surface Water Disputes

In some cases, rivers can be used as either an overt political instrument or as a potential threat. There are many regions in the world where rivers flow through several adjacent nations and the strengths, weaknesses, and absences of existing treaties between political entities can create tensions. In 2009 North Korea released floodwaters from Hwanggang Dam, 26 miles north of the border with South Korea, killing 5 people in the south. South Korea demanded an apology, and has been historically apprehensive over the possibility of a "water offensive" from the North (Choe 2009).

There are other examples of disputes over surface water. The headwaters of the Tigris and Euphrates Rivers that flow into Iraq begin in Turkey and Syria, and the control of those rivers is dependent on release of waters from upstream dams, such as the Atatürk Dam which is the centerpiece of 22 large Turkish dams on those rivers. According to Harte (2011) a recent report submitted to the United Nations Committee on Economic, Social and Cultural Rights alleges that Turkey's dams have failed to conform to "international guidelines designed to prevent human rights violations through development and infrastructure projects." Also, according to Harte (2011) the UN report notes with alarm that the Turkish government has performed no assessment of the environmental and social impacts of these dams, perhaps because they would mostly impinge on already marginalized groups such as the rural poor, nomads, the Alevi, and the Kurds in violation of Article 2.2 of the International Covenant on Economic, Social and Cultural Rights (United Nations High Commissioner for Human Rights 1966).

An emerging region of potential conflict over water is southern Asia, particularly on the borders of India, Pakistan, and the People's Republic of China (Economist 2011). Naissant tensions are growing over rivers that run cross-border in the Jammu and Kashmir region from India to Pakistan (including the Indus River), and from China to India in the Arunachal Pradesh State (including the Tsango/Brahmaputra River system) with, at times, the generation of fierce rhetoric. An April 2011 editorial in the Pakistani newspaper Nawa-i-Waqt stated "Pakistan should convey to India that a war is possible on the issue of water and this time the war will be a nuclear one" (Economist 2011). In spite of a far-sighted, 1960 Indus Water Treaty, Pakistanis harbor fears over existing and planned Indian dams, which have the potential to limit water in critical growing seasons. These fears can be embodied in the comments of Bashir Ahmad, a geologist in Srinagar, Kashmir. He posits, "They will switch off the Indus to make Pakistan solely dependent on India. It's going to be a water bomb" (Economist 2011). Likewise, Indian politicians claim that China has plans to divert the Tsango/Brahmaputra which flows south off the Tibetian Plateau. China has not always been felicitous towards India, having previously blocked an effort by the Asian Development Bank to arrange plans for a dam in the disputed Arunachal Pradesh region. Bangladeshi security expert Major-General Muniruzzaman opined that India's "coercive diplomacy," and rejection of multilateral cooperation on subjects such as river sharing portends that "if there ever were a localized conflict in South Asia it will be over water" (Economist 2011).

The Potential Effect of Climate Change on International Water Security

Global climate change could alter the international water security landscape in many ways. Present climate models predict increased drought in some areas of the world, and increased flooding in others, coupled with an accelerating variability in the timing, amount, and areal distribution of precipitation. These stressors could increase local violence and aggressive political actions regarding water and food supply which depends on irrigation.

Melting of glacial ice, a vast reserve of fresh water, and associated changes in ocean temperature, salinity and circulation have been cited as factors in regional drought, but global warming could destabilize international security in unexpected

ways. For example, according to scientists at NASA and the University of Colorado's National Snow and Ice Data Center, although the summer Arctic ice pack typically reaches a minimum in mid-September, in September of 2012 the existing ice extent reached the lowest value in 33 years since satellite imagery of the pack began, having melted at rates up to an unprecedented 38,600 to 57,900 estimated square miles per day in the summer of 2012, which is over double the climatological rate (World Meteorological Organization 2012). Worldwide, August of 2012 was the 4th hottest month on record. With the observed shrinking of the Arctic icecap, the northmost oceans are opening up to increased commerce and development, with oil, fishing, mining and shipping interests expanding into the region (Kramer 2011), sometimes in the absence of complete governing regulations for such expansion. These interests may become the beneficiaries of more accessible open water, sea-lanes, and seafloor, but also competitors, increasing legal and political complexities. The combination of these transformations in the quality and areal distribution of water could portend instabilities and be a precursor to open hostilities.

The Way Forward

Amid escalating tensions over water and associated armed conflict, there is some good news. Future regions of conflict can be anticipated, cooperation can be promoted, and policy and infrastructure solutions exist. Small scale solutions for clean water require local understanding, community buy-in, and commitment, while the larger scale requires political action based on accurate planning and cooperation.

Future regions of water conflict will likely be in regions of stress and scarcity of this resource. A ratio, between available clean water and population, is often used to assess areas of concern (United Nations 2012). Water stress is defined when annual water supplies fall below 1,700 m^3 per person, water scarcity is defined as times when annual water supplies decline below 1,000 m^3 per person, and "absolute scarcity" is defined as less than 500 m^3 per person. Global water scarcity and water stress have been mapped by groups such as the United Nations (2012). Scarcity can be physical, where the populace does not have plentiful water nearby, and economic, where people do not have the necessary infrastructure to extract and transport water from rivers, lakes, springs and aquifers. These regions of stress and need can be anticipated, and focused investment can be made to improve these locales.

Water treaties and cooperative water agreements can also improve social accord. When engaged with equity and planning, these agreements can serve as the groundwork for lasting political stability (Keller, this issue). Water law and accords are not always initially equitable, or can become outdated, therefore revision and amendment of agreements is sometimes necessary and can be very successful. South Africa's water laws under Apartheid centered on a multitude of specific, individual water rights for property owners. In the last two decades, the Republic of South Africa's water and environmental laws have been rewritten with a more inclusive and comprehensive scope, establishing availability of water as a basic human right and including consideration of ecological requirements for water.

High-quality policies toward water management can also improve societal conditions and reduce stress on communities. Top-down government protocols could include:

1. Clear, quantitative definition of acceptable risk for populations and ecosystems;
2. Creation of hydrological and water quality data storage systems that are transferrable and compatible;
3. Numerical, concentration-based standards for water quality (beyond the limited world health organization standards);
4. Initiation of risk-based remediation of water contamination based on improved site characterization;
5. Rigorous standards for wells and water conveyances;
6. Common vision on Monitored Natural Attenuation of pollutants and Technical Impracticability of remediation;
7. Strengthening of natural protected areas;
8. Upgraded emergency response to potential water crises; and
9. Pro-active anticipation of water problems.

Bottom-up, local policies can include:

1. Water and water quality education (embracing community, primary school and university levels);
2. Holistic sanitary community improvement;
3. Increasing regional analytical and technical capabilities;
4. Water quality protection at wellheads and distribution points; and
5. Improvement of water regulation enforcement (Kreamer and Usher 2010).

Governments and communities can create enhanced policies and continue to renew their web of resources to prepare for, and address, water challenges.

Infrastructure improvements, when done correctly in a sustainable manner, can dramatically and positively impact the water security of a society. These improvements can range from small scale community wells or water/ sanitation improvements, to major structural water diversions, treatment, and large-scale water projects. On the smaller scale, hydrophilanthropic efforts to establish or enhance clean water supply can make a significant local contribution that lowers water tensions in the population in the face of personal privation (Breslin 2010; Kreamer 2010). Large scale projects can also be effective. For example, in the September 2012 Annual Report to Congress on the Paul Simon Water for the Poor Act (P.L. 109-121; Sec.6 (g)(2)), the U.S. Office of Environmental Policy, Bureau of Oceans and International Environmental and Scientific Affairs reported that in FY 2011 "U.S. government investment for all water sector activities worldwide totaled $734 million," resulting in "3.8 million people gaining improved access to drinking water" and 1.9 million having "improved access to sanitation." An unrelated, suggested infrastructure initiative is the conversion of large sea-going vessels to mobile power and desalination plants (Kreamer 2009). These "peaceships" could serve a worldwide humanitarian mission, reacting with celerity to infrastructure failure, natural disasters, and human caused terrorism targeted at water resources. A mobile desalination fleet would be able to utilize "green" energy sources of wind, solar, wave, and tidal power, be able to move to places in need or avoid hurricanes, and be better located at sea (rather than environmentally sensitive coastal areas) to dilute and dispose of briney waste water, which is a by-product of desalination (Kreamer 2009).

Challenging Future

Water may be the upcoming battleground for political and economic aspirations throughout the world, the defining criterion for fiscal and food security, and the emotional flashpoint for future survival and aspirations of betterment. Communities and nations facing challenges of scarcity, the threats of climate variability, and the pressures of providing resources for burgeoning populations, may reach a limit in the global cistern, before other limits are reached. As communities are driven into deep penury, clean water may be the final "line in the sand" of a transboundary river bank, a sandstone aquifer, or a relic lakebed - a line that, once crossed, produces conflict and war. It is undeniable that clean water scarcity poses a threat to international security. An often used quote from Indian author B.G. Verghese states, "Water is the latest battle cry for jihadis. They shout that water must flow or blood must flow."

Acknowledgement

A great deal of the information on historical water conflict utilized in this article has been assembled by the Pacific Institute. The Institute and its fine work is gratefully acknowledged.

Author Bio and Contact Information

David K. Kreamer is a Professor of Geoscience, and also Graduate Faculty in the Departments of Civil and Environmental Engineering, and Environmental Studies, and is past Director of the interdisciplinary Water Resources Management Graduate Program at the University of Nevada, Las Vegas. He also serves as faculty in the Hydrologic Sciences Program at the University of Nevada, Reno. His Ph.D. is in Hydrology from the University of Arizona, and he was an Assistant Professor in Civil Engineering at Arizona State University. David's research includes environmental contamination, spring sustainability, and clean water supply in developing nations. He has given over 150 invited lectures, seminars and workshops in recent years for U.S. Environmental Protection Agency, U.S. Bureau of Land Management, the National Ground Water Association, and the Superfund University Training

Institute, presented short courses for over half the States or Commonwealths in the U.S., and lectured for other groups such as City of Phoenix, University of California Extension, and Hanford Nuclear Site. He has given presentations at over 40 Universities, and has spoken in Europe, Asia, the Caribbean, Pacific island nations, South America, Africa, and the Middle East. He serves as Director of the National Ground Water Association's Division of Scientists and Engineers, is Vice President for North America for the International Association of Hydrogeologists, and serves on the Board of Directors of the Universities Council on Water Resources. He can be contacted at dave.kreamer@unlv.edu.

References

Abbott, P.L. 2004. *Natural Disasters* 4th ed. Chapter 9. 2004. McGraw-Hill, 1221 Ave. of the Americas, New York, NY.

Al-Rodhan, N.R.F. (Ed.) 2007. *Policy Briefs on the Transnational Aspects of Security and Stability*. Lit Verlag GmbH and Co. KG Wien, Zweigniederlassung Zurich, Global Book Marketing, London, 219.

Amnesty International. 2004. Sudan: Darfur: Too many people killed for no reason. February 3, 2004. Available at: http://www.amnesty.org/en/library/info/AFR54/008/2004.

BBC. 2010. Nigeria religious riot bodies found in village wells. Available at: http://news.bbc.co.uk/2/hi/8476534.stm.

Breslin, E.D. 2010. Rethinking Hydrophilanthropy. *Journal of Contemporary Water Research & Education* 145: 65–73.

Catton, W.B. 1984. Catton's Civil War: Mr. Lincoln's Army; Glory Road; A Stillness at Appomattox. New York: Fairfax Press, 1984.

Choe, S.H. 2009. South Korea demands apology from North over dam incident. New York Times, September 8, 2009. Available at: http://www.nytimes.com/2009/09/09/world/asia/09korea.html.

Daniel, C. (Ed.) 1995. Chronicle of the 20th Century. New York: Dorling Kindersley.

Dutch, S.I. 2009. The Largest Act of Environmental Warfare in History. *Environmental & Engineering Geoscience* 15(4): 287–297.

Economist. 2011. Unquenchable Thirst: A growing rivalry between India, Pakistan, and China over the region's great rivers may be threatening South Asia's peace. Briefing, South Asia's Water. *The Economist* November 19-25, 2011.

Eitzen, E.M. and E.T. Takafuji. 1997. Historical overview of biological warfare. In *Military Medicine, Medical Aspects of Chemical and Biological Warfare*. The Office of The Surgeon General, Department of the Army, USA, 415–424.

Environment News Service. 2012. U.S. Forms Water Partnership to Boost National, Global Security, Environment News Service, Washington, DC.

FAO 2012. Statistics. Food and Agricultural Organization of the United Nations. Available at: http://www.fao.org/corp/statistics/en/.

Harris, S.H. 1994. *Factories of Death: Japanese Biological Warfare 1932–1945 and the American Cover-up*. New York: Routledge.

Hart, J. 2011. Turkey's Dams Are Violating Human Rights, UN Report Says. *Green Prophet*. Available at: http://www.greenprophet.com/2011/06/turkeys-dams-are-violating-human-rights-un-report-says/.

Hatami, H. and P. Gleick. 1994. Chronology of conflict over water in the legends, myths, and history of the ancient Middle East. *Water, war, and peace in the Middle East. Environment* 36(3): 6.

Hickman, D.C. 1999. A Chemical and Biological Warfare Threat: USAF Water Systems at Risk. *Couterproliferation Paper No. 3*. USAF Counterproliferation Center, Air War College, Maxwell Air Force Base, Alabama.

Indo-Asian News Service. 2004. Curfew imposed in three Rajasthan towns. *Hindustan Times*, December 4, 2004.

Kramer, A.E. 2011. Warming Revives Dream of Sea Route in Russian Artic. *New York Times*.

Kreamer, D.K. 2009. From Dry Dock to Wet Tap – Converting old ships into mobile desalination plants. *Earth* (formerly Geotimes) 44-51.

Kreamer, D.K. 2010. Hydrophilanthropy and Education. *Journal of Contemporary Water Research & Education* 145: 1-4.

Kreamer, D.K. and B. Usher. 2010. Sub Saharan African Ground Water Protection - Building on International Experience. *Ground Water* 48(2): 257-268.

London Gazette: (Supplement) no. 36030. 1943. 2361-2362.

Marcus, J. 1938. The Jew in the Medieval World: A Sourcebook: 315-1791. New York: JPS, 1938, 43-48.

McDevitte, W. A. and W.S. Bohn. 1869. *The Gallic Wars by Julius Caesar*, Book 8, chapter 40, translated from the Latin by W.A. McDevitte and W.S. Bohn.

Medina, Jr., M.A., A.W. Jayawardena, L.H.C. Ilonze, P. Zeil, and J. Xia. 2007. External Evaluation of UNESCO, Evaluation of UNESCO's contribution to the World Water Assessment Programme. *United Nations Report October 2007*. Available at: unesdoc.unesco.org/images/0015/001540/154035e.pdf.

National Intelligence Council. 2012. Global Water Security, U.S. National Intelligence Council, Intelligence Community Assessment.

Pacific Institute. 2012. Water Conflict Chronology. Available at: http://www.worldwater.org/conflict.html.

Palaniappan, M., P.H. Gleick, L. Allen, M.J. Cohen, J. Christian-Smith, and C. Smith. 2010. *Clearing the Waters: A Focus on Water Quality Solutions*. N. Ross. (Ed.) United Nations Environment Programme. UNON Publishing Services Section: Nairobi. ISO 14001:2004-certified.

Pearce, F. 1993. Draining Life From Iraq's Marshes: Saddam Hussein is using an old idea to force the Marsh Arabs from their home. *New Scientist* 138/1869.

Sauer, J. 2010. Why U.S. Philanthropists Should Care about Water and Sanitation. *The Huffington Post*, April 22, 2010.

Scofield, C.I. (Ed.) 1967. *New Scofield Reference Bible*, Authorized King James Version. 2Chronicles 32:1-4. Oxford, United Kingdom: Oxford University Press.

TED. 2012. Marsh Arabs and Water Loss, 189. American University. Available at: http://www1.american.edu/ted/marsh.htm.

Totten, S., W.S. Parsons, and I.W. Charny (Eds.) 2004. *Century of genocide: critical essays and eyewitness accounts*. 51, Routledge.

United Nations. 2006. *United Nations Human Development Report*. 6-35.

United Nations. 2012. International Decade for Action Water for Life 2005-2015. Available at: http://www.un.org/waterforlifedecade/scarcity.shtml.

United Nations High Commissioner for Human Rights. 1976. International Covenant on Economic, Social and Cultural Rights, Adopted and opened for signature, ratification and accession by General Assembly resolution 2200A (XXI) of 16 December 1966, Available at: http://www2.ohchr.org/english/law/cescr.htm.

United Nations World Water Assessment Programme. 2009. *The 3rd United Nations World Water Development Report: Water in a Changing World (WWDR-3) and Facing the Challenges*. New York. Available at: http://www.unesco.org/new/en/natural-sciences/environment/water/wwap/wwdr/wwdr3-2009/downloads-wwdr3/.

Wax, E. 2006. Dying for water in Somalia's drought: Amid anarchy, warlords hold precious resource. *Washington Post*, April 14, 2006, p. A1. Available at: http://www.washingtonpost.com/wp-dyn/content/article/2006/04/13/AR2006041302116.html.

Workman, J.G. 2009. *Heart of Dryness: How the Last Bushmen Can Help Us Endure the Coming Age of Permanent Drought*. New York: Walker and Company.

World Health Organization. 2010. UN-water global annual assessment of sanitation and drinking-water 2010: targeting resources for better results. United Nations. Presented at the first annual high-level meeting of Sanitation and Water for All, April 23, 2010 in Washington, D.C. Printed in Switzerland.

World Meteorological Organization 2012. Media Center, News, last updated 21 September 2012. Available at: http://www.wmo.int/pages/mediacentre/news/index_en.html.

Past Issues of the *Journal of Contemporary Water Research and Education* and *Water Resources Update*

Issue 149, December 2012. *Water and International Security.* David K. Kreamer, University of Nevada, Las Vegas. (Ed.)

Issue 148, August 2012. *Exempt Wells.* John Tracy, University of Idaho, Boise. (Ed.)

Issue 147, March 2012. *Scale Interatcions.* Shama Perveen, Columbia University, New York, New York. (Ed.)

Issue 146, December 2010. *Stormwater Management.* William F. Hunt, North Carolina State University, Raleigh. (Ed.)

Issue 145, August 2010. *Hydrophilanthropy and Education*. David K. Kreamer, University of Nevada, Las Vegas. (Ed.)

Issue 144, March 2010. *Reallocating Water under Prior Appropriation*. Olen Paul Matthews and Michael Pease. (Eds.)

Issue 143, December 2009. *The Energy-Water Nexus*. Gerald Sehlke. (Ed.)

Issue 142, August 2009. *Geography: A Vibrant Agenda for the Next 20 Years of Water Resources Research*. William James Smith, Jr. and Graham A. Tobin. (Eds.)

Issue 141, March 2009. *Three Years after Katrina: Restoring and Protecting New Orleans and Coastal Louisiana*. Gerald E. Galloway, University of Maryland. (Ed.)

Issue 140, September 2008. *Complexity and Uncertainty in Water Resources Management.* John Tracy, University of Idaho. (Ed.)

Issue 139, June 2008. *A Creative Critique of U.S. Water Education*. Charles "Chuck" Howe, University of Colorado-Boulder. (Ed.)

Issue 138, April 2008. *The Role of Science in Watershed Management.* Burrell Montz, Binghamton University. (Ed.)

Issue 137, September 2007. *Increasing Freshwater Supplies.* Karl Wood, Water Resources Research Institute, New Mexico State University. (Ed.)

Issue 136, June 2007. *Water and Watersheds.* Penny Firth, National Science Foundation; Michelle Kelleher, National Science Foundation; Barbara Levinson, U.S. Environmental Protection Agency. (Eds.)

Issue 135, December 2006. *Integrated Water Resource Management: New Governance, Tools, and Challenges—Selected International Perspectives.* Bruce Hooper, DHI Water and Environment. (Ed.)

Issue 134, July 2006. *River and Lake Restoration: Changing Landscapes*. Lynne Y. Lewis, Bates College. (Ed.)

Issue 133, May 2006. *River Adjudications.* Andrea Gerlak & John Thorson, Columbia University. (Eds.)

Issue 132, December 2005. *Desalination.* Tamim Younos, Virginia Polytecnic Institute and State University. (Ed.)

Issue 131, May 2005. *Allocating Water: Economics and the Environment.* Gary Johnson, University of Idaho; Sarah Bigger, Boise State University; Ari Michelsen, Texas A&M University. (Eds.)

Issue 130, March 2005. *National Flood Policy a Decade after the 1993 Mississippi Flood.* Stuart A. Davis and Mark C. Dunning, Institute for Water Resources. (Eds.)

Issue 129, October 2004. *Water and Homeland Security.* Regan Murray, USEPA. (Ed.)

For complete listing visit: www.ucowr.org

UCOWR

UNIVERSITIES COUNCIL ON WATER RESOURCES

Journal of Contemporary Water Research and Education
Subscription Form

(Please Type or Print Clearly) Date: _____

Last Name _____ First Name _____

Full Mailing Address: _____

_____

City: _____ State: _____ Zip: _____

Phone: _____ E-mail: _____

YEARLY SUBSCRIPTION minimum 3 issues starting month:_____ year: _____

☐ Annual domestic subscription rate $ 35.00
☐ Annual international subscription rate $ 80.00

PAST ISSUES can be purchased for $15 per copy (domestic), $30 per copy (international), subject to availability. Call UCOWR Headquarters for discount pricing on orders of 10 or more of the same issue.

____ copies of Issue # _____ $ _____
____ copies of Issue # _____ $ _____
____ copies of Issue # _____ $ _____ total for past issues $ _____

To view a list of past issues, please visit the UCOWR website www.ucowr.siu.edu and click on DATABASES AND PUBLICATIONS, then scroll down to PUBLICATIONS, and click on the first entry.

PAYMENT MUST ACCOMPANY APPLICATION **UCOWR FEIN 47-0617822**

FOR SECURITY PURPOSES, DO NOT EMAIL CREDIT CARD INFOMRATION.

Amount $_____ for the period July 1, 20____ to June 30, 20 _____

☐Visa ☐MasterCard ☐Discover ☐American Express ☐ P/O or Check # _____

Card Number _ _ _ _/_ _ _ _/_ _ _ _/_ _ _ _ Expiration Date __ __/__ __ Security Code _ _ _

Cardholder's Name: _____Signature: _____

Cardholder's email address: _____ Cardholder's Zipcode _____

Mail or Fax Membership Application and payment made out to UCOWR to:
UCOWR, 4543 Faner Hall – Mail Code 4526, Southern Illinois University Carbondale, 1000 Faner Drive, Carbondale, IL 62901
Phone: 618.536.7571 FAX: 618.453.2671 E-Mail: UCOWR@siu.edu

http://www.ucowr.org (rev6/12)

FRIENDS OF UCOWR

In appreciation of their vision and leadership in the advancement of Water Resources Research and Education, the following individuals have been named "Friends of UCOWR."

1984
Ernest F. Brater
Norman H. Brooks
Ven Te Chow
Nephi A. Christensen
Robert E. Dils
Warren A. Hall
John W. Harshbarger
A.T. Ingersoll
John F. Kennedy
Carl E. Kindsvater
Emmett M. Laursen
Arno T. Lenz
Ray K. Linsley
Walter L. Moore
Dean F. Peterson
Sol D. Resnick
Verne H. Scott
David K. Todd
Calvin C. Warnick
M. Gordon Wolman

1985
Bernard B. Berger
William Butcher
Ernest Engelbert
David H. Howells
William Whipple

1986
Leonard Dworsky
Peter Eagleson
Benjamin Ewing
George Maxey
George Smith
E. Roy Tinney

1987
Wade H. Andrews
John D. Hewlett
Gerard A. Rohlich
Dan M. Wells

1988
Merwin P. Dougal
John C. Frey
Daniel J. Wiersma

1989
Daniel D. Evans

1990
Henry P. Caulfield
Maynard M. Hufschmidt
Absalom W. Snell

1991
Eugene D. Eaton
William B. Lord
Willliam R. Walker

1992
J. Ernest Flack
Gerald E. Galloway, Jr.
John C. Guyon
Ernest T. Smerdon
Warren Viessman, Jr.

1993
Marvin T. Bond
Glenn E. Stout

1994
Robert D. Varrin
Henry J. Vaux, Jr.

1995
Jon F. Bartholic
M. Wayne Hall
William L. Powers

1996
L. Douglas James
David H. Moreau
Howard S. Peavy

1997
Faye Anderson
Patrick L. Brezonik
Theodore M. Schad
Yacov Y. Haimes

1998
Peter E. Black
Helen M. Ingram

1999
John S. Jackson
Kyle E. Schilling
Robert C. Ward

2000
William H. Funk

2001
Charles W. Howe

2002
Duane D. Baumann

2003
Lisa Bourget
C. Mark Dunning
Tamim Younos

2004
Ari Michelsen
Margaret Skerly
Walter V. Wendler

2005
Lynne Lewis

2006
Mark Limbaugh
New Mexico Water Resources Research Institute

2007
Paul Bourget
Gary S. Johnson
Michael O'Neill
Gilbert F. White

2008
Penny Firth
Don Rice
Alan Vaux

2009
Gretchen Rupp
M. J. Nehasil
Ronald D. Lacewell
Michele Zinn

2010
David Kreamer
Gerald Sehlke
Edmund Archuleta

2011
Colorado Water Institute
Jonathan Bulkley
Institute for Water Resources USACE

2012
Ivanhoe Foundation
Joseph J. Delfino
Roseanne (Rosie) Gard

WARREN A. HALL MEDAL HONOREES

William Butcher - 1993
Warren "Bud" Viessman, Jr. - 1994
Gilbert White - 1995
Richard S. Engelbrecht - 1996
Yacov Y. Haimes - 1997
Neil S. Grigg - 1998
William W-G. Yeh - 1999
Daniel Peter Loucks -2000
Vernon L. Snoeyink - 2000
Miguel A. Marino - 2002
Charles W. "Chuck" Howe - 2003
Robert A. Young - 2004
Henry J. Vaux, Jr. - 2005
Robert C. Ward - 2006
Patrick L. Brezonik - 2007
Peter Rogers - 2008
Gerald E. Galloway - 2009
Thomas Dunne - 2010
Jery Stedinger - 2011
John B. Braden - 2012