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Introduction

International programs have been a part of New Mexico State University since its founding in 1888 due to its location near the international border with Mexico and common interests of the Land Grant Mission. These programs have spread beyond the U.S.-Mexico border to most of the arid regions of the world. Like many countries, part of the border between the U.S. and Mexico involves a river or what those in the United States call the Rio Grande and those in Mexico call the Rio Bravo.

Examples of other shared rivers include the Danube River, which flows through and forms boundaries with many countries in central Europe. The Nile River does the same in northeastern Africa as does the Mekong River in southeastern Asia. Shared boundaries and water lead to conflicts, which lead to ever-changing policies, regulations, treaties, and agreements.

Conflicts over Rio Grande (Bravo) water go back over 100 years and resulted in a treaty in 1906. Conflicts over the Jordan River in the Mid-East go back centuries if not millennia. Both the Rio Grande and the Jordan River flow through great expanses of arid land. Can lessons be shared and learned between scholars, policy makers, and managers of the two rivers?

A conference was held at New Mexico State University in January 2009 for this purpose. Its title was "Transboundary Water Crises: Learning from Our Neighbors in the Rio Grande (Bravo) and Jordan River Watersheds". The conference was sponsored by the New Mexico Water Resources Research Institute, NMSU's International Relations Institute, NMSU's Institute for Energy and the Environment, and Sandia National Laboratory.

NMSU's International Relations Institute was formed in 2008, and one of its missions is to perform critical sponsored research and projects that increase the knowledge base; enhance business development and trade; lead to peer-reviewed publications and scholarly presentations; yield solutions to pressing international issues; and create the foundation and stimulus for advocating needed change.

The conference had about 300 attendees from a cross-section of southwestern society plus national and international visitors. Speakers were brought from Mexico, Jordan, and Israel. Many of the speakers from the United States had extensive experience in Mexico or Mid-Eastern countries.

The proceedings of this conference are now found in this first issue of the *Journal of Transboundary Water Resources*. We hope you find the information both educational and useful.

Karl Wood, Director
New Mexico Water Resources Research Institute
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NEW MEXICO
WATER RESOURCES RESEARCH INSTITUTE
(NMWRRI) MISSION STATEMENT

The mission of the NMWRRI is to develop and disseminate knowledge that will assist New Mexico, the United States and the world community in solving water resources problems. Specifically, the Institute encourages university faculty to pursue critical areas of water resources research while providing training opportunities for students who will become our future water resources scientists, technicians, and managers. It provides an outlet for transferring research findings and other related information to keep water managers and the general public informed about new technology and research advances. The Institute maintains a unique infrastructure that links it with federal, state, regional, and local entities to provide expertise and specialized assistance.

Preface

In early 2009, New Mexico State University (NMSU) hosted the conference, "Transboundary Water Crises: Learning from Our Neighbors in the Rio Grande and Jordan River Watersheds." The event brought together experts from the world of water planning, water management and water policy who spoke of their activities in the Jordan and Rio Grande basins. Thanks to presentations by Utah State University's Mac McKee and others, we in the southwest United States—facing our own form of water disputes—have a better understanding of the combination of water shortage, regional controversies and political challenges that stymie efforts at management of the Jordan River.

Nine speakers from the NMSU conference agreed to submit articles for this, our first edition, of the *Journal of Transboundary Water Resources*, a new publication of the New Mexico Water Resources Research Institute (WRRI). A tenth paper, written by former Mexican ambassador to the United States Alberto Székely and submitted originally to the Institute in 2003, addresses the intense diplomatic efforts undertaken by Mexico and the United States historically in dealing with transboundary water issues. Ambassador Székely, who remains active on this subject, resubmitted his paper for this publication.

If you are interested in the Jordan River basin, I point you to the article from Utah State University's Dr. McKee, mentioned above, which outlines the complexity in identifying appropriate solutions for water resource sharing and management in this troubled region. He also provides some guidance for researchers interested in pursuing this objective. Tom McDermott, UNICEF's retired regional director for the Middle East and North Africa, offers a passionate insight into the linkages between water, trade and economic prosperity, a combination that may, in the author's opinion, hold one of the region's best potentials for peace.

Neda A. Zawahri of Cleveland State University gives us insight into the formal and informal attempts to share the Jordan River system, along with an analysis of the causes and consequences of fragmented governance of this multilateral basin. Of significance, she provides her assessment of the changes necessary for a basin-wide accord.

Those whose interests take them to the Rio Grande basin will find a fine article from Colorado State University's Stephen P. Mumme who outlines an agenda for strengthening binational water governance among the many shareholders of the Rio Grande basin.

Dr. Mumme's extensive knowledge of U.S.-Mexico relations shines through and gives us a well-grounded perspective on environmental relations between these distant neighbors.

Jean Parcher of the U.S. Geological Survey found time to write an excellent article on her work in mapping the physical and cultural surroundings of this transboundary watershed. Her work highlights environmental challenges that will require a collaborative, binational effort. For those seeking a comprehensive background on the river, both its culture and history, I recommend highly the article from Ron Lacewell and his team at Texas A&M. The authors provide a thorough description of this important transboundary basin, no stone unturned, while highlighting several obstacles that may stymie or slow environmental improvement.

Bobby Creel of our own WRRI and Alfredo Granados-Olivas from La Universidad Autónoma de Ciudad Juárez host dual articles, respectively, from the U.S. and Mexico that cover the likely direction of future water research, including the type of resources that may be needed to address identified research priorities in the Paso del Norte portion of the watershed. Not to be overlooked is our lead article from Edmund G. "Ed" Archuleta, CEO and manager of El Paso Water Utilities Public Service Board, whose record of water resource planning and management merits attention. He shows us how good planning, the use of technological tools, and great communication have improved water use efficiency in El Paso, Texas.

The JTWR addresses a long-standing need for an academic forum to address scholarly research and encourage open discussion on transboundary water issues. JTWR invites research papers from a broad range of disciplines including the sciences, economics, management, policy, and encourages papers that move the water dialogue forward. The Journal's mission is to highlight, through scholarly effort, potential solutions to water issues associated with shared, transboundary water resources. Some researchers have called to ask our definition of "transboundary." For the Journal, we are using the following:

> Transboundary water research is any scholarly activity that highlights new or significant information that might be useful in addressing issues relevant to the use, planning, management, measurement, allocation, sustainability, assessment, or understanding of a water resource where the resource is shared by two or more politically, economically or culturally distinct communities.

Our view takes into account water issues among governments, states, even neighborhoods or tribal entities where there is a distinction between the two groups. It also includes water issues relevant to resources shared by indigenous peoples, or, more generally, water resources that are an issue among conflicting cultures. Our definition of a water issue does not always mean there is a background of dispute or conflict. Issues might also include the need for better understanding of a water resource or, what is sometimes the case, an open discussion about a misunderstanding regarding a water resource. Sometimes, a simple exchange of data is the key to addressing a significant water resource issue. All in all, JTWR is open to articles from many research disciplines as long as the research is intended to move the information and dialogue forward.

All this brings up another question: What do we not want to publish? Well, I can say for fact that we have no interest, at present, in articles on the physical properties of water. Other journals have much to say about that. Likewise, articles on the chemical properties of water, its ability to carry an electrical charge, for example, are outside our scope.

I hope here that I answered some of your questions. If you have others, I welcome your call or email. We don't have all the answers yet on the prospects for continuing the Journal. For the time being, however, I urge you to enjoy this, our first issue. There are a number of fine articles included here. And, if you are interested in the Rio Grande or Jordan River watersheds, I know of no better place to start.

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January 25, 2010

This, our first edition of the Journal of Transboundary Water Resources, is dedicated to the memory of our good friend and colleague Dr. Bobby Creel of New Mexico's Water Resource Research Institute. Dr. Creel passed away in February 2010 at his home in Las Cruces.

Contents

How Cooperative Planning And Technology Have Led To Successful Water Management In The Paso Del Norte Region *

ED ARCHULETA
President & CEO
El Paso Water Utilities

The city of El Paso, Texas, was once dependent almost entirely on groundwater for its growing population. Today, after 20 years of successful water management practices, the utility boasts sizable reductions in per capita consumption and a series of investments that have position the city for future growth. Ed Archuleta presented a summary of what he has accomplished as president and CEO of the El Paso utility during the past 20 years. He provides recommendations on how other water managers might accomplish a similar objective. "Communication, communication, communication," is a key to the utility's regional success.

I want to talk to you about water planning and technology and its connection with successful water management. Because of cooperation, planning, and technology, we have come a long way in water management compared with where we used to be. I have been with El Paso Water Utilities (EPWU) now for about 20 years. When I came here, the situation was different. Clearly there had to be changes in how we handled water in this region.

First, I would like to orient those of you who are not familiar with El Paso and the region. El Paso is about 40 miles south of Las Cruces. El Paso is a large city and, obviously, we are a desert city. We share resources with New Mexico and Mexico in the Hueco Bolson, one of the aquifers on the east side of the Franklin Mountains. We also share the Mesilla Bolson on the west side of the mountains. We have other west Texas aquifers, which I will just touch on. As part of our long-term plan, 30 to 40 years out, we may have to import water into El Paso, primarily to keep up with population growth.

* This paper is a written version of a presentation delivered Jan. 22, 2009, during the conference "Transboundary Water Crises: Learning from Our Neighbors in the Rio Grande (Bravo) and Jordan River Watersheds" held on the main campus of New Mexico State University in Las Cruces.

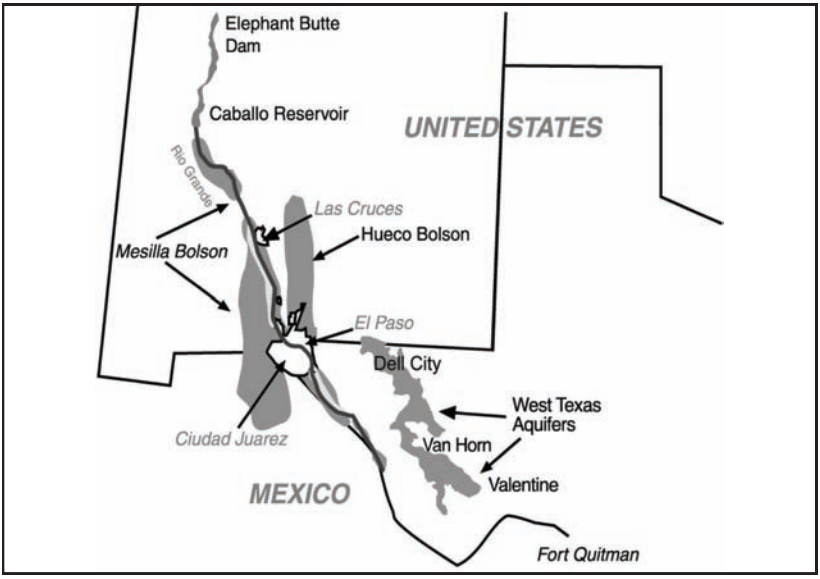

Figure 1. Water Resources in the El Paso Region. El Paso is located in the northern extreme of the Chihuahuan Desert and shares diverse water resources amongst two U.S. states and two countries.

I work for a seven-member board called the Public Service Board. We are part of the City of El Paso, but are independently managed. The mayor sits on the Board and the six other members are appointed by the City Council. I manage the utility, called El Paso Water Utilities (EPWU). We provide water, wastewater, reclaimed water, and storm water services to the greater El Paso area. We serve about 750,000 people. Our city continues to grow. We don't go up and down in population with the economy. We have about a 2.8% steady growth rate in El Paso. We have a large capital improvements program as well. About $80 million per year over the next 10 years has been targeted to deal with growth of the city, rehabilitation of the infrastructure, and the changing regulations on safe drinking water and clean water.

El Paso Water Utilities Public Service Board (EPWU)
• The PSB is charged with setting policy, adopting fiscal budgets, rates and fees to provide water, wastewater, reclaimed water, and stormwater service to its customers
• EPWU provides water service to 97 percent of El Paso County (750,000+ residents)
• EPWU's capital improvement needs over the next 10 years are projected to be over $800 million
• Management of water resources is challenging due to jurisdictional differences, i.e., different laws within the region

Table 1. EPWU: major issues and challenges.

I want to explain how water management is different in this area compared to other areas. We are located in a region that includes El Paso, Texas; Las Cruces, New Mexico; and Ciudad Juárez, Chihuahua. For our municipal and industrial water supply, El Paso uses water from the Hueco Bolson, the Mesilla, and the Rio Grande. El Paso practices conjunctive use of water. Las Cruces takes water only from the Mesilla Bolson, and Juárez takes water only from the Hueco. Some of you know that Juárez is building a project west of the city to pump water from the Mesilla Bolson in an area called Conejo Medanos. The city of Juárez will soon be taking water from both aquifers. If you look at the agricultural supply of water, all three (El Paso, Las Cruces, Juárez) take water from the Rio Grande.

	El Paso, TX	Las Cruces, NM	Ciudad Juárez, Chih.
Municipal & Industrial Supply	Hueco Bolson Mesilla Bolson Rio Grande	Mesilla Bolson	Hueco Bolson
Agricultural Supply	Rio Grande	Rio Grande	Rio Grande
Ground Water Law	Common Law	Prior Appropriation	Mexican Federal
Surface Water Law	International Treaty Rio Grande Compact	Prior Appropriation International Treaty Rio Grande Compact	Compact

Table 2. Water management.

Now let's focus on groundwater and surface water law. In El Paso we follow the doctrine of Common Law. You must own the land above the water in order to have the right to capture. We now have groundwater districts in Texas with different regulations to deal with, but essentially we follow Common Law. In Las Cruces or New Mexico you have the rule of Prior Appropriation. The New Mexico state engineer appropriates the water based on permits that are issued. In Mexico, certainly in Juárez, water is owned and allocated by the Mexican federal government under permits that are not forever (open ended). A Mexican permit might be for five years, 15 years, or some other duration. Surface water in our region is managed according to international treaty between the United States and Mexico. There's also the Rio Grande Compact involving Colorado, New Mexico and Texas. In Las Cruces the rule is Prior Appropriation, international treaty and the multi-state Rio Grande Compact. When you set the stage in terms of how you manage water and you understand that water is a transboundary resource, you realize clearly that you must work together in this region.

Our common resource is ground and surface water. Our communities in El Paso and New Mexico demonstrate population growth. Juárez is growing very rapidly too and continues to do so. Years ago, when I was in school, Juárez was a much smaller city than El Paso. Now it is twice as large. About 1.5 million people or more live in Ciudad Juárez. In this area total, we are looking at more than 2 million people. We all are pressed to continue to expand our infrastructure to meet this growth. We all need to continue to engage in regional planning and management to make sure we respect our laws and nations and end up, hopefully, not in conflict.

Commonalities
• Groundwater/surface water supplies
• Growing population/water demands
• Need to expand and improve infrastructure
• Need for regional planning and development of regional water management policies

Table 3. Resources shared by El Paso, TX, Las Cruces, NM, and Ciudad Juárez, Chih.

We don't have the time to talk about all the conflicts that occurred in the 1980s and early 90s over water. When I came here in the 1989 to manage EPWU, El Paso had been in litigation with New Mexico for about 10 years. One of the things my board asked me to do was identify anything that could be done other than fighting New Mexico for groundwater. El Paso had sued New Mexico to import water from New Mexico federal lands into El Paso. Back then, El Paso was mostly using groundwater. We had one river water plant, a surface water plant. We didn't have anything else particularly going for us.

Conflicts Within The Region
• During the 80s and early 90s El Paso and New Mexico were engaged in litigation on groundwater for over a decade
• El Paso had filed a lawsuit to import water from New Mexico
• Litigation lasted for over 10 years
• Conflicts were resolved on March 6, 1991

Table 4. Litigation.

At that time, it seemed that groundwater was the answer to water management. We actually resolved the New Mexico conflict in two years from the time I came here. We entered into negotiations, and I convinced my board that what we needed to do was regional planning and develop our own plan and try to develop a partnership with the entities involved: the irrigation districts, the city of Las Cruces, and the state of New Mexico. Because we started this plan during the litigation, New Mexico was not able to work with us at that time. But we worked with the local irrigation district and with El Paso County (irrigation district). El Paso developed its first 50-year water plan in 1990-1991. Based on that plan, we felt we had enough information to change the strategy, to be able to reach a negotiation with New Mexico. We wanted to quit spending money on attorneys and spend the money on planning, technology, and policy development.

Out of the litigation, the court settlement created what is called the New Mexico-Texas Water Commission. This organization met frequently at first but has since met less often. For at least 14 or 15 years, we met in El Paso and Las Cruces and involved a lot of folks in water planning. At first, a lot of attorneys were present. We had formal minutes and lots of rhetoric. After about two years the attorneys began to go away. Pretty soon, technical people met. People who had vested interests in the settlement's cooperation and outcome began attending the meeting.

In the 90s we signed our first informal memorandum of understanding (MOU) between EPWU and the Juárez water utility, called the Junta Municipal de Agua y Saneamiento. This was something that I signed with them directly. We also have the International Boundary Water Commission (IBWC), a State Department entity with offices in El Paso-Juárez. It operates on both sides of the border with its Mexican counterpart, CILA, or the Comisión Internacional de Límites y Aguas. IBWC-CILA is an example of bi-national cooperation. Regarding the MOU, we looked into what we could do together (El Paso and Juárez) in conservation and technology transfer. When I came here, no one in my utility really had personal contact with anybody in Juárez regarding water. We were aware of what they did, but there was no communication or coordination about water. But I felt this was a neighbor city, and we shared resources. We ought to talk with each other and share ideas and thoughts, to see how we might work together.

In El Paso, we have developed a major desalination plant working with the U.S. Army at Fort Bliss. The plant has the capacity to treat 27.5 million gallons per day, which is part of our water strategy. We also have been working on our 50-year water plan in Texas. In 1997 the (Texas) State Legislature required that all regions and cities in Texas develop 50-year water plans and update them every five years.

That was 1997. We started working in our region, which is the far west Texas planning region, an area east of El Paso. Our work led to better cooperation and understanding with small rural communities.

Accomplishments Since 1989 For Cooperative Regional Water Planning And Management
• El Paso's 50–year Water Resource Management Plan (updated every 5 years)
• New Mexico/Texas Water Commission
• Informal Memorandum of Understanding (EPWU/JMAS)
• Development of joint 27.5 mgd desalination facility between EPWU and the Army
• Planning within the Far West Texas Water Planning Area (Region E) comprised of 7 counties (16 planning regions) in Far West Texas
• Paso del Norte Task Force
• Activities to increase public awareness of water issues (TecH_2O Center)
• Groundwater Modeling
• Rio Grande Salinity Management Coalition

Table 5. Examples of collaborative efforts.

In the early 90s some small communities in west Texas felt threatened when El Paso purchased land in other counties. As I mentioned, in Texas you have to own the land to have the right of capture. So we knew, in time, that we might have to import water into El Paso. We wanted to make sure we owned the land. Today, we own about 75,000 acres outside El Paso County and about 25,000 acres in El Paso County for water rights purposes. We own both groundwater and surface water rights. We feel that we are well positioned from a water rights perspective for the future. If we have to import water, if and when that time comes, it's going to be expensive. We will have to invest in big pipelines, pump stations, and will feel higher delivery costs. Water is water. You have to do what you have to do. This is part of our long-term plan.

We also developed—and I want to thank the IBWC at that time and the commissioner of CILA (Comisión Internacional de Límites de Aguas) for providing some funding—a group called, the Paso del Norte Task Force, which still exists. The PDNTF is an international group. We knew we had the New Mexico-Texas Water Commission, but we were missing Mexico in that group. The Paso del Norte Task Force is an organization among organizations. It includes Doña Ana County, New Mexico, El Paso, and Juárez. It includes universities, the agricultural districts, cities and individuals and organizations interested in cooperation and communication. We meet periodically; we try to meet quarterly if not bi-monthly. We have done a lot of work together. A lot of it involves understanding. I tell my staff "communicate, communicate, communicate," because you can't communicate enough. If you can communicate you can understand; if you can talk with others, you are probably going to be better off than if you just closed the door.

Later in this presentation, I will tell you about a public awareness facility that we built. It is a beautiful facility right next to the desalination plant (in east El Paso). The other thing that we accomplished was groundwater modeling. In the late 1970s, the Texas Water Development Board (TWDB), which at the time was doing planning for the state, predicted that if El Paso kept growing the way it was and extracting groundwater from the Hueco Bolson, our principal source of supply, the city would run out of water in 30 years. That was the message back then, and it was loud and clear. I heard, "There is no plan for water. We have been on groundwater; we need more groundwater." Where was all the groundwater? It's in New Mexico, right? That was the message. The follow up was: "Go get it." All this was based on that earlier work.

When I came to El Paso, I looked at this history, and I was suspicious. I thought, in time, we're going to need to update that information. Meanwhile, we were introduced to computers and groundwater modeling. If you are a geo-hydrologists or hydrologists, you know the kind of tools we have today differ compared to the tools that exited in the 1970s. One thing I did as soon as I could was adopt USGS (U.S. Geological Service) technology. We worked jointly with Juárez. We already had an agreement. So, I said, "Can we work together on modeling, transboundary modeling on the Hueco Bolson?" At the same time, I approached the state engineer in New Mexico, but he decided not to work with us. I guess he was too mad about the outcome of the lawsuit.

Nevertheless, I decided to cut our modeling off at the New Mexico state line. The Hueco Bolson goes into New Mexico. I told the staff that we would not include the Tularosa Basin (in New Mexico) or any part of it. I also worked with Fort Bliss, which is a major, 1.8 million-acre U.S. Army installation in New Mexico and Texas. Over a period of five years, we modeled the Hueco Bolson. We shared data. That's how we got the IBWC to come to the table. They decided they needed to be a part of this effort. There is no groundwater treaty between the United States and Mexico. So IBWC was included in it.

We finished the modeling work in about five years. After we finished it, we found that because of the change in our strategy and because of some of the inaccuracies in the previous models, we were in much better shape than we thought in regard to water reserves in the Hueco Bolson. When I saw the results, I didn't think anybody would believe it. So, we asked five independent hydrologists to come in and run the model. They came to their own conclusions. Sure enough, the things we had been doing and the things that we predicted showed a much better picture than what we previously had thought.

More recently, the Rio Grande Project, covering the region from Elephant Butte to Fort Quitman, has come together. We need to study the salinity in the Rio Grande, much like the Colorado River has been studied for many years. Annually, there is a huge Congressional appropriation for the Colorado River to look and resolve some of the salinity issues. The Rio Grande has never been a proponent or a recipient of that type of analysis. I asked, "Why not study the Rio Grande and take a look at some groundwater resources and see the impact on salinity?" I want to look at the salinity issue to see how we might improve on our water quality.

So, with the Rio Grande Compact commissioners of Colorado, New Mexico, Texas, and the irrigation districts, cities, and several federal agencies involved—including a team of engineers, Bureau of Reclamation, USGS, and a number of other people—we now have the Rio Grande Salinity Coalition. The first phase of the work was signed and is now ongoing. I think that is something that's going to remain ongoing in regard to salinity management of the river. A lot of people say the Rio Grande is polluted. It's not really polluted, at least not the stretch of it we use. The biggest issue we have locally, as cities and as farmers, is salt. The river is naturally murky; it carries a lot of sediments. It doesn't look like a freshwater Colorado stream. But it is not polluted in a way that prevents it from being used for what is being used for. So that is just kind of a misnomer when people say it's a polluted river. Also, when I say "this stretch," I mean the stretch of the river from El Paso all the way to Colorado.

One thing I'd like to share with you might be useful for students. I have developed four principles—four legs of the stool shown here—for successful water utility management. I'm talking about water resource planning and technology. I am a firm believer in planning, and we have done that. But you have to follow up on planning; you have to implement it, not just put it on a shelf.

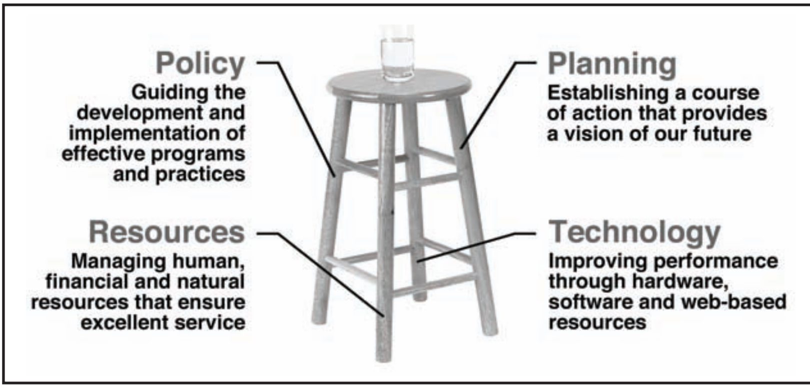

Figure 2. El Paso Water Utilities' criteria for success.

I am a believer in technology. We have a lot of technology in our business, in our practices. In anything we do, we're on top of technology. You also have to have resources: water-use resources, human resources, and financial resources. Above that, you have to have policy. If you don't have the correct policy—with the city, the utility, and with the board—and you are not responding to what the community needs and wishes, then you aren't going to advance very far. In planning, we do an updated strategic plan every year with my board and my staff, because things change.

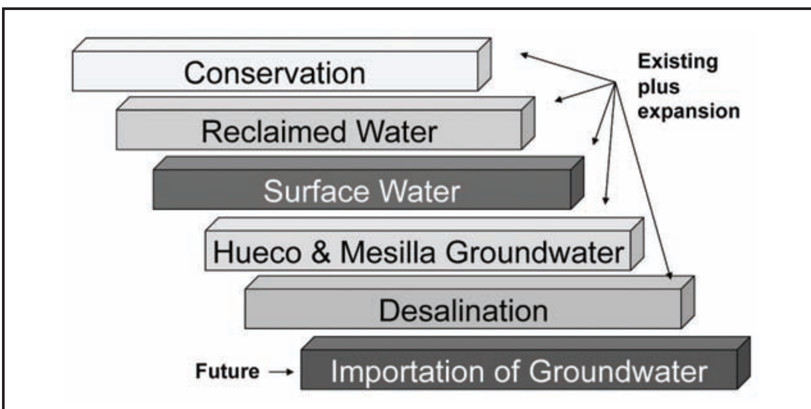

Figure 3. Water resources planning.

Here are the water resources that we've been using since we developed our plan in the 1990s. First, we developed a major, aggressive conservation program. In 1990, 1991, and 1992, I went to Rotary Clubs, Lions Club, and Chambers of Commerce. I was not a popular guy. I was promoting conservation. I was promoting odd-even watering for residential users. I was promoting watering only certain times of the day. I was promoting a new rate structure that was a conservation-oriented rate structure on an inverted block. For those of you who know about rate structures, it is a system that bases water rates, charging much more for water use above and beyond what should be used normally, summer vs. winter. I was not a popular guy. As a matter of fact, I went to a meeting and some guy said, “You are from New Mexico, right?” I said, “Yes.” And he said, “That’s an environmental community. This is Texas. We don’t do that in Texas.” In spite of that, because we embraced conservation, it ended up being one of our biggest success factors.

On reclaimed water: I’ll share with you what we are doing with it in a minute. As for surface water, I already told you we are using the Rio Grande. We purchased water rights and lease water rights. We use water from the Hueco and Mesilla bolsons. The desalination plant has been board operating a year since August. If we have to, we can import water because we have the water rights.

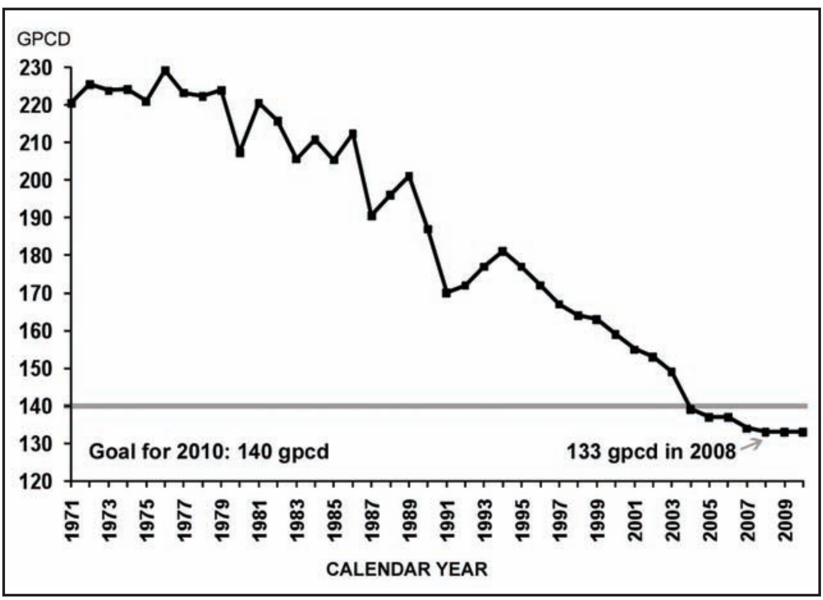

Figure 4. El Paso’s per capita consumption.

Here is our per capita water consumption and how it has dropped over time. You can see that at one time we were using as much as 225 or so, almost 230 gallons per person per day in El Paso.

This is all water we take, pumped water, or diverted from the river, divided by the population. When we developed the plan in 1990, we set a goal of 160 gallons per person per day. By 2000, we met our 10-year goal. Then, I went to the board and I said, "I think we can get to 140 (gallons per person) if we do this, and do that and that." Well, we met that goal. As you can see, we have been below 140 gallons per person for the last three years or so.

This year we finished up at 133 gallons per person per day. For those of you who perform modeling, we have done econometric modeling that shows how we can get to 120 gallons per person, if we have to. At that point it is all about pricing. Pricing will get us there. Our program deals with education, with pricing, and with enforcement. Primarily, what we are trying to do right now is more about education.

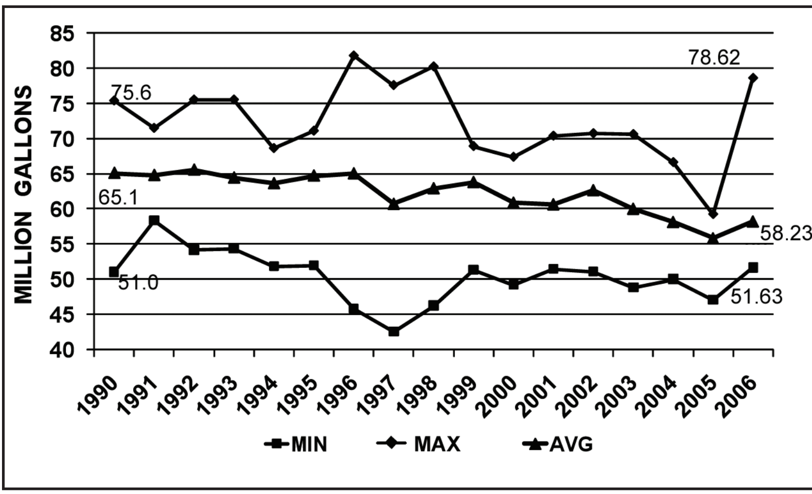

Figure 5. Declining wastewater flows.

This is how our wastewater flows. The news media, for some reason, don't like to pick up information about wastewater. They prefer to write just about water. You can see our wastewater flow also has declined. By the way, from 1990 to now we have probably grown by almost 200,000 people in El Paso. We are pumping from the Hueco Bolson now at the level we were back in the late 1950s. Our wastewater flows have gone down, which shows that indoor conservation is working. The one glitch that you can see is what we saw with the storm and flooding of 2006. We saw a lot of inflow into the system during the storm.

The next slide shows a picture of the water and wastewater plants we have, from south to north. You can see the Franklin Mountains in the middle. We have three water plants and the two surface water plants along the river. They can treat up to 100 million gallons per day. In 1990 we had the one plant treating 40 million gallons per day. So, we added more capacity, and the water rights that go with it. When water is released at Elephant Butte reservoir—and the releases this year for us start February 18—there will be good snow pack and water available. This will be the result of the cooperative efforts between irrigation districts and the Bureau of Reclamation, which now allow for carryover water. We have been trying to get that for years. Now, the Elephant Butte Dam will be managed more, rather than drawing the water up and down. There are now incentives to carry over water and allow that water credited to the storage at the dam. In the past, we operated on a use-it-or-lose-it system.

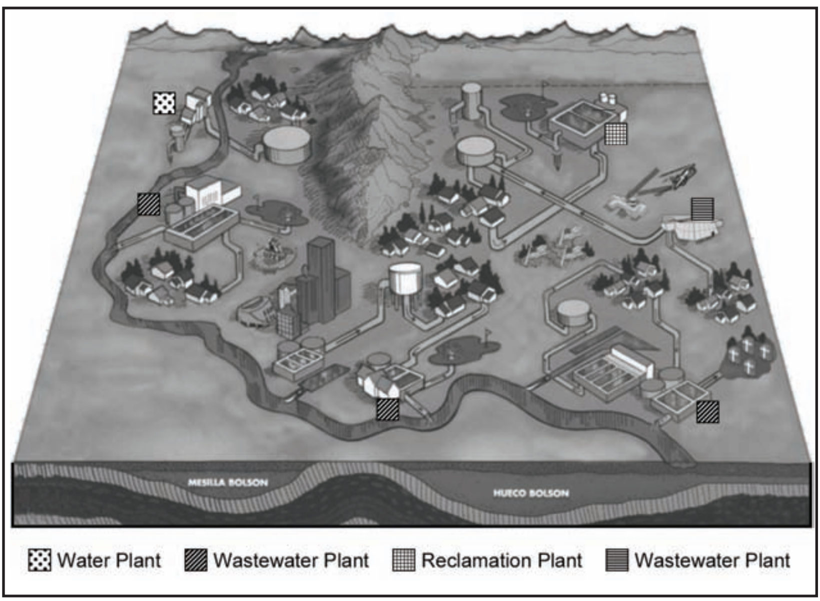

Figure 6. El Paso water & wastewater plants.

There are more opportunities for conservation, to be frank, especially with surface water. I don't want to get into it here, but you have to think about how water is applied on the pecan orchards. This poses opportunities for surface water, supply side conservation, not just demand side. We have the two plants on the river. We have an arsenic plant in the (El Paso County) upper valley. It's a 30-million gallon per day plant. We are one of the fortunate cities that have arsenic in the water, naturally occurring. We had to meet the new rules. So we built a big plant. We have the three wastewater treatment plants, including one reclamation plant that treats wastewater to drinking water standards. We inject reclaimed water into the aquifer. Then, we recover it in wells that may be a mile or so downstream. We practice aquifer storage and recovery. We have been doing that since 1985. We have, of course, the desalination plant, which you can see in the northeast quadrant (of the city).

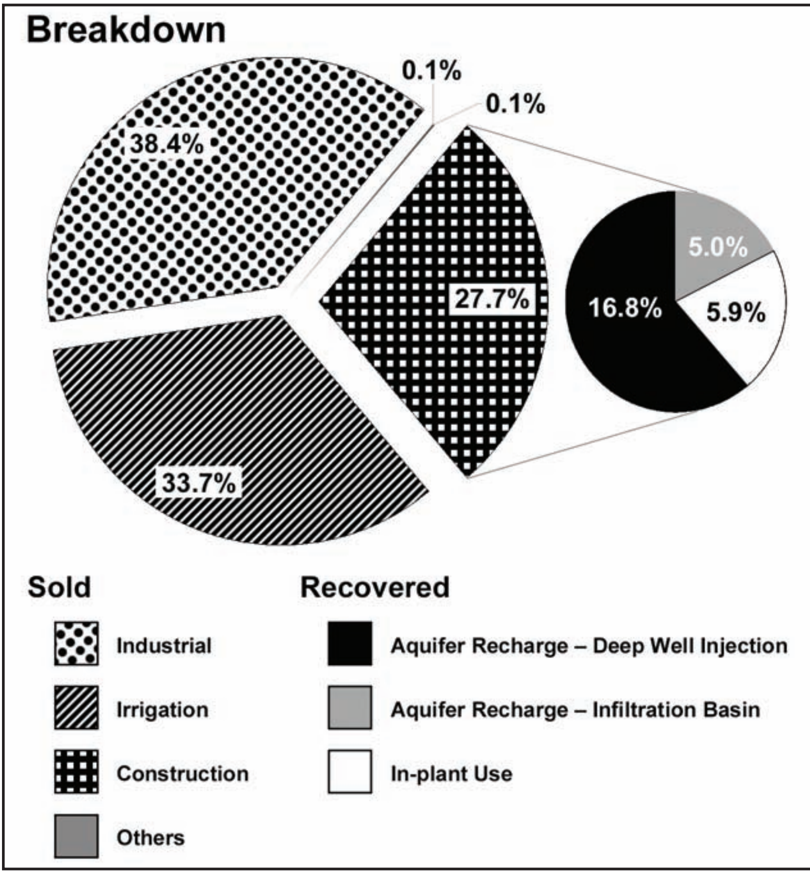

Figure 7. Total reclaimed water production.

Let me talk a little bit about reclaimed water. One thing I am proud of is our planning. We did planning on reclaimed water back in 1990. I try to look at other cities and private utilities to see what they do and the best management practices they use. So I went to Tucson, because I thought Tucson was a good model for reclaimed water use and management. They have been reclaiming water for long time on the golf courses, on the school grounds there. We came up with a plan for reclaimed water. We have a lot of customers representing cemeteries, parks, schools grounds, golf courses, apartment complexes, and cooling towers for industrial use. We reclaim a lot of this water. Reclaimed water, some of you maybe are not familiar with the term, it is just sewage wastewater or sewage water that has been treated to standards high enough to apply it for non-potable use. Back in 1990, we had about 200 million gallons per year in reclaimed water. Today, we are reclaiming about 2 billion gallons per year of treated wastewater. We sell it to costumers at a discounted rate for uses that don't require potable water. Our region, the Paso del Norte, is one area where you will see more and more reclaimed water used. Because we work with Juárez, the city there also has a reclamation program. They are doing very well. It is not large as ours, but they are doing very well with their facilities.

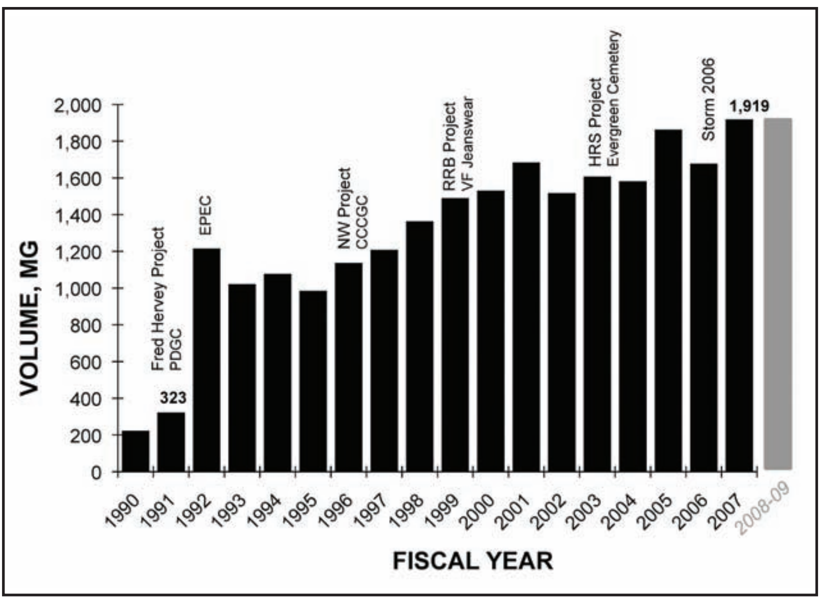

Figure 8. Reclaimed water sold.

I mentioned to you that at one time we were pumping a lot of water from the Hueco Bolson. It was our principal source of water in El Paso. You can see in late 1980s we were pumping about 80,000 acre-feet per year. We have dropped that down to 40,000 acre-feet per year. With the desalination plant going on line and full supply from the river last year, we were at 27,000-29,000 acre-feet or so. So we have backed off the Hueco Bolson. The Hueco was dropping at one time two or three feet per year in certain areas. Now it's stabilized. This is probably one of the most telling charts that I can show people in terms of actual results from diversifying resources.

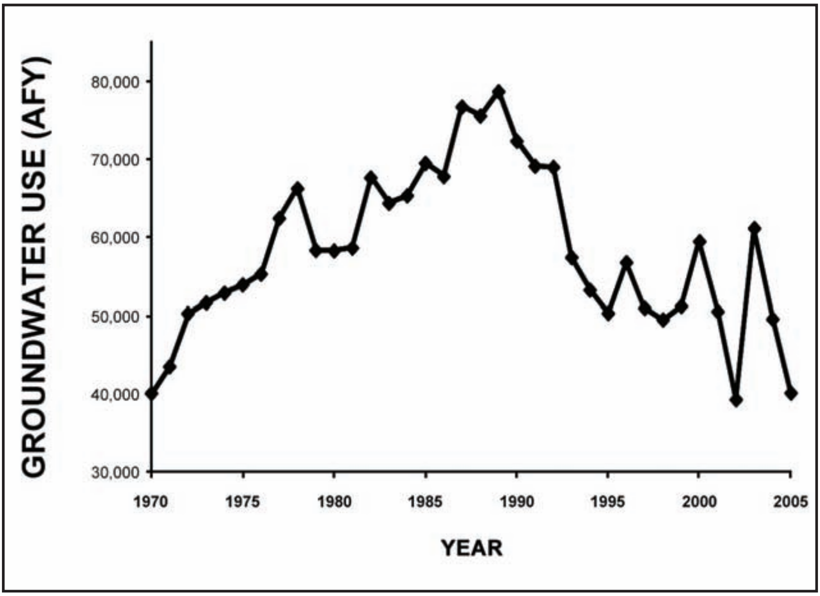

Figure 9. EPWU Hueco groundwater pumping.

We are prepared for climate change. Whatever you want to call it, we fell into it. If we had zero water coming to the river right now in El Paso, we could meet all the demands next summer. We have that diversity in groundwater, desalination, and reclaimed water to meet all the demands. That wouldn't be forever. As the population grows, you have to do something else. We do have that. If we can preserve the groundwater, we could drill additional wells and take more groundwater from the fresh groundwater supplies to augment during times of growth.

This is a pictorial of the inside the desalination plant. We were planning a 20-million gallon per day plant. The U.S. Army was thinking about a 7.5-million gallon per day plant. We approached the Army. We had to do a lot of work with the U.S. Army Corp of Engineers and the Pentagon to develop a joint plant.

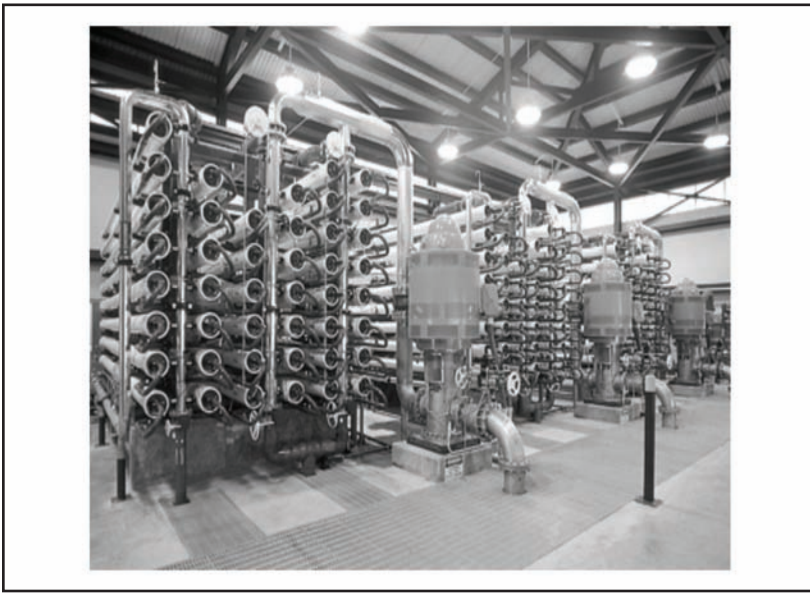

Figure 10. Desalination plant (interior).

This is the plant on Fort Bliss. It's owned by us. We built it; we planned it; we piloted it; designed it; we constructed it. We lease the land from Fort Bliss, and we also pay them for the brackish water. As far as I know, we are the only city that is paying somebody for brackish water, for salty water. We pay them $35 an acre-foot. It turns out that by the time we pay them for the land and the lease, and then paying for the water, it is almost a wash. It's not a big hit to them at all. Inland desalination is very cost-competitive, particularly as the scale gets larger. Ocean desalination is still expensive because of the concentration of the water. It's much more concentrated compared to the brackish water that we have here.

We could not have done such a good job of locating this plant had we not done the modeling. We actually had three sites where we could have placed the desalination plant. We chose Fort Bliss. Fort Bliss covers about 1.2 million acres in Texas and New Mexico. As a result of this plant and as a result of the planning we have done, Fort Bliss has a $4 billion construction program going on right now to accommodate its growth. Three years ago, there were 9,000 troops. Now there are 18,000 troops. In another two years there will be 37,000 troops. If we include the civilians and the dependents, it will go from maybe some 30,000 to 100,000 people.

It is a major, major expansion. In my opinion, it would not have happened without the planning, without the desalination plant, and the cooperation.

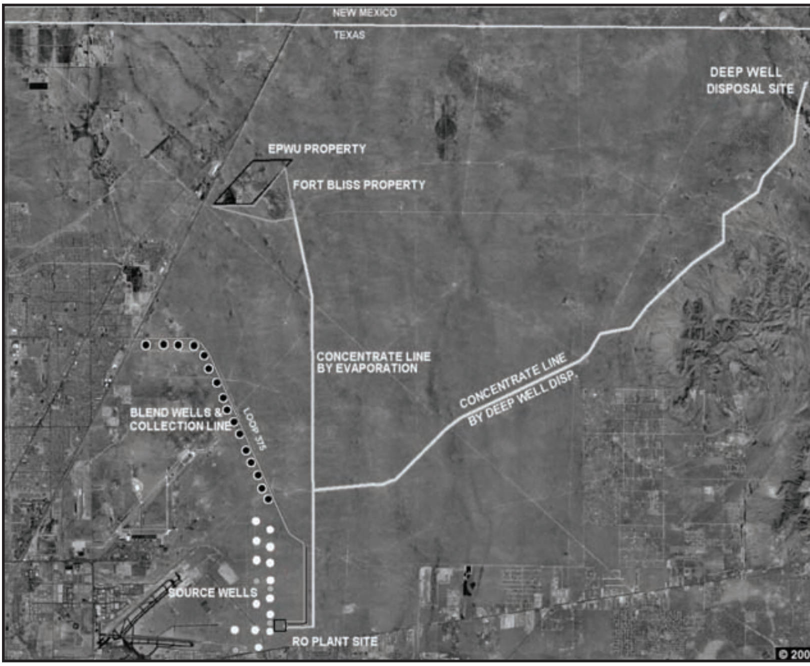

Figure 11. Desalination facilities.

The desalination plant is on the east side of the city. It's a reverse osmosis membrane plant like the ones in Israel. We do have brackish water. You see the source water wells that were fresh at one time. Through groundwater modeling, we found out that the brackish water has been moving from northeast to southwest, across. We told the Army that they really needed to work with us because we sunk 16 wells after drilling monitoring wells. We've had brackish water intrusion into the fresh water supplies. Groundwater is not uniform, quality-wise. It's like a sandwich. It goes up and down. The further away you get from the mountains, the more brackish the water.

The city limits of El Paso are about where the fresh water begins to tail out. The intent is to take that brackish water from those wells, run it through the river osmosis plant, bring it down to a low level, and then mix it with the fresh water wells in order to stretch supply. The plant has a capacity of 15-million gallons per day, but we blend it with 12.5 million gallons per day, and we produce the

27.5-million gallons per day. Those of you familiar with the desalination process know that there is a product called concentrate. It's what's left over, the salt that you take out. With the membrane, you separate out the H_2O by molecular size and you let everything else pass. Think about how small these openings are to let these molecules pass.

You may know of the deep-well disposal we built. We built a pipeline 22 miles to a site where UTEP had done some geothermal work years ago. The water is hot down there, and it is very poor quality. When I went to the Army, I said if you will do the environmental impact statement (EIS) and drill some test wells on your property, we'll plan it, design it, construct it, and sell you as much water as you need. That's what they did. We ended up with three finished disposal wells of 4,000 feet deep.

The water is going in at about 2,200 feet. We are pumping out there, but then it moves by gravity. It is doing very well. There's shale below it, dolomite, and the fractured rock where it's going in. The water quality is worse than what we're putting in. This process has to go through extensive permitting with the TCEQ (Texas Commission on Environmental Quality), but it is working very well. We're only using a small portion of that plant right now. It's wintertime. It's built for growth on the east side of El Paso and Fort Bliss, and it's built for drought, as a drought contingency. If you use the brackish water, it doesn't matter whether it rains or not, or whether there is a snow pack in the Rio Grande watershed. The water is there.

This is the TecH_2O Center. We're having a lot of conferences there. To build this was a major decision by my board, to allow us to use ratepayer monies to build a 30,000 plus square foot facility that would be a water resource learning center. It has a lot of exhibits for kids and adults. It's meant to educate future generations about the importance of water in the Chihuahua desert. The exhibits are all bilingual, Spanish and English. There is a big auditorium. There are breakout rooms for conferences and seminars. It is heavily used. NADBank was here, the general manager, Jorge Garcés is here (in the room). He gave us a small grant, but an important grant, to provide water conservation training. Jorge, thank you.

On a transboundary basis, we are working with the state of Texas on similar venues. The El Paso facility doesn't have to be the only center for water conservation. It's actually a center for water efficiency improvements. On that note, water efficiency is going to be moving forward, just like energy efficiency. Conservation will be part of that. It has to be the whole picture, from demand-side conservation to supply-side conservation, to diversity, to using impaired waters: waters that previously were thought to be unusable like brackish groundwater. These will have to be used in this country, and certainly in this region.

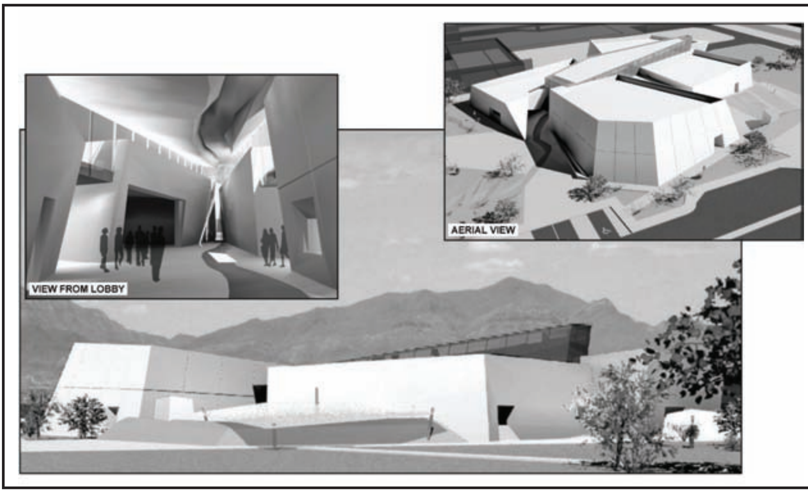

Figure 12. The TecH_2O Learning Center.

Water utilities across the nation will continue to be restructured and will have to consider strategic political and regional issues, like we have. To ensure efficient use of resources, we need to have these kinds of policies and programs in place. In the past, we did not communicate all the time with our customers. This is the information age, and people want to be aware. There is a public involvement movement, and we have to continue to capitalize on technology.

Some of us were interviewed by the news media, and they asked, "What do you see as the future?" I think the future of water planning and management is going to be in diversification of resources. You are going to see more reclamation, reuse of wastewater. I think at some point you are going to see what we call "direct potable reuse," where you actually treat wastewater to drinking water standards and you pipe it back in. That is something that can't be done in this country now, and it won't be done for quite some time. But it is going to be done. In fact, I believe it is going to be done nearby in Cloudcroft, New Mexico. Today, the problem with applying direct potable reuse is mostly psychological. In some cities like ours we have our reclamation plant. It is located in a bedroom community. We do not allow industrial entities into that area, because you don't want those industrial wastes jeopardizing your supply. But the technology is there and regardless where you live you are not at the top of the mountain. Everybody is drinking the water that someone else has used before.

I remember when I was in Albuquerque—I used to be with the water utility there, and I was in the private sector before that—the joke in Albuquerque was, "flush twice because El Paso needs the water." Now, they don't want the water to come downstream. They don't want to flush, not even once. Albuquerque has built a plant to take surface water from the river. They are looking at reclamation and reuse. There are folks in the private sector that are looking at desalination west of Albuquerque, to tap that water. In fact they are touring our plant tomorrow. So, reclamation and reuse is going to be there. Desalination is going to be there and conservation.

The other thing is that water is too cheap in America. I know in Europe water is much, much more expensive than it is in the United States. We learned about price elasticity, just like gasoline. If the price is higher, you are going to appreciate it more. When we go to the service station, we don't let half of it spill on the asphalt. Somehow, when you water your grass, some people say, "let it run down the storm sewer." Well those are the things we want to educate our kids on and future generations: Water is precious, especially here in the desert. Take care of it.

Thank you very much.

Research Needs In The U.S. Portion Of The Rio Grande Watershed

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Water issues in the Rio Grande watershed range from local site specific issues to global challenges that affect the entire watershed and beyond. The watershed encompasses alpine-desert-costal terrain and includes a significant human population as well as vast environmental resources. Some water research needs in the watershed are discussed. These research needs require expertise in many disciplines. Some will require teams of multi-disciplinary scientists to address adequately.

The Rio Grande is the fifth longest river in North America. Originating in the southern Rocky Mountains of Colorado and New Mexico, the Rio Grande extends 600 miles (960 km) from its headwaters and flows through New Mexico to the border cities of El Paso, Texas, USA, and Ciudad Juárez, Chihuahua Mexico. Downstream of El Paso, the river forms the international border between the United States and Mexico on its way to the Gulf of Mexico. The Rio Grande is two river systems. From its headwaters in Colorado and New Mexico downstream to Fort Quitman, Texas, where it essentially runs dry it is the upper Rio Grande. Spring runoff from mountain snowpack in the headwaters is the primary source of surface water for the upper basin.

Flows in the upper basin are highly variable from year to year and there have been prolonged periods of drought. The Otowi Gauge is an important Rio Grande Compact index gauge. It measures the flow of the main stem Rio Grande as well as the Rio Chama, an important tributary. The contributing drainage area is 11,360 square miles. Average annual flow for the period 1896–2007 is 1,485 cubic feet/second (cfs) (US Geological Survey, 2009). Below El Paso, Texas, at the Fort Quitman gauge the river is almost totally depleted. The average annual flow for the period 1923–2008 is 6.08 cubic meters/second (m^3/s) (214.7 cfs) (International Boundary and Water Commission, 2009). The river gains flow again at Presidio Texas where the Rio Conchos, a tributary from the Mexican portion of the basin joins the Rio Grande (Rio Bravo). The average annual flow for the period 1900–2008 is 33.44 (m^3/s) (1,180.9 cfs) (International Boundary and Water Commission, 2009a). The Rio Pecos is a tributary that originates in New Mexico and joins the main stem Rio Grande near Del Rio, Texas. There are a number of smaller tributaries in the lower reach mostly from Mexico. The flow of the Rio Grande below the Amistad Dam near Ciudad Acuna, Coahuila and Del Rio, Texas, includes the contribution of the Rio Pecos. The average annual flow for the period 1954–2008 at this gauge is 65.08 m^3/s (2,298.3 cfs) (International Boundary and Water Commission, 2009b).

Population Growth And Economic Development

The Rio Grande watershed has experienced substantial growth in population and economic development since the 1960s. The watershed includes the major metropolitan areas of Santa Fe, Albuquerque, and Las Cruces in New Mexico and El Paso, Presidio, Del Rio, Eagle Pass, Laredo, and Brownsville in Texas. The Rio Grande watershed in the US includes most of 7 counties in Colorado, 22 counties in New Mexico, and 26 counties in Texas. The combined population of these counties in 1960 was 1,735,478. By 2000 the combined population had grown to 3,647,653 (see Table 1 at end of article). Population growth projections to 2030 show combined population in the counties at 5,804,555 (see Table 2 at end of article). These data are summarized in Figure 1, which shows the trend in growth. The population growth in the Colorado counties is minor and is currently limited by high mountain terrain and a high percentage of public lands. The growth in New Mexico is expected to almost triple the 1960 level by 2030 and the growth in Texas is expected to almost quadruple the 1960 level by 2030.

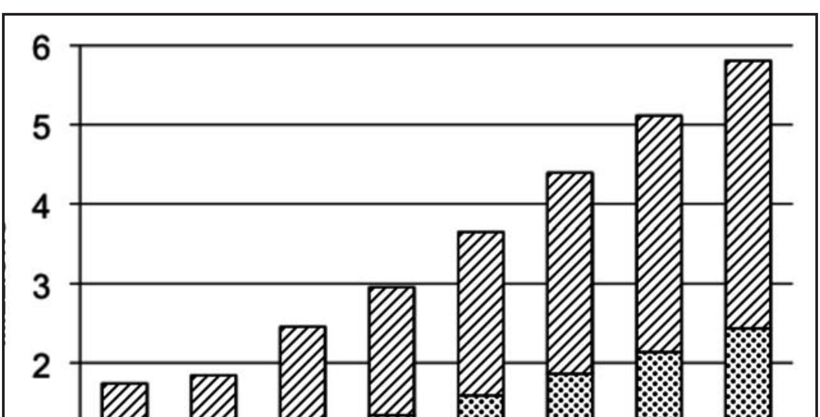

Figure 1. Population in US Rio Grande watershed counties by state 1960-2000 and projections to 2030.

Climate And Climate Change

Climate change is also likely to affect the availability of water in the future. Although existing climate models are an uncertain tool for estimating change, there is a growing consensus among researchers that precipitation will increase at higher latitudes and decrease in the subtropics as warming occurs. As mean temperature increases, the volume of snowpack will decrease at higher elevations and snowmelt will occur earlier than in the past, causing an earlier release of water and greater losses (Seager *et al* 2007). Because the bulk of water supplies in the upper basin are obtained from snowmelt, any change in the timing of releases will have serious repercussions for management. Despite the uncertainty associated with the results of climate forecasting models, simulations made from different assumptions have led to a consensus on several characteristics of the impact of climate change. There is widespread agreement that precipitation will become more variable and will create amplified variations in runoff and streamflow (Houghton 2004, Seager *et al* 2007, Christensen *et al* 2007). Associated with this increased variability will be an increase in the frequency of extreme events such as floods and droughts (Seager *et al* 2007).

Climate modeling is an emerging science, and varying degrees of reliability characterize the forecasts of future change that are derived from climate models. The prognosis that there will be greater variability in precipitation leading to more floods and droughts is also reliable, and it is predicted with some confidence that rainfall will increase at higher latitudes and decline in the subtropical regions. However, accurate estimates of changes in the amount of precipitation in different regions and in different locales within regions are more difficult to forecast (Seager *et al* 2007). New developments in hydrologic modeling will also be important. The response of aquifers to changes in snowmelt and runoff patterns cannot be assessed with precision, although it is known that recharge is higher from snowmelt than from rainfall-generated runoff. Much remains to be learned about large-scale hydrologic processes and about the interrelationships between hydrologic and climatological processes. Advances in the physical sciences that underlie and explain the behavior of water resources will be critically important in the future.

Water Quality Degradation

Future water supplies are also threatened by declines in water quality caused by pollution. As agriculture advances, major increases will occur in nitrate- and pesticide-loading of nearby surface and ground waters. In certain soils, enhanced drainage from agricultural operations can leach toxic metals from the subsurface to surface and ground waters. In areas where adequate sanitation services are absent, growing populations inevitably lead to increased levels of pathogens in water supplies. Decades of land disposal or accidental release of untreated toxic waste have created a serious ground water contamination problem in many areas, and much of the waste still lies in the soil. Ground water contamination is extremely expensive to remediate, and it is unlikely that all the resources needed will be available in the future to support significant remediation efforts. Soil salinization will continue to be a problem in the Rio Grande watershed that plagues irrigated agriculture, particularly in arid and semiarid climates. Salt buildup in shallow soil can significantly decrease crop yields and in extreme cases can render the soil unfit for farming. Ironically, the best way to avoid salinization may be to apply water at a rate substantially in excess of crop water needs to avoid buildup of salt in the crop root zone.

Research Needs

It is difficult to undertake necessary research when adequate data is lacking. Knowledge of the water supply of the US Rio Grande watershed, like many the other watersheds of the US, is limited due to funding. Stream flow gauges as well as water quality monitoring programs are expensive and declining or flat budgets have reduced the number of active sites in the watershed over the years. These reductions have occurred from both the federal as well as state. If reduced flow projections do happen and/or summer monsoon events become stronger from climate change then it is even more important to have more measurement sites rather than less. If mainstem flows which result mostly from spring snowmelt are less and occur earlier in the year and summer thunderstorms in the lower elevations of the watershed produce higher flows it is very important to be able to measure these tributary and side channel flows and well as predict when they will occur. Water demand estimates are compiled by region and state and use different techniques and are rarely done. State estimates of water use are only repeated on 5 year cycle. We need techniques/technology that allows seasonal resolution of water use data.

With the increased pressure of growth combined with decreased flows will also stress the groundwater aquifers of the watershed. With reduced surface flows water users will attempt to make up the shortfall by increasing groundwater pumping. We are just beginning to acquire data to monitor the health of the groundwater basins. Most of the aquifers lack sufficient characterization to allow adequate management. It is important to note that there have been some very good isolated basin programs developed, but they were mostly a one-shot effort and do not have long-term updating and monitoring in place. What is needed throughout the watershed is a joint federal-state program to characterize all of the groundwater basins similar to the program established by US PL 109–448 Transboundary Aquifer Assessment Program initiated in 2006.

Better-cheaper tools and techniques are needed that are applied to all measurement, monitoring, and assessment including flow measurement, quality sampling and analysis, snowpack, precipitation, evaporation and evapotranspiration. We need cheap and reliable sensors and measurement systems to remotely measure water volumes and movement inexpensively, precisely, and in real time in all rivers, lakes, aquifers, wetlands, snowpack and soil. Existing hydrologic models should be strengthened, integrated, and transformed into tools for making decisions on watershed and subwatershed scales. Hydrologic models should be coupled with institutional models to provide a full suite of physical, economic, and technological decision tools for water managers. We also need improved and expanded technologies for enhanced use of marginal or impaired water supplies as the Rio Grande watershed has lots of it.

The certain growth and uncertain climate change predicted for the future will also likely have an impact by contributing more pollution in the watershed. We cannot afford to degrade the resource and must develop additional means to reduce the impacts. This assigns high importance to more and cheaper treatment technologies. We need the development of innovative technologies to use water more efficiently. It is also important to increase and improve research in the social, behavioral, and economic sciences to provide the understanding and tools to deal with the human impacts of changing water availability and use. The watershed has and will experience increasing pressure from invasive species that consume the water or clog the system. We can also expect to have to deal with new pollution sources such as emerging contaminants of concern. This is a term used to describe contaminants such as pharmaceuticals, health care products, steroids/hormones, caffeine, and the like. Are they likely to have human health effects? Some say no because even though they are detected their concentration is so low that they will not. However, they may affect aquatic species. If you are involved in water research or are a student thinking of a science career, I see plenty of work ahead.

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Table 1. County population in Rio Grande watershed 1960–2000.
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County	1960	1970	1980	1990	2000
Alamosa	10,000	11,422	11,799	13,617	14,966
Conejos	8,428	7,846	7,794	7,453	8,400
Costilla	4,219	3,091	3,071	3,190	3,663
Hinsdale	208	202	408	467	790
Mineral	424	786	804	558	831
Rio Grande	11,160	10,494	10,511	10,770	12,413
Saguache	4,473	3,827	3,935	4,619	5,917
Total Colorado	38,912	37,668	38,322	40,674	46,980
Bernalillo	262,199	315,774	419,700	480,577	557,167
Catron	2,773	2,198	2,720	2,563	3,567
Chaves	57,649	43,335	51,103	57,849	61,285
Doña Ana	59,948	69,773	96,340	135,510	175,013
Eddy	50,783	41,119	47,855	48,605	51,416
Grant	18,700	22,030	26,204	27,676	30,893
Guadalupe	5,610	4,969	4,496	4,156	4,687
Lea	53,429	49,554	55,993	55,765	55,152
Lincoln	7,744	7,560	10,997	12,219	19,537
Los Alamos	13,037	15,198	17,599	18,115	18,279
Luna	9,839	11,706	15,585	18,110	25,016
McKinley	37,209	43,208	56,449	60,686	74,586
Otero	36,976	41,097	44,665	51,928	62,225
Rio Arriba	24,193	25,170	29,282	34,365	10,082
Sandoval	14,201	17,492	34,799	63,319	91,246
San Miguel	23,468	21,951	22,751	25,743	30,074
Santa Fe	44,970	53,756	75,360	98,928	129,829
Sierra	6,409	7,189	8,454	9,912	13,246
Socorro	10,168	9,763	12,566	14,764	18,057
Taos	15,934	17,516	19,456	23,118	30,067
Torrance	6,497	5,290	7,491	10,285	16,946
Valencia	39,085	40,539	61,115	45,235	66,358
Total New Mexico	800,821	866,187	1,120,980	1,299,428	1,544,728

Table 1. County population in Rio Grande watershed 1960–2000.

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County	1960	1970	1980	1990	2000
Brewster	6,434	7,780	7,573	8,681	8,880
Cameron	151,098	140,368	209,727	260,120	336,562
Crane	4,699	4,172	4,600	4,652	3,950
Crockett	4,209	3,885	4,608	4,078	4,027
Culberson	2,794	3,429	3,315	3,407	2,946
El Paso	314,070	359,291	479,899	591,610	679,622
Hidalgo	180,904	181,535	283,229	383,545	573,599
Hudspeth	3,343	2,392	2,728	2,915	3,344
Jeff Davis	1,582	1,527	1,647	1,946	2,229
Jim Hogg	5,022	4,654	5,168	5,109	5,269
Kinney	2,452	2,006	2,279	3,119	3,384
Loving	226	164	91	107	65
Maverick	14,508	18,093	31,398	36,378	47,347
Pecos	11,957	13,748	14,618	14,675	16,713
Reeves	17,644	16,526	15,801	15,852	13,051
Schleicher	2,791	2,277	2,820	2,990	2,917
Starr	17,137	17,707	27,266	40,518	53,815
Sutton	3,738	3,175	5,130	4,135	4,032
Terrell	2,600	1,940	1,595	1,410	1,061
Upton	6,239	4,697	4,619	4,447	3,379
Val Verde	24,461	27,471	35,910	38,721	45,010
Ward	14,917	13,019	13,976	13,115	10,820
Webb	64,791	72,859	99,258	133,239	194,592
Willacy	20,084	15,570	17,495	17,705	20,051
Winkler	13,652	9,640	9,944	8,626	7,077
Zapata	4,393	4,352	6,628	9,279	12,203
Total Texas	895,745	932,277	1,291,322	1,610,379	2,055,945
Rio Grande	1,735,478	1,836,132	2,450,624	2,950,481	3,647,653

Sources

1960–1990: U.S. Census Bureau, 2009, Population Division, County Population Census Counts 1900–90. Retrieved from http://www.census.gov/population/www/censusdata/cencounts/index.html

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Table 2. County population in Rio Grande watershed 2010–2030 (projections).

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County	2010	2020	2030
Alamosa	17,255	20,015	22,901
Conejos	8,804	9,485	9,990
Costilla	4,011	4,339	4,606
Hinsdale	883	1,067	1,250
Mineral	989	1,111	1,144
Rio Grande	13,359	14,691	15,532
Saguache	7,070	7,955	8,575
Total Colorado	52,371	58,663	63,998
Bernalillo	621,940	679,538	740,646
Catron	2,735	2,826	2,854
Chaves	66,699	68,958	71,070
Doña Ana	227,009	282,152	345,458
Eddy	60,602	65,295	69,400
Grant	34,954	38,313	41,238
Guadalupe	4,114	4,111	4,014
Lea	58,891	59,913	60,730
Lincoln	18,589	21,250	23,948
Los Alamos	20,123	21,079	21,758
Luna	31,640	39,102	47,405
McKinley	81,673	91,671	100,729
Otero	61,057	64,277	66,238
Rio Arriba	41,201	43,823	45,794
Sandoval	128,396	170,199	221,662
San Miguel	31,479	33,398	34,539
Santa Fe	157,925	192,514	230,915
Sierra	12,502	13,380	14,046
Socorro	18,469	20,156	21,651
Taos	29,604	32,126	34,239
Torrance	19,016	23,389	28,220
Valencia	87,575	112,909	142,089
Total New Mexico	1,816,192	2,080,380	2,368,643

Table 2. County population in Rio Grande watershed 2010–2030 (projections).

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County	2010	2020	2030
Brewster	9,577	10,002	10,055
Cameron	414,407	486,737	550,005
Crane	4,474	4,843	4,874
Crockett	4,532	4,718	4,593
Culberson	3,360	3,538	3,523
El Paso	797,699	902,270	978,642
Hidalgo	741,466	919,204	1,094,886
Hudspeth	3,817	4,082	4,090
Jeff Davis	2,393	2,427	2,272
Jim Hogg	5,592	5,817	5,861
Kinney	3,450	3,459	3,427
Loving	66	62	60
Maverick	55,600	62,839	68,263
Pecos	17,895	18,566	18,495
Reeves	14,035	14,330	14,065
Schleicher	3,194	3,335	3,249
Starr	65,713	76,765	86,357
Sutton	4,509	4,732	4,694
Terrell	1,178	1,211	1,189
Upton	3,774	3,919	3,870
Val Verde	51,319	56,410	60,088
Ward	11,503	11,776	11,831
Webb	256,020	322,003	387,743
Willacy	22,430	24,164	25,277
Winkler	7,565	7,692	7,396
Zapata	13,978	15,718	17,109
Total Texas	2,519,546	2,970,619	3,371,914
Rio Grande	4,388,109	5,109,662	5,804,555

Sources

2010–2030: New Mexico: Bureau of Business and Economic Research, 2008, New Mexico County Population Projections July 1, 2005 to July 1, 2035, Bureau of Business and Economic Research, University of New Mexico. Released August 2008.

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Environmental Governance In The Rio Grande Watershed:
Binational Institutions And The Transboundary Water Crisis

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Water shortage in the international reach of the Rio Grande River is more a crisis of governance than a hydrological one. While drought afflicts the region stressing border communities and United States-Mexico relations, institutional capacity for sustainably managing binational water resources has not kept up with the human stressors on the River. This paper traces the binational framework governing the allocation and management of Rio Grande water and then reviews three contemporary problems (Mexico's treaty water deliveries; security infrastructure; and groundwater management) that reveal its weaknesses and vulnerabilities. The paper concludes by pointing to needed changes in the present treaty regime, the need for greater inter-sectoral coordination between water and security policies, and the need for better institutional articulation between binational governance entities.

As we survey the Rio Grande River basin in its international reach it is evident that what many observers perceive to be a transboundary water crisis is more of an institutional and political crisis than a hydrological one. It is certainly true that throughout the basin we are now enduring a persistent drought and one that presents a considerable challenge to water managers and water beneficiaries alike. Geologists and hydrologists have told us for years that climate change was a historic factor in throughout the region that shaped and occasionally destroyed entire civilizations—witness the Anazazi. This reality, the periodic occurrence of extreme and protracted drought, affects the entire basin, indeed it applies to the whole of the southwestern region of North America. As presently experienced in the Rio Grande basin the scarcity challenge seems particularly acute in the international reach of the river, that portion of the basin that is shared jointly by Mexico and the United States.

While climate is certainly a factor in this story, the stressors on our transboundary water endowment are mainly human. They appear in the form of rapid population growth throughout the basin, certainly along the international reach of the river, causing an increase in traditional municipal-industrial and agricultural uses, in the emergence of new demands on available water stocks, and in the spoliation of the water stock by human activity. Even salinity, though endemic, often has a human catalyst or cause.

Our transboundary water crisis in the Rio Grande basin, in all its aspects including the preservation of the natural environment, has human prints all over it. It may well be described as a crisis of governance. This may strike some as ironic since the past two decades have given us marked progress in binational cooperation for water management, particularly where environmental values and sustainable development objectives are concerned.

To understand why we have a transboundary water crisis on the Rio Grande in the context of marked progress in binational cooperation for environmental protection and shared water management, we review the development of a complex of binational institutions with mandates for Rio Grande water management. We need to understand the strengths and limitations of the multilevel system of binational water governance we now have.

What becomes clear as we proceed is that even as our two nations in recent times have made considerable progress in advancing and defending environmental values along the river, we are still short of needed treaty authority. Moreover, we see considerable disarticulation between policies and institutions. As one might expect, the reform process has been largely additive and rarely integrative, somewhat decentralizing, and very much reflective of the give and take that may be expected of contiguous and sometimes cooperative federal systems of government. It has also been beset by new, unanticipated challenges. Let us now take a look at this system to better understand its strengths and limitations.

Governance, Development, And Rio Grande River Management

The governance of binational water resources has developed in a well known trajectory that over time has given us a set of partially nested, or tiered, institutions each with its particular mandate, jurisdiction, and administrative practices affecting water management on our international rivers. This institutional complex has emerged as a series of consecutive binational policy initiatives that originally addressed traditional water concerns focused on regional economic growth. Environmental considerations were later added to the mix of priorities (Table 1). More recently, the two nations have embraced notions of sustainable development in managing their binational rivers. Since the historic 1944 U.S.-Mexican water treaty that applies to the international stretch of the Rio Grande, the environmental scope of binational water management concerns has widened from a narrow interest in border sanitation to a diverse set of ecological and environmental concerns.

Era	Dominant Theme	Dominant Institution
Development & Growth 1889-1973	Capturing Sovereign Endowments	IBWC
Transitional 1973-1990	Adjusting to Environmental Protection	IBWC/La Paz Agreement
NAFTA	Sustainable Development of Water Resources	BECC-NADB/La Paz Agreement/IBWC
Post-9/11	Security and Sovereignty v. Sustainable Development	BECC/IBWC

Table 1. Binational water history: eras, themes, institutions.

The policy characteristics of the binational and trinational institutions in play in border water management today are summarized below in Table 2. The core institutions include the venerable International Boundary and Water Commission, United States and Mexico (IBWC), the La Paz Agreement in its current iteration, the Border 2012 Program, the Border Environment Cooperation Commission (BECC/COCEF) and its institutional partner the North American Development Bank (NADB/BDAN), and the trinational Commission for Environmental Cooperation (CEC/CCA). Not included in the table but also worth of mention are national advisory bodies, the U.S. Good Neighbor Environmental Board (GNEB)and Mexico's Northern Border Sustainable Development Council, that were created, in part, to channel public and regional concerns on border environmental matters to each nation's federal environmental authorities.

Table 2 suggests a number of practical problems that impede binational coordination and cooperation across a conceivable spectrum of environmental issues relevant to the sustainable development and utilization of the Rio Grande River in its international reach. It is evident, for instance, that our binational and trinational agencies differ in respect to their core policy orientation. Several, particularly the IBWC and the BECC/NADB agencies, are focused primarily on distributive problems, allocating resources and expending funds for water related projects, including water storage, delivery, and sanitation projects supporting the growth of communities on both sides of the border.

Agencies & Programs	Policy Type	Jurisdiction	Agency Structure	Type of Representation	Issue Articulation
IBWC	Distributive; some regulatory	Treaty based; narrow; allocation emphasis; operational on international reach of the rivers	National sections under treaty umbrella subject to authority of foreign ministries	Hierarchical; ad-hoc consultative and advisory; limited stakeholder inclusion	Boundary centered water allocation; water quality and pollution; hydropower; flood control; boundary maintenance
BECC/ NADB	Distributive	Project certification; some scoping and technical assistance	Binational; Board integrated binationally and functionally	Advisory; consultative; promotes public participation at project level; broader stakeholder inclusion	Environmental infrastructure within the official border zone (100k north and 300k south of the boundary
La Paz-Border 2012	Regulatory, some distributive	Binational discussion, envisioning; ad hoc planning within a defined border region	Binational program led by national environmental ministries coordinating with states, tribes, and public	Advisory; consultative; broad stakeholder inclusion; promotes public participation	Environmental health and pollution in the officially designated border zone. Limited focus on biodiversity
CEC	Regulatory	Investigative; convening	Trinational; hierarchical	Advisory; Consultative	Environmental issues of continental scope in North America

Table 2. Binational environmental institutions' policy characteristics.

Other agencies and programs, notably the La Paz agreement programs and the CEC, are at their core oriented towards insuring the two nations live up to their environmental promises and cooperate to strengthen and enforce environmental regulations and practices along the border. These orientations are not exclusive, of course, and in practice regulatory and distributive aspects can be found in the mandates of all these agencies. Even so, there are critical differences in the policy orientation of these agencies and programs and these differences matter. In modern democracies, distributive agencies are known to enjoy greater public support for their specialized functions, whereas regulatory agencies and programs tend to be more controversial and are less likely to enjoy public approval, even when their public good is widely recognized (Lowi, 1966).

We can also see important differences in the core jurisdictions and mandates of these agencies. While all these institutions have a border-wide mandate, the oldest and best institutionalized body, the

IBWC,[1] has a treaty-based mandate and jurisdiction focused narrowly on the boundary reach of the international rivers. Issues that are separate and exclusive to the domestic territories of the respective countries are the province of other domestic agencies and largely disregarded by the Commission.

In contrast, both the BECC and NADB, and the Border 2012 Program operate within a more expansive jurisdiction originally defined by the La Paz Agreement and subsequently extended for BECC and NADB in 2001 (Abel, 2001; Agreement, 1983; Agreement, 1993; EPA, 2003). Not only do they share a broader geographic jurisdiction, but the scope of their programs is broader as well. In further constrast, the CEC's jurisdiction extends to the whole of North America in matters of transnational environmental concern and is, on paper at least, nearly all inclusive in its substantive reach (NAAEC, 1993).

There are also obvious differences in institutional structure, how these institutions represent interests and constituencies, and the types of issues they are most wont to engage. Only one set of agencies, BECC and NADB, is truly binational and operates in a fully integrated way. The IBWC, in contrast, functions as a coordinate set of national sections tasked by a common treaty mandate, while the Border 2012 iteration of the La Paz process also operates as national bodies at the implementation level while blurring the lines sometimes at the deliberative level in seeking common ground solutions to border environmental problems (Treaty, 1944; EPA, 2003). The CEC's governing Council tilts towards trinational integration in its fact finding and investigative functions, but national differences have limited its Secretariat to a more restricted range of convening and scoping activities well short of its original mandate (NAAEC, 1993).

If we were to place their representative orientations on a continuum, the IBWC would clearly be located at the less representative end of the continuum, while the La Paz Border 2012 program would place at the most representative end of the scale. As for each institution's articulation with water and environmental issues, the IBWC has an issue-range that centers heavily on water allocation, control, and sanitation within the scope of the 1944 Water Treaty with a subsidiary interest in water related boundary effects, the BECC and NABD focus on water projects for border area communities, the La Paz process focuses on water pollution and to some degree on habitat preservation, while the CEC's water focus—apart from citizen initiated investigations of government failures to enforce their environmental laws—centers on biodiversity, climate change, and long-term processes affecting terrestrial and marine species of North American concern.

Clearly, we have a varied mix of institutional types and capacities in play where binational water management is concerned. We have gained institutional capacity over time, yet the mix of these capacities is uneven and far from comprehensive, both limiting and facilitating binational cooperation on the important transboundary challenges along the international reach of the Rio Grande River. Most evident is that while we have made much progress in adding on new institutional capabilities for managing water related environmental problems on the river, we do not have a comprehensive or strategically integrated institutional approach to dealing with a pressing range of problems.

Moreover, recent events remind us that progress made at the binational level is heavily contingent on domestic affairs and highly susceptible to changing national priorities. If binational policy gains are to be consolidated and strengthened, there must be greater articulation of programs and practices and sustained attention to the environmental dimensions of water management. These truths are evident in several of the most visible environmental problems on the river today: the problem of water allocation under the treaty regime, the potential harms from security infrastructure development along the river, and the threat presented by overconsumption and pollution to transboundary groundwater reserves along the river.

Three Problems: Mexico's Treaty Water Deliveries, Security Infrastructure, And Groundwater

To better appreciate current strengths and deficiencies in the governance of environmental values along the Rio Grande River it is useful to review developments in three important issue-areas, or cases. The first, the crisis generated by Mexico's under-deliveries of water from the Conchos and other tributaries below Ft. Quitman, is an example of institutional underdevelopment involving the 1944 Water Treaty and the IBWC/CILA. It is also reveals the value of more recent institutions not envisioned by the treaty for assisting in solutions to treaty related water problems.

Mexico's treaty water deliveries. The drought-driven conflict over Mexico's treaty water deliveries on the Rio Grande has roots in the early 1990s as precipitation declined throughout the basin. By 1995, water shortages on Mexican tributaries were so reduced that Mexico was compelled to ask for assistance from the United States, both in the form of an emergency water release from Amistad dam to bail out Mexican cities on Rio Grande and through a temporary relaxation of its delivery obligation to the United States (Mumme, 1999). Under Article 4 of the 1944 Water Treaty, Mexico must provide the United States with a minimum average of 350,000 acre-feet of water annually over a five-year cycle (Treaty, 1944: Article 4).

In 1997, at the end of the 25th accounting cycle, the U.S., acting through the IBWC, agreed to roll-over the debt at Mexico's request. According to one prominent participant in these negotiations, the Mexican view was that the U.S. had accepted the idea that an extraordinary drought prevailed. After the U.S. disagreed, the Mexican delegation made their view explicit in 1999, though at this point there was clear disagreement concerning the existence of an *extraordinary drought* (Vina, 2005). Despite this, and notwithstanding considerable outcry by Texas farmers pointing fingers at Mexico, the debt remained unpaid into 26th cycle in 2002. By this time the issue had reached the presidential agenda, a rare event not witnessed since the Salinity Crisis in the early 1970s.

This high level dispute was formally pursued through the offices of the IBWC/CILA, though by 2000 the foreign ministries were fully involved (TCPS, 2001). A good deal of criticism was directed at the respective national sections of the IBWC for failing to adequately defend national interests, with particularly harsh criticism of the U.S. Section from south Texas agricultural interests. Scholars also weighed in (Schmandt, 2002; Nitze, 2004). Negotiations reached something of a breakthrough, however, in June 2002, when the two countries signed IBWC Minute 308. Under this agreement, and without any formal rule, acknowledgement, or imputation of Mexican failure to abide by the Treaty's provisions, they agreed to improve hydrological data exchange and support funding conservation projects in the headwaters of Mexico's Rio Conchos.

Mexico also agreed to pay down its arrears and give "the highest priority" to satisfying Article 4 provisions. The two parties further agreed to form an international advisory council "to strengthen the IBWC's role in the area of sustainable management of the basin and drought management," and to host a "bi-national summit meeting of experts and water users from each country" aimed at "providing the proper authorities and stakeholders information concerning sustainable management of the Rio Grande Basin" and advising the two governments on a "binational sustainable management plan for the basin" (IBWC Minute 308, section G, items 2 and 3, 2002: 4). Not long after, in 2003, the Commission's United States Section, acting on its own initiative, established the Lower Rio Grande Citizen's Forum acknowledging the need for better communication between river stakeholders and the Commission (IBWC, 2003).[2]

Acting on the provisions of Minute 308, the IBWC and the governments turned for conservation infrastructure to the BECC and NABD, whose geographic and functional mandates had broadened by binational agreement in 2001. Under the Monterrey accords, these paired agencies were newly authorized to support a wide range of environmental projects within a geographic reach of 300 km below the border (Abel, 2002). Three Mexican irrigation districts in the upper Rio Conchos basin were targeted for improvements supported by a newly established NABD facility, the Water Conservation Investment Fund (IBWC, Minute 309, 2003). Certified by BECC, construction began on these projects in late 2002, concluding in 2006. In November 2005, the Commission convened a binational summit, fulfilling the governments' commitment under the Minute (IBWC, 2005a).

The water debt crisis was not over, however. Mexico, aided by more favorable hydrological conditions in 2003-2004, continued to pay down its obligation while Texas farmers backed by state officials clamored for reparations. Concerned that Mexican repayment would weaken their case for compensation, a group of Texas irrigator sued Mexico under NAFTA's Chapter 11 investor protection rules (Associated Press, 2004). Their novel argument that Mexico hoarded treaty water and used it to support export-agriculture thus gaining an unfair trade advantage was subsequently set aside in 2006, though on appeal it is now under further review (Michaels, 2008).

In March 2005, Secretary of State Condelezza Rice announced a formal understanding providing for completion of water transfers and vacating the Mexican water debt by September 30, 2005 (IBWC, 2005a). The water transfers were completed on schedule and the IBWC issued a formal announcement of deficit elimination on September 30, 2005 (IBWC, 2005b). In September 2007 the 27th cycle was completed with Mexico in full compliance.

While drought conditions still persist in the region, Mexico remains in treaty compliance. In a twist of fate, extreme weather conditions in September 2008 produced flood conditions that seriously damaged communities and towns along the lower Conchos and Rio Grande. Sadly, both boundary commissioners perished when their light aircraft failed while investigating the damage caused by the flooding (IBWC, 2008). The floods were otherwise a boon for border water supply. A short 28th cycle finished on October 8, 2008 as U.S. conservation capacity topped off, followed by a another short 29th cycle, initiating the 30th Rio Grande water accounting cycle on March 1, 2009 (see IBWC water accounting data online at: http://www.ibwc.gov/Water_Data/mexico_deliveries.html).

The 13 year rolling crisis over Mexico's treaty water deliveries may be past, but the institutional problems associated with the crisis have only partially been addressed. There are a number of important governance lessons here. First, it is clear that the institutional mechanism for dealing with drought under Article 4 of the 1944 Water Treaty is deficient. This is a complex governance issue, involving both the powers granted the IBWC and the way the Commission interacts with other stakeholders basin-wide on both sides of the border.

As so many observers have noted over the years, the Article 4 provisions appear deficient in several ways; in failing to specific the operational criteria for determining the existence of an extraordinary drought; in failing to envision the possibility of needing to roll-over debt for more than two consecutive cycles; and in failing to stipulate or otherwise guide the governments in a course of action in response to a joint declaration—or, more accurately as in the present circumstances, a unilateral declaration—of extraordinary drought.

Moreover, as Minute 308 in fact acknowledges, the 1944 Treaty makes no provision for basin-wide or sub-basin advisory bodies to counsel the governments on best practices and preventive measures to guide water utilization in the basin and avoid a treaty failure of the sort we recently experienced (IBWC, Minute 308, 2002).

Second, it points to the need for further development of the treaty regime. While the specific concerns related to Mexico's treaty water obligation drove the controversy and the debate, the eventual focus on conservation as the long term solution to a reoccurrence of Mexican shortages in the basin points to the need for a more comprehensive approach to basin-wide water management linked to the treaty regime.

This, arguably, requires further development and extrapolation of treaty authority to address environmental needs within the basin, needs ranging from invasive species prevention and control, to habitat and biodiversity support. Such concerns also reinforce the integration of basin stakeholders and concerns in an advisory mechanism that enables the IBWC to play a more strategic role in basin-wide water management. As I have argued elsewhere, it make's sense for the IBWC as representative of the federal governments for treaty matters to take the lead in issuing reports and warnings of pending drought based on best science and stakeholder advice that would then guide the actions of federal, state, and local bodies in mitigating severe drought within the basin (Mumme, 2004).

Third, it points to the need for better governance connectivity to other binational agencies and to stakeholder communities in the basin if future crisis are to be avoided. On the positive side, the new NAFTA generated bilateral water management institutions have proven useful in at least partially filling the governance gap in ways that were not originally envisioned by their designers. The governments' ability to use the facilities of BECC and NADB to extend the reach of the treaty regime shows the resiliency and flexibility of these bodies and their ability to complement the national sections of the IBWC and domestic water agencies.

The IBWC lacks the authority to undertake conservation works in the domestic territory of either nation and must partner with other agencies to do so. The adoption and incorporation of this mechanism in Minutes 308 and 309 in effect extend the mandates of the IBWC and BECC and NADB in ways that suggest the creative use of other such partnerships to deal with treaty related issues in the basin (IBWC, Minute 308, 2002; Minute 309, 2003).[3] The IBWC-U.S. Section's citizen forum initiative is helpful here, but falls well short of constituting a standing collaborative and binational advisory body of the sort found in U.S.-Canadian watershed management that could strengthen collaborative watershed management on the Rio Grande.

The challenge of border security. The link between border security and water related environmental concerns was not much noticed until 2006, and is still underappreciated. The issue has come to the fore as implementation of border security infrastructure has gone forward, particularly in the form of the controversial works authorized by the 1996 Illegal Immigration and Immigrant Responsibility Act, the 2005 Real ID Act, and the 2006 Secure Fence Act (PL 104-208, 1996; PL109-13, 205, 200 PL 109-367. 2006).

The environmental values of the Rio Grande River are considerable, of course, particularly in the form of wetlands and islands of habitat supporting numerous species of fauna and flora the length of the river and throughout the basin. Along the international reach of the river numerous protected and unprotected wetlands are found ranging from El Paso's Rio Bosque Park to the Big Bend and Sierra del Carmen national parks, to the "string of pearls" that comprise the Lower Rio Grande National Wildlife Refuge. The list of species supported by these wetlands includes such charismatic fauna species as the monarch butterfly, jaguar, black bear, and ocelot and flora such as the sabal palm (Moya, 2007; Peters, 2007; Riemann, 2007).

Michael Chertoff's (Secretary of the Department Homeland Security) April 1, 2008 decision to invoke his Real ID Act authority and waive all otherwise applicable federal, state, and local environmental regulations allowed DHS to proceed with plans to construct federally mandated security infrastructure (US-DHS, 2008: ES-1; New York Times, 2008: A22). The fence, 700 miles in all with segments distributed the length of the border, was officially scheduled for completion by December 2008. More than 180 miles of barriers are now either in place or under construction along the Rio Grande River at various locations between El Paso and Brownsville (Witt, 2008), broken into segments—21 such segments are found in the Rio Grande Valley Sector alone (US-DHS, 2008). These barriers are to be supplemented by various so-called virtual fencing installations of surveillance towers and supporting facilities along the river.

The new infrastructure impacts the river in various ways that may constitute potential violations of binational treaty commitments and impair natural values that binational management of the river was meant to sustain (Bies, 2007; Segee and Cordova, 2009 forthcoming). Moreover, the procedures employed by this unilateral U.S. initiative direct attention to one of the notable failures of binational environmental governance as presently structured, namely, its lack of articulation with other policy domains at the domestic and international levels. A brief discussion is in order.

Viewed strictly through the lens of U.S. and Mexican treaty commitments, the border fence is troubling for several reasons. First, under the terms of the 1970 Boundary Convention, domestic infrastructure undertaken by either party should not obstruct or deflect the normal flow of the river or its flood flows.[4] This point has already been raised by the IBWC which expressed concern with DHS plans to site a stretch of border fencing along the northside levee along the Rio Grande in the Rio Grande Valley and is coordinating with DHS on fence design in this area (Marin, 2008). The same issue has also arisen along the limitrophe section of the Colorado River.

While levee modifications are an obvious potential hazard and a threat to the integrity of the river and adjacent lands during flood conditions, the impact of other DHS structures on the river's north bank has not been adequately studied. DHS, in issuing the Real ID waiver, did commit to developing environmental assessment and stewardship plans for each affected segment of the fence, providing for limited public comment. While it did not consider itself bound by these findings, it did state it would strive to take environmental values into account (US-DHS, 2008: ES-1). Reports for each affected segment of the boundary were issued in July 2008. With modest exceptions, these are largely compilations of older existing field data available through U.S. Fish and Wildlife and other agencies within the U.S. agriculture and interior departments.

The process has been sharply criticized by stakeholder groups in the Rio Grande Valley and the El Paso area (Sierra Club, 2008). Moreover, where adverse impacts are identified, DHS has consistently determined that national security values (the fence) should trump environmental concerns—see discussion of impacts on the Lower Rio Grande Valley National Wildlife Refuge (U.S.-DHS, 2008: 7.1-7.26) Indeed, the Real ID waiver seems to preclude any serious U.S. government assessment of these potential impacts or accountability. The waiver does not trump international treaties, however; it just trumps the U.S. enabling legislation for those treaties. Under the Boundary Convention and provisions of the Vienna Convention on the Law of Treaties, if adverse barrier effects on the river or the boundary can be shown then Mexico would certainly have grounds for protest and a potential basis for litigation under international law.

Not yet officially raised by the Commission but troubling is the problem of beneficial uses of river water as set out in Article 3 of the 1944 Water Treaty (Treaty, 1944). While the Treaty, as seen above, does not yet specifically safeguard environmental values, it does accord its sixth beneficial use priority to the utilization of the treaty rivers for fishing and hunting which by extension may be interpreted to apply to the protection of wetlands and habitat. An interesting argument can be made that where barriers obstruct access to the river or impede the free migration of species that routinely cross the river—and boundary—that some sort of binational understanding should be reached prior to constructing such works if the other party to the treaty objects. In fact, the IBWC alluded to the wildlife issue in its 2007 comment letter to DHS (Marin, 2008).

While the Treaty law is certainly murky here, what is certain is that the binational value of these wetlands has been well recognized for quite some time. What is also true is that a strong precedent has already been established by IBWC Minute 242, which settled the Salinity Crisis on the Colorado River, that implied uses of river water may be protected (IBWC, 1973).[5] Interestingly enough, the trinational CEC has been engaged with domestic natural resources agencies in documenting and advocating for the protection of wetlands supporting the survival of transboundary species. The only issue in this case, really, is whether the north bank wetlands affected by DHS barrier construction receive any degree of protection under the Treaty. If so, binational consent would seem to be indicated.

The more compelling issue from a governance perspective is that the various binational agencies and programs protecting environmental values on the river are policy isolated from programs related to security and migration. National security, to be sure, is historically a prerogative of national governments and rarely entrusted to international bodies except in the form of strategic alliances. The exceptions, as seen in the case of the United Nations' collective security programs, are controversial. To a somewhat lesser degree the same may be said of immigration and border control policies. In the case of the Rio Grande River which functions as an international boundary, Mexico and the United State both concede their neighbor's right to regulate their boundary as they see fit. The problem here is not with the right to regulate per se but with the straight-jacketed manner in which domestic security is currently practiced, as seen in the case of U.S. border security infrastructure.

As documented in a paper presented in 2006 at the annual meeting of the Association of Borderlands Scholars (Mumme, 2006), there was virtually no representation of environmental concerns in the debate leading up to the adoption of both the Real ID Act and the Border Fence Act, even though the level of infrastructure under debate would arguably exert a greater adverse impact on the border environment than any set of works since the reclamation era. The lack of inter-sectoral review and discussion was painfully evident in congressional hearings and debate leading to the authorization of the Real ID and Secure Fence acts. Not one natural resource agency at the federal or state levels testified and not one international, national or subnational environmental organization testified as to the likely impacts of these measures on fauna and flora or water management. The policy disconnect was complete.

Now more than two years since the Secure Fence Act took effect, a broad coalition of anti-fence activists, environmental organizations, and some government agencies—particularly in Mexico and local governments in the U.S.—has begun to question the policy isolation in which border security measures are made (for a sample of this coverage, see Segee and Cordova, 2009; Paterson, 2008; Millis, 2008; Frank, 2008; Hurowitz, 2007. Also consult *noborderwall* listserve at Yahoo online). The focus here is obviously on the U.S. but the principle applies equally well to Mexico. Various organizations have actively called for repeal of the waiver provisions of the Real ID Act and a restoration of environmental review of national security measures. They are also demanding review of DHS procedures and greater voice in the development and implementation of security infrastructure measure. As the GNEB argued in its 10th report, it seems obvious that security should not be the enemy of sustainable development along the Rio Grande or any other region of the border and that effective governance for sustainable development must extend to security agencies and practices (GNEB, 2008).

In sum, the heightened emphasis on security/immigration infrastructure along the international reach of the river and the boundary as presently implemented threatens conservation and sustainable development values along the river and points to the need for better integrated governance structures, structures capable of incorporating environmental concerns in security protocols. To a considerable extent the present challenge involves U.S. domestic institutions and their articulation with binational water and environment programs. As many have argued, leaving environmental considerations bearing on the boundary rivers strictly to the discretion of the DHS Secretary is not very sensible and may seriously undermine longstanding and carefully designed conservation programs as well as the accrual of binational cooperation for environmental management along the river.

But the problem is not just domestic. Our current binational institutions are also deficient and underutilized (GNEB, 2007). As seen above, the current water treaty regime provides at best weak protection for environmental values in the context of binational relations. As the GNEB has suggested (Table 3), our La Paz procedures and programs are marginalized by security policy and need to be better integrated (GNEB, 2007). At present there is no Border 2012 policy forum or task directed at the issue of border security impacts on border area natural resources. BECC and NADB's potential for mitigating security impacts has also been neglected. In general, the two countries should give greater attention to finding conservation compatible security solutions and binational cooperation in achieving security along the international boundary.

Human Crossing Challenges	Suggested Response/Policy Synergies
1. Environmental damages due to undocumented migrants, smugglers, and interdiction agencies	a) Employ technology to achieve security goals when feasible; b) DHS should identify sensitive natural resources along the U.S.-Mexico border and minimize or mitigate security impacts on these; c) strengthen communication and outreach with land management agencies and DHS to insure public input on project development and implementation; d) establish an office within a relevant federal agency dedicated to analyzing and communicating the impacts of border security on the environment
2. Trash and waste deposited by migrants and drug smugglers is an environmental and health hazard	Provide federal support to tribes, private landowners, rural communities, state parks and protected areas, and federal land management agencies to address sanitation and solid waste issues associated with undocumented crossings
3. Impenetrable fences may present significant negative consequences for wildlife and the environment	Hold national conference on fencing/barrier technology that highlights successes to date and educate the public, with participation from the private sector and nongovernmental organizations. As an outcome, develop recommendations for prototype fences that meet security goals while minimizing environmental damage or even improving environmental conditions
4. Lack of collaboration across agencies with responsibility for border security, land management, and environmental protection tends to lessen the likelihood of win-win scenarios for both security and the environment	a) Establish an interagency Task Force comprised of DHS, DOI, and USDA to develop strategic plans and establish mutual goals regarding law enforcement changes that would affect federal lands, including sensitivity to environmental impacts; b) Federal government should identify communications gaps and place liaison personnel in the border states who facilitate communication among security, environmental, and border land management agencies

Table 3. GNEB identified environmental challenges associated with border security along the U.S.-Mexico boundary.

SOURCE: Good Neighbor Environmental Board, 2007: 19-24.

Transboundary groundwater. Binational cooperation for the sustainable utilization of transboundary groundwater basins is a longstanding border challenge. More than 35 years have lapsed now since the 1973 IBWC agreement, Minute 242, identified the need for a comprehensive treaty on shared groundwater basins (IBWC, 1973). Yet the actuality of shared governance remains in its infancy. While Minute 242 arguably extends the 1944 Treaty mandate so as to place groundwater within the IBWC's jurisdiction, the Commission has yet to reach another formal agreement on groundwater.

Along the international reach of the Rio Grande River it is plain that drought conditions and surface water shortages contribute to greater reliance on groundwater. This is certainly true in the groundwater dependent El Paso-Ciudad Juárez region where the need to utilize groundwater for municipal-industrial needs has led to the world's largest inland desalinization facility. The Kay Bailey Hutchison Desalination Plant began operation in 2007, providing roughly 25 percent of El Paso's municipal water supply from brackish groundwater in the Hueco Bolson (EPPU, n.d.). Ciudad Juárez' Junta Municipal de Aguas and Mexico's National Water Commission (CNA) are contemplating similar measures.

These are not the only Rio Grande River communities contemplating desalination to augment scarce water supplies. The City of Brownsville also draws on a desalination plant using brackish groundwater and just completed a seawater desalinization plant in December 2008 (Regional Water News, 2004: 3; TWDB, 2008a). On the U.S. side of the river at least two Texas border counties have established Groundwater Conservation Districts to control pumping and protect groundwater quality (TWDB, 2008b) and Texas state agencies have prioritized the characterization of groundwater availability and quality in Rio Grande aquifers (GNEB, 2005: 24). Groundwater contamination worries most border communities dependent on this resource.

While formal binational cooperation on groundwater has been painfully slow to evolve and is aggravated by specific disputes along the border as seen in the case of the All-American Canal lining project, some progress has occurred. In 1997-1998, an innovative project supported by the IBWC undertook to compile, study, and share available data on the aquifers in the El Paso and Ciudad Juárez region (IBWC, 1998). The utility of that study for local planners lent support to legislative efforts in the U.S. to authorize a border-wide study of groundwater resources along the international boundary (McHugh, 2005). That effort finally came to fruition in December 2006 with passage of Public Law 109-448, the United States-Mexico Transboundary Aquifer Assessment Act.

The law authorizes the Secretary of the Interior through the U.S. Geological Survey to "characterize, map, and model priority transboundary aquifers along the United States-Mexico border at a level of detail determined to be appropriate for the particular aquifer" (PL 109-448, 2006). The priority basins identified in the legislation are the Hueco Bolson and Mesilla aquifers at El Paso and the San Pedro River and Santa Cruz river on the Arizona-Sonora boundary. Obviously, this requires Mexico's cooperation and that is acknowledged in the statute. In this regard an innovative feature of this legislation its incorporation of Ciudad Juárez' Junta Municipal de Aguas in its Tri-Regional Planning Group. Strongly implied in its language on binational partnerships if not directly stiplulated is the assumption the data will be shared with Mexico to facilitate binational cooperation in managing these transboundary basins. In August 2009 the two countries signed an agreement on implementing the legislation (IBWC, 2009). The study is to be completed in ten years with 50 million dollars authorized in support (PL109-448, 2008).

Other favorable developments at the binational level include support for local and regional watershed planning through the Border 2012 Program and enhanced authority at the BECC and NABD to help fund projects that may incorporate a component safeguarding groundwater resources. In the El Paso-Ciudad Juárez region the activities of the IBWC initiated Paso del Norte Water Task Force (PNWTF, n.d.), convened in 1999, has received some support from the Border 2012 program, principally in the area of water quality assessment. BECC certified water projects may also incorporate groundwater impact data in their sustainable development certification procedures. The IBWC's other citizen's forums have also added value here though these are limited to the U.S. Section.

These are positive governance developments that certain contribute to the long-term advancement of binational groundwater cooperation. Little, however, presently restrains the race to the bottom. As I have argued elsewhere (Mumme, 2005), the likelihood of reaching more formal binational understandings regarding binational groundwater in the near future is slim. Even so, public awareness of the severity of this problem in many border locations is rising and the development of informal relationships and defacto partnerships between U.S. and Mexican stakeholders is emerging in certain locales. This may hold greater promise for binational cooperation in the next five to ten years. At the present time, however, the only initiatives of this sort, with the exception of El Paso and Ciudad Juárez, are found outside the Rio Grande basin.

In sum, binational cooperation aimed at sustainably managing transboundary groundwater still suffers a serious governance deficit. Groundwater is tenuously linked to the 1944 Water Treaty and this needs reinforcement. The federal governments, represented at the binational level through the IBWC and CILA, are reluctant to push powerful national resources agencies and states and localities and would probably fail if they did. Where local support exists, however, the IBWC has facilitated some data development and exchange, as seen in the El Paso-Ciudad Juárez region.

The new federal legislation, if implemented, is also a significant step forward that will generate a better factual basis for assessing groundwater stock and flow. What is needed, however, is greater articulation among binational agencies (IBWC-BECC-Border 2012) and between federal and subnational governments. In the U.S., state governments must do what they can to support local groundwater conservation and informal dialogue with Mexican sister communities sharing the aquifer. It would be helpful, for instance, if BECC gave a systematic certification priority to projects shown to contribute to sustainable aquifer management. At the end of the day, governance solutions for transboundary groundwater management are sure to emerge bottom up, not top down.

Governance Challenges And Rio Grande Water Management: Final Observations

As these cases reveal, binational water management on the Rio Grande confronts a wide range of governance challenges. One distinct set of challenges follows from deficiencies in the treaty regime. Another set of challenges stem the lack of inter-sectoral integration among policy fields as seen with security infrastructure on the border. Other challenges arise from the limited articulation of binational institutions with each other and with the public and stakeholder communities which they serve.

The importance of advancing the treaty regime is well recognized but difficult to achieve. The 2005 binational water summit convened by the IBWC underlined a number of needed reforms in the spirit of the Minute 308 and 309 commitments. These include the development of a basin wide advisory council to the IBWC, the development of a further agreement specifying the interpretation of the Article 4 “extraordinary drought” provision, a binational agreement protecting wetlands, specifying the role of IBWC and other binational, national, and state and local agencies in determining and responding to drought emergencies, further protocols on data sharing and collaboration between IBWC and national resource agencies in both countries, and coordination of regional water planning between state and national agencies in each country under the formal auspices of the IBWC.

The need for a binational agreement or multiple agreements on groundwater management is certainly evident. Other proposals have focused on the authority and composition of the Commission itself and its role and relations with the national foreign ministries. The problem of inter-sectoral coordination that is so much in evidence in the case of national security infrastructure is another very challenging obstacle to better river management. If national security administration is to figure as highly in the crafting of boundary area infrastructure as it presently does, then it should be developed in a coordinate manner with other affected agencies, including those tasked with the environmental protection, natural resource conservation, and the sustainable development of the border region.

This has been recognized by the GNEB's 10th report and should be front and center on the agenda of both the Obama administration and the government of Felipe Calderón. It should begin with repeal of the poorly considered waiver provisions of the Real ID Act and continue with the re-crafting of inter-agency advisory bodies to DHS. It should also be reflected in the reconfiguration of congressional committees such that environmental concerns may be reflected in legislative deliberations on security. Beyond this, the U.S. and Mexico should extend their current level of cooperation on border security, now focused almost exclusively on narcotics interdiction and terrorism, to include discussions on mitigating harmful threats to both countries in ways compatible with the sustainable development of both countries, especially at the border and including the Rio Grande.

The task of achieving greater articulation among existing binational water and environment agencies is also formidable. Without a doubt the emergence of new institutions and the evolution of existing programs under the umbrella of the La Paz process have enhanced the overall capacity of the two countries to address water issues on the international reach of the Rio Grande River. These reforms have also generated new opportunities for citizen participation within the context of binational water management and more "bottom-up" opportunities for influencing the binational river agenda of the sort often advocated in the basin (see, for instance, U.S.-Mexico Binational Council, 2003: 8).

Yet while these new and reformed bi-national institutions and programs have overlapping and sometimes complementary mandates, factors that reinforce binational capacity to address critical problems, they remain functionally distinct, with different organizational imperatives and constituencies. In the absence of any one over-arching institution capable of articulating a strategic vision for the sustainable development of the basin, they are too often delinked from each other's work.

In sum, the structure of binational water governance on the Rio Grande leaves much to be desired. But we have seen progress. The additional capacity that our new institutions bring to border water management is evident in each of the issue-areas reviewed above. In the case of Mexico's water payments the conservation solution is underwritten by the NADB and certified by the BECC, providing a long-term solution and an opportunity to improve existing agricultural practices that benefit both countries. More can certainly be done and the IBWC must move forward with the agenda outlined in the recent binational summit. In the area of security, the value of the treaty architecture and our newer institutions has recently been on display. The IBWC is mindful of the need to take river and boundary management into account even in the design of nationally based infrastructure, the CEC demonstrates the importance of the river in conserving transboundary species and ecosystems, while the BECC and NADB could be utilized to explore environmentally sustainable solutions that advance security values.

If we look at the groundwater situation where so little formal progress has been achieved, the advances that have been made draw on a mix of agencies and initiatives including the IBWC, Border 2012, and BECC in generating databases and supporting local and regionally based groundwater protection initiatives. This suggests the utility of further collaboration among these agencies and the importance of continuing to develop partnerships and collaborative initiatives that advance binational cooperation in managing this extraordinary shared resource, the Rio Grande.

Notes

1 All references to the IBWC in this paper also apply to the Mexican Section, Comisión Internacional de Límites y Aguas (CILA) unless otherwise specified.

2 The U.S. IBWC's Citizens' Forum initiative was launched in 1999 under then Commissioner John Bernal. The first such forum was established in the El Paso-Las Cruces reach of the Rio Grande. The Lower Rio Grande Citizens' Forum was established in 2003.

3 It bears mentioning that the merger of the BECC and NADB boards in 2005 eliminated IBWC's ex-officio representation on the joint board of directors. Just how this affects coordination between IBWC and these two agencies remains to be seen.

4 The 1970 Boundary Treaty obligates each nation to maintain the integrity of the boundary including the limitrophe reaches of the two boundary rivers, the Colorado and the Rio Grande. Article IV of the Treaty allows each nation to build works on its side of the river to prevent erosion, contain floods and preserve the boundary so long as these works do not adversely affect the other country and are approved by the Commission. Each nation is also obligated to prohibit works in its territory that the Commission determines would cause deflection or obstructions of the river. The Treaty thus places the Commission as a binational body in the position of authorizing such works, a condition that requires the explicit consent of the neighboring country; a nation's obligation to prohibit works is, however, contingent on the mutual agreement of both members of the Commission, allowing each nation the option, in effect, of blocking an effort to prohibit its works. While the physical infrastructure mentioned in Article IV is channels and levees the intent of the wording is clear and would arguably extend to all works affecting the position of the boundary and the normal flow of the river (Treaty, 1970, Art. IV).

5 Mexico's argument in the Salinity Crisis was that municipal and agricultural uses of treaty river water expressly identified as priority uses of treaty river water in Article 3 of the 1944 Water Treaty were protected under the treaty even though the same treaty obligates Mexico to accept water from "any and all sources" on the Colorado River. Mexico's argument was validated by Minute 242 in which the United States accepts an obligation to provide usable water to Mexico (Treaty, 1944). Minute 242 thus has the effect of affirming a binational obligation to honor treaty water use priorities and address differences in this area on a binational and not a unilateral basis.

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A Few Thoughts On Water, Trade, And Peace In The Jordan Valley

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The author, a former senior UN official, argues that any lasting solution to the Arab/Israeli conflict will require repair of broken trade links, particularly trade in agricultural products. The complicated water issues of the region will not be easy to solve. Yet among the many other issues in dispute, recent history of the Jordan shows that solutions are possible. As a first step, however, governments will need to reconsider their policies on water use, and in particular, on subsidization of export crops.

Conflict around a water channel comes as no surprise to any soldier, historian, or hydrologist. After all, the word "river" has a common origin with the word "rival." Beyond simple rivalry between those who draw water upstream and those further downstream, there are many issues of how each party ultimately uses those waters and how the commodities—particularly agricultural commodities—produced from those waters are later traded. The Israel/Arab conflict obviously involves much more than the allocation of the Jordan River's waters between the surrounding countries. Yet allocation of those waters has played and continues to play a central role in the conflict.

In this paper I look on the water problems of the Jordan Valley partly in terms of interrupted regional trade in agricultural commodities. I also look at these broken trade links in terms of the trading communities, which once served as the backbones of trade between the great cities of the Middle East, and argue that restoration of trade links will require an ethnic "re-mixing" of the region. Water is an extraordinarily precious commodity in and around the Jordan Valley, and particularly so in arid Israel and Jordan. With or without a wider peace agreement, countries of the region need to carefully review how they use water and the products they produce from water. In particular, governments need to question agricultural subsidies and ask themselves whether growing bananas, strawberries and even fish in the desert really makes sense. This question becomes particularly relevant when crops are subsidized in the name of national food security, but then are exported to foreign markets. As one might expect, efforts to reform pricing structures for irrigation water face strong opposition by farm lobbies.

Syria is the major agricultural producer of the region. Improved trade in agricultural products between Syria and Israel must be an objective of any peace agreement. There is need, as well, to think "beyond the Valley" in considering how agricultural trade might serve as an element of a more stable Middle East. In particular, Turkey, Egypt, and Sudan offer important opportunities to expand agricultural production and trade.

Figure 1. Countries surrounding the Jordan Valley.

International law on sharing of transborder waters remains weak. Although an international convention was finally agreed in 1997 (after some 24 years of negotiations), today it still lacks the number of national ratifications needed to turn it into formal law. In addition, two important concerns still lie outside this convention—the sharing of waters in "closed basins" (such as the Jordan Valley) and the sharing of transborder groundwater aquifers (such as in the West Bank and Israel). Un-ratified law, however, is better than no law at all. At minimum, the convention can provide guidance and an informal basis for sorting out issues. I have included several annexes which may be of interest to the reader. Annex 1 summarizes my suggestions on positive actions governments can take. Annex 2 recounts events of the 1950's when the U.S. took a heavy hand in mediation of the Jordan water dispute. Annex 3 describes two other water-sharing challenges facing the region: The Tigris-Euphrates and Nile rivers. Annex 4 summarizes international law regarding sharing of water.

An Oversimplified View Of Some Very Complicated History

The Jordan Valley intersects several historic trade routes. The Middle East is, after all, "the middle", the place where Africa, Asia and Europe meet. The Jordan Valley cuts north to south across much of this "middle." One might expect then that the Jordan Valley would be rich and heavily populated. This is not the case. Unlike most other valleys, people living around the Jordan Valley have not—at least until very recently—seen it as a good place to live or to work. The Valley has remained an obstacle to cross, not a place to reside.

Traditional trade routes either ran through more difficult terrain in the highlands, parallel and on either side of the Valley, or crossed it quickly before again ascending to the high ground on the other side. Reluctance to travel or live in the Valley reflects its vulnerability to attack, and more importantly, the fact that drinkable water exists in only a small northern part of the Valley. There is also the fact that most of the Valley lies well below sea-level, and people simply prefer to live elsewhere. This latter idea may seem odd to the tourists who today crowd luxury hotels along the Dead Sea or the Sea of Galilee, or to rich city-dwellers who on cold weekends escape to warmer temperatures on their "farms" in the Valley. Still, the fact remains that few people feel comfortable living year-round below sea level and, as a consequence, the Valley largely remains today a place to visit rather than a place to live.

Even today, there are only three significant cities in the Valley—Tiberias in the north (population around 40,000), Jericho in the middle (population about 20,000) and in the south the twin port cities of Eilat in Israel and Aqaba in Jordan (combined population about 142,000). Compare this small valley population with the surrounding highlands where great cities abound: Jerusalem (748,000), Amman (2.1 million), and Damascus (4.1 million).[1]

During most of the period of Ottoman rule (roughly 1512 to 1918) the Valley remained a wild and neglected part of the empire, known principally for banditry of caravans of merchants and pilgrims. Towards the end of the 1800's, as their empire began to weaken, the Ottomans tried to improve security in the area by settling nomadic bedouin tribes (with only moderate success), as well as bringing new immigrants from other parts of the empire, notably the Circassians from the Caucasus (with much greater success). In the early part of the 1900's the Ottomans built a railway system which included north/south routes parallel to, and one east/west line across the Valley. Railways allowed traders and pilgrims to avoid its dangers, as well as supporting export of the only significant crop at the time—sugar cane.

For all of its many faults, by its end in 1918 the Ottoman Empire had provided for at least 400 years a single economic and political environment in which trade and communication could take place. Moreover, this vast imperial territory had its origins much before the Ottomans—at least as far back as the Persian Empire (roughly 530 BC) and through Phoenician, Greek, Roman, Byzantine and Ottoman periods. The British defeat of the Ottomans in 1918 thus marked the end of a very long period of fairly easy north/south and east/west trade and communications.

In the late 1800's the Ottoman Empire started to unravel. Part of this decline was due to foreign pressure and loss of territory. Part was due to inability to compete with the West in terms of commerce and technology. Part was simply poor leadership. Ethnic tensions grew. Wars in the border regions—the Balkans, Caucasus, Egypt, etc.—were accompanied by massacres of ethnic groups thought to be disloyal, most notably Armenians, Greeks, and Jews.

World War I provided the final act in the collapse of the Ottoman Empire. In order to undermine the Ottomans and their German allies, the British championed on the one hand Arab nationhood and on the other creation of a Jewish homeland. In the process the British double promised the lands around the Valley to Arab and Jewish nationalists. Meanwhile, the British and French secretly agreed to divide—at least temporarily—most of the region between themselves. As a result, after the war ended France took control of what is now Syria and Lebanon. Britain took control or strengthened already existing control over most of the rest (i.e. what is now Israel, the West Bank, Gaza, Jordan, Iraq, Egypt and Sudan). Remaining parts of the Empire were reformulated as independent Turkey, Saudi Arabia and Yemen.

Between the World Wars the process of national and ethnic division accelerated. The British began dividing their mandated territories almost immediately, first separating Iraq from Palestine in 1921 and then dividing the remainder into Palestine and Transjordan in 1922. The French separated Lebanon from Syria in 1926. Although all these lands were under British or French control, "proto-national" governments quickly took shape, forming the basis for the independent states which appeared after World War II. The current map of the region became complete in 1947 when the British withdrew from their mandate over Palestine. The following year Israel achieved independence through a war with surrounding Arab states. Later wars resulted in further shifts of territory. In terms of the Valley, the 1967 war resulted in Israel occupying the West Bank (Jordan's mandate) and the Golan Heights (Syrian territory) and thereby gaining control of most of the sources of the Jordan.

Middle-eastern trading families were particularly hard-hit after the 1948 war. Whether due to pull or push or both, Jewish trading families left the cities where they had lived for centuries and migrated to Israel. At the same time Palestinian traders became refugees in neighboring countries. Similar disruption occurred among other ethnic groups—Arab, Armenian, Circassian, and Druze. Both Israel and Arab states imposed new restrictions on those who remained. This made communications and travel difficult for businessmen and traders, who now found themselves separated by new borders. Trade and travel now came to involve crossing multiple borders.

After 1948 the Arab League imposed a boycott on Israel and on any foreign businesses trading with Israel. This boycott and continuing hostility between Arabs and Israelis produced yet another important split in trade relations within the region, leaving Israel isolated from its neighbors and encouraging instead trade with more sympathetic but also more distant partners, most especially in the U.S. and Europe.

The oil boom of recent decades led oil-producers and oil-consumers to form close trading links, often at the expense of regional links. Countries like Syria, Lebanon, and Egypt oriented their education systems more towards Europe and North America than to their Arab neighbors. The oil boom drew more and more educated youth into Gulf countries where they did most of their business with oil-consumers in the West. It is no exaggeration to say that today many educated Arab and Israeli youth know far more about the U.S. and Europe than about their neighboring countries.

Finally, economic sanctions were employed by the U.S. and its Western partners as a means of pressuring individual countries in the region. Iraq suffered under sanctions from 1991 to 2003. Syria, Iran, and Sudan remain under sanctions today. Beyond formal sanctions, the West often vetoed development assistance by the World Bank, IMF and other institutions.

The result of all these factors is a much fractured pattern of regional trade, in which most players have far closer links with distant countries than with their immediate neighbors.

What's All This Got To Do With Water?

Throughout most of history the Jordan Valley remained a relatively empty and often dangerous place. It was therefore not surprising that the Valley would eventually form a conflict zone between new states. As elsewhere, water was highly prized, and all the more so in this unusually arid region. The new countries all needed water to satisfy both food security for their growing populations and to allow development of new export crops.

Books about "water wars" often cite the Jordan Valley as an example of how such conflicts multiply and intensify. There is no doubt that water resources have been an aspect of the Valley's wars, and that some level of conflict is likely to continue. Yet what is remarkable about the Jordan Valley is that several major issues have been settled by quiet negotiation and understanding of each other's needs, instead of war.

As described in Annex 2, the U.S. in the 1950's played a major role in an initial settlement of water sharing issues between Israel and Jordan. This was achieved partly by a "carrot and stick" approach: on the one hand, cutting off aid; and then on the other, agreeing to finance major water systems for both countries, so long as they would adhere to an initial agreement over water sharing. Syria and Lebanon were largely left out of these arrangements, although neither was particularly affected by them. What is interesting to note here is that neither Israel nor the Arab states ever actually agreed to the proposed division of water (the Arab side, in fact, formally rejected the agreement). Yet all sides adhered to their allotted shares for nearly 40 years,[2] making minor adjustments to accommodate times of water shortages, and settling disputes as they arose.

Despite Israeli military hegemony over the Jordan Valley, Israeli action to control water resources has not always been unilateral. The 1967 Arab-Israeli war led to Israel capturing both the West Bank from Jordan and the Golan Heights from Syria. The capture of the Golan Heights presented a major change in the surface water equation, as Israel now had control over the Banias River, the second of the three sources of the upper Jordan River (the first of the sources, the Dan, had been in Israel's control since 1949).

In 1978 and again in 1982 and 2006 Israel invaded southern Lebanon and thereby gained control over the third source of the upper Jordan, the Hasbani River. More importantly, when Israel occupied southern Lebanon from 1982 to 2000, it had control over the Litani River, long considered by Israel as a potential source for additional water to be diverted to the Jordan. What is remarkable is that despite having full control over all three sources of the upper Jordan, plus potential control over Lebanon's Litani, Israel made no significant changes in earlier water sharing allotments with Jordan or Lebanon. Water issues between Jordan and Israel and between Jordan and Syria have focused on the Yarmouk River, the Jordan's major tributary south of the Sea of Galilee. The Yarmouk initially forms the border between Syria and Jordan, and subsequently the border between Jordan and Israel. South of the Sea of Galilee, the Jordan's waters are for the most part too saline and too polluted for use, even after meeting the Yarmouk. The drawing of waters from the Yarmouk upstream from the Jordan is thus important to all three countries. Despite many disagreements over damming of the Yarmouk and unregistered withdrawals from the river, the three countries have so far been able to work out difficulties as they arise.

As part of their 1994 peace agreement, Jordan and Israel renegotiated the allocations set down in the earlier American-brokered agreement. While many will argue that this "final" division of waters was just as unfair to Jordan and to the West Bank (which had no voice in these negotiations) as the earlier agreements, the interesting fact is that the two countries managed to reach peacefully a stable basis for future national planning. Moreover, the agreement for the first time addressed (albeit in very general terms) the issues of groundwater and the possibilities of cooperation in developing new water sources, such as desalination.

Past progress in sharing water between Israel and Jordan does not mean that other important issues of water sharing will be settled easily or soon. Still ahead are critical issues of water allocations in the Golan Heights and the West Bank. Yet the Israeli/Jordanian history does give a positive precedent for settling issues through negotiation instead of war.

Looking at it another way, it is possible that among the many difficult issues facing any future peace agreement, water might be the easiest to settle. Consider the other complicated issues seen as most critical to any future comprehensive peace agreement:

- The future of Israeli settlements in the West Bank.
- Guarantee of an Arab East Jerusalem with free access to it.
- Protection and assured access to Muslim, Jewish, and Christian holy places throughout Jerusalem and the West Bank.
- Palestinian control over their borders.
- Return of the Golan Heights to Syria .
- Return of the Shebaa Farms to Lebanon and final definition of an Israel/Lebanon border.

Against these complicated issues the remaining water issues are:

- Syria's "unregistered withdrawals" from the Yarmouk (Jordan/Syria agreement and Israeli "understanding").
- Control over the sources of the Banias River and access to the Sea of Galilee (assuming eventual return of the Golan Heights to Syria).
- Creation of a joint management structure for the Hisbani River.
- Defining the West Bank's share of Jordan and Yarmouk River waters (assuming eventual creation of an independent Palestinian state).
- Control over the West Bank's ground water aquifers (requiring a formal Palestinian/Israeli agreement).

None of the water issues will prove easy to settle, but at the same time none involves the emotional baggage and security concerns implied in questions like "who 'owns' Jerusalem" and "what will become of Israeli settlements."

And Agriculture?

Taken together, the agricultural sectors of Israel, Syria, Jordan, Lebanon and the West Bank,[3] make a contribution to GDP of about $30.2 billion.[4] In most economic aspects Israel dominates the region. In agriculture, however, Syria dominates, earning about $21.7 billion (about 24 percent of its annual GDP) from agriculture. By comparison, Israel earns only about $5 billion (2.7% of its GDP) and Lebanon about $2 billion (5%) from agriculture. Jordan and the West Bank trail far behind ($996 million and $403 million respectively).

Considering the "Valley countries" as a whole, Syria has 83% of the arable land and 78% of the irrigated land. By contrast, Israel has only 6% of the arable land and only 11% of the irrigated land.

I am not suggesting that Syria alone could "solve" the agricultural deficits of its neighbors. Syria has a big population and is, therefore, a big consumer. Like the other countries of the region, Syria is a net importer of grain. Moreover, as in other countries of the region, much of Syria's agricultural production is of non-food crops, especially cotton, and of other crops grown for export, such as fruits and vegetables.

The food and agriculture problems of the region cannot be solved simply through improved trade. However, improved trade, plus joint planning and monitoring, could help alleviate current problems, including the scarcity of water for irrigation. As Syria is the dominant country in agriculture, it follows that agricultural trade with Syria needs to figure in discussions of peace. Moreover, there is a strong case for closer coordination of all countries around the Valley in planning and monitoring demand and supply of food crops. Such planning should seek to address national concerns about food security and prices. Other developments could include the creation of regional food storage "banks" and investment facilities for agricultural development.

In the wider region Turkey and Egypt have enormous agricultural sectors. Iraq also has the potential to regain its former huge agricultural potential. The agricultural sectors of the three countries together contribute a total of $137.1 billion towards their joint GDP, dwarfing the $30.2 billion earned jointly by the "Valley countries."

This fact provides an incentive to think "beyond the Valley." In fact, at the moment only Turkey and Iraq (i.e. the Euphrates and Tigris basins) have the capacity to increase significantly their agricultural production. However, in the future the Nile Valley might also be able to expand production—not in Egypt, but in Sudan and

Ethiopia. What would be needed is improved investment in the agriculture sectors of both countries, along with better planning and coordination.

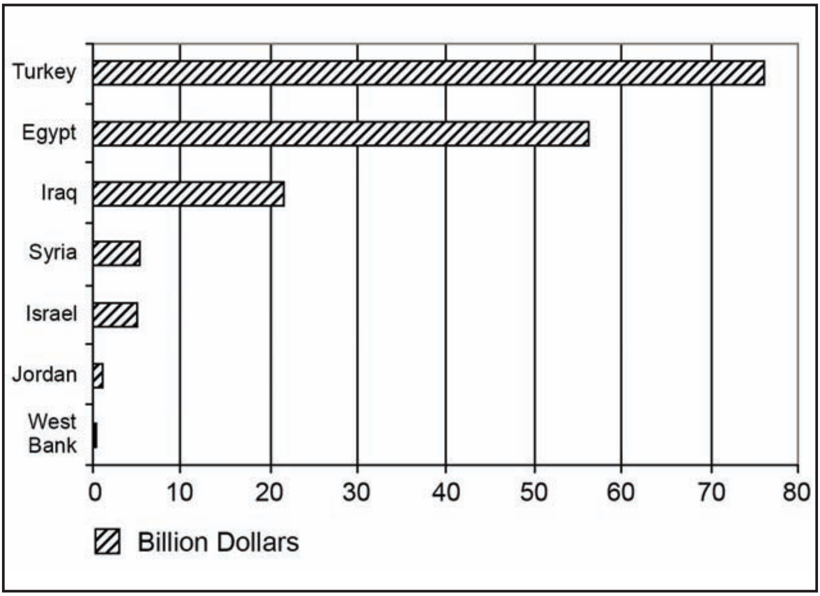

Figure 2. Value of agricultural production.

Professor Tony Allan introduced in 1998 the useful concept of "virtual water", as a means of measuring the production cost and value of any product. Allan points out that since the early 1970's most countries of the Middle East have been able to feed their populations only by substituting imports of cheaper grain for expensive irrigation water. As Allan puts it, "More water 'flows' into the Middle East each year as 'virtual water' than flows down the Nile into Egypt for agriculture."[5]

Seen in terms of investment of scarce irrigation water, growing a metric ton of wheat "costs" approximately 1,300 metric tons of water. Therefore if a country imports a ton of wheat, instead of growing it locally, there is a "savings" of 1,300 metric tons of water that can be put to other uses. In arid countries like those around the Valley, such savings are important. Unfortunately, at the same time that countries are "saving" some irrigation water via imports, they are also exporting water in the form of fruits, vegetables, cotton, etc.

Carrying the concept forward, Allan points out that drinking, domestic, municipal and industrial uses require only about 20 to 100 cubic meters of water per person per year. On the other hand, growing the food for one person requires about 1,000 cubic meters per year.[6] Thus, there is a strong incentive for arid countries to give priority to the use of scarce water for domestic and industrial use and to minimize the use of water for irrigation of export crops. From the water devoted to crop irrigation, there is a clear priority for non-exported and high-value crops—in particular, fruits and vegetables for the domestic market.

While the economic case may be clear to planners, the existence of strong farm lobbies and concerns for food security present major obstacles to logical allocation of limited water resources. All countries worry about their access to basic foodstuffs in times of scarcity or crisis. Moreover, countries worry that once a farming sector has disappeared, it may well be impossible to resurrect. As a result, many countries end up providing irrigation water to farmers at prices far below the real costs of drawing and transporting that water to their fields. While costs of processes like desalination have fallen and will continue to fall, the resulting water is likely to continue to be very expensive. As "new" water from desalination becomes available, countries will need to sort out "real-cost" pricing mechanisms. This likely means that they need to establish different prices for each type of water—desalinated, ground, and piped surface—reflecting the real costs of discovery, production and delivery to field.

And Trade?

One point of this very over-simplified review of history is that in a comparatively short period of time (1918 to 1948) the Middle East moved from a long-established and unified trading zone to a patchwork of small states, each holding different and often conflicting views of national needs, including trade, industry, and agriculture.

It is useful to think of trading organizations in the Middle East not in terms of western companies, but more as far-flung families and ethnic communities. By 1918 the steady disintegration of the Ottoman Empire and accompanying ethnic strife had already shaken many communities and trading families. As new governments took hold and a sense of ethnic nationalism grew, family units found it increasingly difficult to maintain their trade relations across borders. The problems were not simply the differing tax and customs rules in the new states. Many families found that their particular ethnic group was no longer welcome in their new "nation." Migration followed, as families tried to redefine themselves inside new national boundaries. As a result, trade suffered.

Trade is an essential part of any successful regional economy. On the one hand, enhanced trade will require full integration of Israel into a regional economy through rebuilding trade links with neighbors. The U.S. has tried to force renewal some trade relations between Israel, Jordan and Egypt, using free trade agreements and tariff reductions to induce Arab firms to participate in the manufacture of Israeli products entering the U.S. market. The result has been similar to the US/Mexico experience of *maquiladora*[7] factories. The factories are often located far from local populations. Much of the labor has been imported from countries as far away as Bangladesh. The products manufactured are almost never seen on local markets. There is thus little local "stake" in such manufacture. The only effect of these industries seems to be an increased dependence of both Israeli and Jordanian exporters on the U.S. market.

Sanctions have also caused serious disruption of the regional economy. Trade relations with Iraq were cut off from 1991 to 2003. These relations were particularly important to Jordan, Syria, and Turkey. More recently, Syria and Iran have been hit by sanctions. Banking restrictions and vetoes of World Bank loan proposals are other frequently used tools of Western policy aimed at isolating and punishing regimes. Western countries need to re-examine their tactics. There is a need to consider whether sanctions are worth the long-term costs in disruption of the regional economy.

Trade relations depend on much more than governments. Trade relations imply a network of traders who know and trust each other. In the Middle East this knowledge and trust usually implies families and supporting ethnic communities. These families and communities need to live in various parts of the region with each feeling secure and "at home" in a particular country.

Much will depend on the ability of families to migrate, settle securely and communicate freely. Any future peace agreement thus needs to look to more than government relations, but also to facilitate travel, migration, and settlement of traders. In short, what is needed is encouragement to traders to re-populate and "re-mix" each other's markets.

And Borders?

A second point of this brief history is to note that the conflict over the upper Jordan Valley has its origins not in the creation of Israel in 1948, but rather in the division of French and British mandates in 1922.

Confusion about the exact shape of the border between French and British mandates continued up to the end of World War II. Many years later this lack of precision led to conflict between the successor states. The continuing debate between Israel, Syria and Lebanon over the Shebaa Farms has its origins in this confusion (some maps show the area as part of Syria and others as part of Lebanon[8]).

Most borders of the region have been fought over in recent years, but none is particularly well grounded in history or ethnicity. The Valley today remains lightly settled and most of those who live there are migrants or settlers whose families arrived in recent years. Druze and Alawites living in the northern Jordan Valley have divided loyalties and many hold actual citizenship in neighboring countries. The longer governments delay reaching permanent border agreements, the harder it will become for affected populations to re-settle once final borders are drawn.

And Population?

The countries around the Valley already have large populations and significant growth rates. The total population of Israel, the West Bank, Jordan, Lebanon and Syria is presently about 39.4 million people. By 2050 the UN projects that this population will grow to 68.2 million. As in other areas of the world, competition for resources such as water and arable land will increase at least as fast as the population.

Population	Growth Rate
Lebanon	1.15%
Israel	1.7%
Syria	2.2%
West Bank	2.25%
Jordan	2.34%

Table 1. Population growth rates.
SOURCE: CIA Factbook. Statistics as of 2007.

By 2050 Syria's population alone is expected to amount to nearly 35 million people, roughly equivalent to the entire population living today in the four countries. More important, the region already has a very large proportion of people living below their respective national poverty lines. The total number of people "living in poverty" currently amounts to about six million, or nearly 17% of the population. If the current rates of poverty continue to 2050, there will be some 11.4 million people "living in poverty."[9]

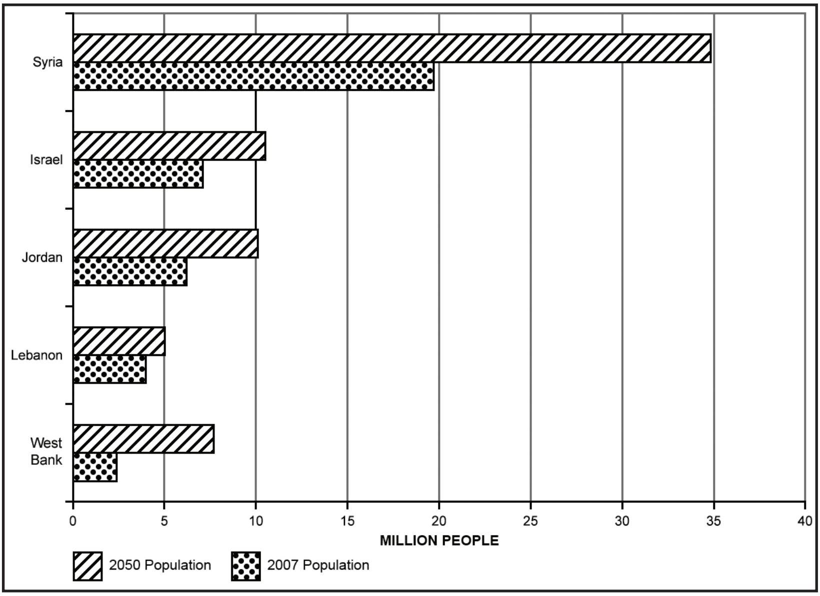

Figure 3. Current and projected 2050 populations.

SOURCE: CIA Factbook Projections Source: UN Statistical Database. Statistics as of 2007.

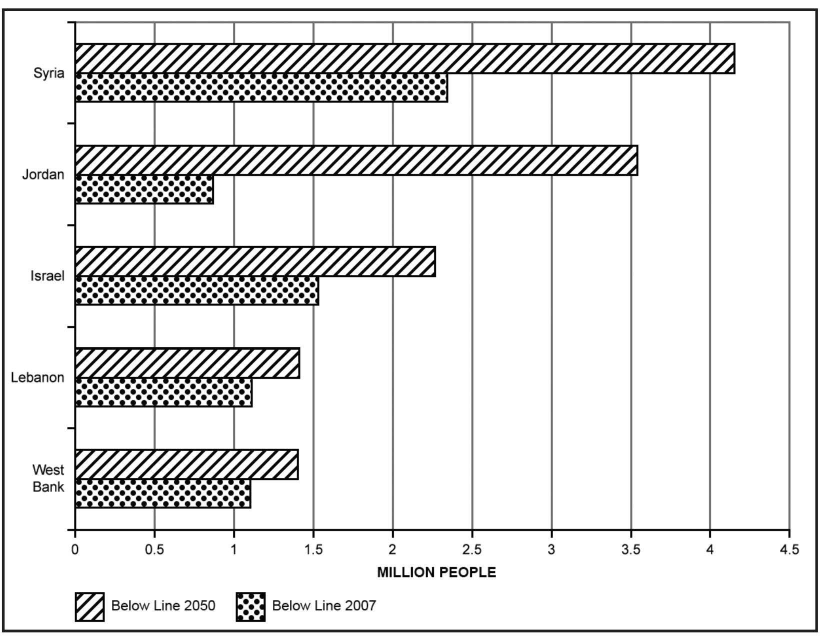

Figure 4. Population below poverty line 2007/2050.

SOURCE: CIA Factbook Projections Source: UN Statistical Database. Statistics as of 2007.

In short, the region is poor and fast-growing. If major changes in the economics of the region do not take place soon, the situation of the poor will become dramatically worse.

Moreover, the Valley countries are bordered by other fast growing countries with high rates of poverty, in particular, Iraq and Egypt. Egypt, for instance, currently has a population of nearly 82 million and is expected to grow to 121 million by 2050. Twenty percent of Egypt's population currently lives below its poverty line. If this rate holds, it implies a 2050 population "living in poverty" of about 24 million people, or more than twice the projected 11.4 million poor people living in the four "Valley countries" by 2050.

Final Thoughts

Since the fall of the Ottomans in 1918 and the creation of Israel in 1948, the Jordan Valley has gone from a neglected area to a front-line of conflict. Yet, despite the history of conflict, the Valley also shows hope for the region. Patient negotiation, maintenance of informal agreements, and respect for "understandings" have resulted in a basis for water-sharing and plans for future cooperation. Clearly, there is still a very long way to go before we can talk of a stable region. The stakes are high—not just for the countries around the Jordan Valley, but also for the world.

Nationalism needs some serious rethinking in the context of the Middle East, where family, tribe, and ethnicity play such important roles. Governments need to take steps to re-open their countries to the diverse populations which characterized their cities just a century ago. This will require that they guarantee the rights of ethnic and religious minorities, giving them a sense of freedom, "home" and participation in national decisions. A sustainable peace will require a return to more open borders, improved trade, and, above all, a new sense of ethnic and political tolerance.

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Annex 1: What Can Governments Do?

Water

Begin negotiations soon on the remaining water issues of the Jordan Valley, even if bigger political questions remain unsettled. Remember that past experience indicates that un-signed and even un-acknowledged agreements are better than none at all. Governments outside the region could help in financing independent and politically neutral technical plans. Issues where planning and negotiations need to get underway soon include:

1. Allocations of the Yarmouk between Syria and Jordan.
2. Allocations of the Yarmouk and Jordan between the West Bank, Israel, and Jordan.
3. A joint Israel/Syria planning and management structure for the Banias (note that this needs to be done before, not after, the wider question of return of the Golan Heights).
4. A joint Israel/Lebanon planning and management structure for the Hasbani (as with the Banias, this issue should be separated from the wider question of the return of the Shebaa Farms and the final definition of the Israel/Lebanon border).
5. A joint Israel/Palestinian planning and management structure for the groundwaters of the West Bank.

Agriculture

1. Create a regional plan on food security and agriculture. As with water, countries outside the region can help in financing a politically-neutral plan.
2. Establish a permanent food and agriculture monitoring structure.
3. Consider establishment of food banks and joint agriculture investment facilities.
4. Within the Valley put particular emphasis on cooperation with and agricultural development in Syria.
5. Beyond the Valley look to Turkey, Iraq, Sudan and Ethiopia.

6. Carry out careful analysis of the “virtual water” content of agricultural imports and exports. Use this analysis to reset priorities for use of precious irrigation waters.
7. In setting priorities weigh the relative value of water for domestic and industrial consumption vs. agricultural uses. Pay particular concern to the use of irrigation water used to grow export crops.
8. Ensure that irrigation water reflects the full costs of delivery
9. Review other subsidies to agriculture in arid zones.

Trade

1. Consider trade as a key element in any peace agreements.
2. End the Arab boycott of Israel (the boycott is already effectively dead).
3. Let national leaders take visible public steps to endorse and encourage Arab/Israeli trade.
4. Encourage resumption of regional trade links through use of eased tariffs, customs and border procedures.
5. Discourage the establishment of “maquiladora” industries and so called “free” trade agreements.
6. Review the proper limits and costs to long-term stability of the region before imposing economic sanctions against governments in current disfavor.
7. Ease problems faced by businessmen and traders in travel and communication.
8. Encourage the re-mixing of ethnic communities by reviewing laws on nationality and migration.
9. Publicly support the principles of ethnic and religious diversity. Encourage ethnic communities to maintain language and traditions.

Borders

Settle the remaining border issues:

1. The Shebaa Farms and the Israel/Lebanon border
2. The Golan Heights
3. The borders of the future Palestinian state

Poverty
Take all steps possible to reduce poverty, including:

1. Investing in primary and secondary education, particularly for girls
2. Creating new and stable employment
3. Improving child survival and thereby encouraging smaller families

International Law

1. Work for ratification of the international Convention
2. Where international law is lacking, encourage partners to study and apply customary law and "good practices" from elsewhere

Annex 2: The Value Of Outside Mediation (Or Interference?)—Eric Johnston And The "Unified Plan"

The Jordan Valley's water issues first grew serious in 1953 when Israel began building diversion works above the Sea of Galilee. This led to fighting with Syrian forces and a diplomatic confrontation, first with the UN and later with the US. Both saw the diversion work both as a violation of the 1949 Armistice and a threat to Jordan. Fearing another war, the U.S. cut off all aid to Israel. It was in this tense atmosphere that U.S. President Eisenhower decided to press for an agreement between Israel, Syria and Jordan on sharing of the waters.

When U.S. Ambassador Eric Johnston arrived in the Middle East in October 1953, he carried with him instructions from Eisenhower to negotiate the "mutual development of the water resources of the Jordan River Valley on a regional basis for the benefit of all the people of the area."

Despite a wealth of experience, Johnston was an unlikely choice for such an assignment. After all, two areas in which Johnston had little or no knowledge were the Middle East and water.

To put it mildly, at age 57 Johnston had already enjoyed a colorful career.[10] A former stevedore and shoe salesman, Johnston joined the Marines during World War I, and rose to the rank of Captain, eventually becoming Military Attaché in Beijing. Injured and retired, Johnston restarted his U.S. career as a vacuum cleaner salesman, but ended up buying the company and turning it into a major appliance manufacturer. He eventually became President of the U.S. Chamber of Commerce. During World War II President Roosevelt appointed Johnston as a special envoy to South American countries and later to Russia.[11] In 1946 Johnston became the President of the Motion Picture Association. During the McCarthy era Johnston became infamous for agreeing to institute the "Hollywood blacklist" of actors and others in the film industry suspected of Communist-sympathies.

By 1953 the UN had already commissioned the Tennessee Valley Authority to study possible water divisions for the Valley. The TVA then contracted the work to an American consulting company, Chas. T. Main (a plan therefore later known as the "Main Plan"). Previous plans had been commissioned respectively by Israel and the Arab states, but this was the first independent study of the problem.

From the beginning Johnston believed that neither side was likely to accept any plan "as written." He understood, however, that it was useful to have something to put on the table and allow the parties to fight over. Johnston invited both sides to propose changes and continued technical discussions over a period of two years. After two years of debate and adjustments, technical committees representing the two sides reached agreement and recommended adoption of the plan. Israel's Knesset decided not to vote on the plan and the Arab League outright rejected it, arguing that to do so would constitute recognition of Israel.

Some might have viewed such an outcome as failure. In fact, it was the beginning of a success story. The U.S. offered funds to both Israel and Jordan to build their respective water systems, so long as they continued to adhere to the allocations set out in the final plan. Israel constructed its National Water Carrier and Jordan built its East Ghor Canal. Long after the U.S. funding ran out, both countries continued to adhere to the allotments set down in the un-signed agreement. There were disputes, particularly in water-short periods, but these were generally resolved through bilateral discussions.

I mention Johnston's work here for several reasons. Firstly, it was a successful example of "carrot and stick" diplomacy. The "carrot" was the considerable U.S. funding available for both countries and the "stick" was the credible threat of further cut off in aid in the event of non-compliance. Secondly, Johnston used the TVA technical plan as "something to fight over"—in short, a good independent plan as the starting point for further negotiation. Finally, although Johnston's plan was never agreed to by the parties, it was nonetheless adhered to for many years.

Future efforts to resolve issues like the Palestinian/Israeli sharing of underground aquifers or the allocation of water in the Golan Heights may require similar outside mediation—first, a technically solid independent study which provides "something to fight over", followed by carrot and stick diplomacy.

Annex 3: Other Regional Water Conflicts

There is a tendency to think of the water issues of the Middle East mainly in terms of the conflict between Israel and its neighbors over control of the waters of the Jordan valley. However, two other conflicts may play even greater roles in the region:

- The Tigris and Euphrates basin shared by Turkey, Syria and Iraq.
- The Nile, shared by ten riparian states, in particular Egypt, Sudan, and Ethiopia.

The Euphrates And Tigris

Turkey has invested heavily in its Southeast Anatolia Project, a huge network of some 22 dams aimed at doubling the country's agricultural production.[12] The diversion of water from the Euphrates and Tigris has resulted in disputes with Syria and Iraq. Construction has also provided a target for attacks by Kurdish separatist groups in Turkey.

Syria has constructed its own network of dams on the Euphrates and its tributaries. However, the reservoirs behind these dams remain only partly filled, largely due to the decreased quantities of water coming from Turkey. For its part, Iraq has constructed seven dams on the Euphrates. As in Syria, these operate at lower capacity due to reduced flows from Turkey and Syria.

Since Iraq's war with Iran in 1980, Iraq has not given much attention to its water disputes with Turkey and Syria. Subsequent wars with the U.S. and its coalition partners in 1991 and 2003 again diverted attention from the water issue. This lack of Iraqi attention to its two main rivers, however, is now likely to change.

According to one scenario, peace in Iraq will lead to renewed economic development. Iraq will then need water both for agriculture and industry. It will then have to negotiate with Turkey and Syria over its water share.

There is also the opposite scenario—after U.S. troops withdraw, Iraq could return to civil conflict and eventually divide into ethnic pieces. Both the Tigris and Euphrates enter Iraq through territories which since 1991 have formed a semi-autonomous Kurdish state within Iraq. Under this scenario the water situation for south and central Iraq would become even more critical, as the Kurdish state would form another upstream riparian partner. In addition, any declaration of Kurdish statehood would almost certainly lead to demands for autonomy by Kurds in Turkey and Syria. War with Turkey would be a very likely outcome. Such a war might well impact the dams controlling the Tigris and Euphrates.

Thus, both scenarios for Iraq—peaceful development or return to civil war—would lead to extremely complicated issues of control over the waters of the Euphrates and the Tigris.

How do The Conflicts Over The Tigris And The Euphrates Affect The Dispute Over The Jordan?

The most direct impact is on Syria, which has already lost water from the Banias and the Jordan. In addition, Syria faces disputes with Jordan and Israel over "unregistered withdrawals" of water from the Yarmouk River.

As in the case of the Jordan, the relative power of one partner (in this case, Turkey) and "facts on the ground" may result in "unfair" allocations to the less powerful partners (Syria and Iraq). However, certainty about allocations may once again prove more important than "fairness." In the end what matters most is that all partners have a firm basis on which to plan their development.

There is another, perhaps more important, consideration. The Tigris and Euphrates basins in Turkey, Syria and Iraq represent some of the region's best zones for agricultural production. Instead of trying to produce food in arid Jordan, Israel and the future Palestinian state, it would be more efficient to produce food where ample water exists.

The Nile

There are ten riparian states to the Nile. At present only two, Egypt and Sudan, have practical control over use of the river. However, if Ethiopia and an independent Southern Sudan eventually begin to exercise control, this situation could change drastically.

Egypt and Sudan have a long history of joint management of the Nile. This fact owes partly to water agreements put in place during the British period and a tradition continued after independence. It also owes to Egypt's history as the breadbasket of the region and its military and economic strength.

Ethiopia provides most (up to 86%) of the Nile's water,[13] but so far has had little control over use of that water. During the colonial period Britain obtained agreements from the Italians and later from the Emperor of Ethiopia that the country would not divert waters of the Nile. Later Ethiopian governments have renounced these agreements. Future economic development of Ethiopia is likely to lead to building of dams for hydropower and irrigation and, no doubt, to conflicts with Sudan and Egypt over the resulting diversion of water.

The situation has grown more complicated due to the signing of the southern Sudan peace agreement. If, as expected, the referendum now scheduled for 2011 leads to full independence of southern Sudan, the Nile will then have an eleventh riparian state. Moreover, unlike Uganda, Kenya and other smaller contributors to the Nile, southern Sudan would be in a position to control much of the Nile's flow.

The need for long-term regional planning and wider agreements between the riparian partners is obvious. Unfortunately, it is doubtful that such planning or agreements could happen anytime soon, due to both:

- Economic and military instability in all states south of Egypt.
- Egypt's belief in its historic right to the Nile's waters.

What do Potential Conflicts Over The Nile Have to do With The Jordan?

As with the Euphrates and Tigris, negotiations over the Nile are likely to influence how riparian states look to the long-term future in settling present day problems.

Secondly, there is the interest of Israel (and to a lesser extent, Jordan) in buying Nile water from Egypt for use in southern parts of their countries. Availability of such water might reduce pressure on the Jordan, but at the same time this diversion would add new strains within Egypt and with the Nile's riparian partners.

Thirdly and most important, the Nile basin in Egypt and Sudan represents some of the region's best agricultural lands. Instead of moving water to arid lands, there are clear advantages to using water where it is already available, and then moving the produce to where it is needed.

Annex 4: International Law

It would be comforting to believe that disputes between states could be settled amicably through reference to well-established international law. It would be even more reassuring to have an international body monitoring and supporting settlement of water sharing disputes. Unfortunately, neither exists.

The first serious steps toward establishing formal laws came in 1911 when the Institute of International Law set out the *Madrid Declaration on the International Regulation regarding the Use of International Watercourses for Purposes other than Navigation*.[14] Among other points, the declaration recommended that riparian partners establish joint water commissions.

In 1966 the International Law Association set out the *Helsinki Rules*,[15] which established the principle that riparian partners must use water equitably and avoid substantial harm to each other. The Helsinki Rules were the first to address environmental concerns and adopted the principle of "the polluter pays" as well as calling on riparian partners to work for sustainability of the river.

In 1970 the UN took up drafting of a formal international convention. Negotiations dragged on for 24 years, but finally reached agreement on the text of The Convention on the Law of Non-navigable Uses of International Watercourses. The Convention establishes the principles of due diligence and equitable and reasonable utilization by riparian partners. Although the UN General Assembly adopted the Convention in 1997, it still has not become law, because the Convention lacks the 35 national ratifications needed to "enter into force." Moreover, the Convention did not cover two important issues:

- "Confined" groundwater systems, such as the Jordan Valley.
- Groundwater aquifers such as in the West Bank and Israel.

Finally, in 1994 the International Law Association set out the *Berlin Rules*,[16] a comprehensive set of guidelines, covering both national and international waters. The Berlin Rules go much further than previous attempts in addressing issues such as management of groundwater resources. Berlin represented a great step forward in summarizing customary law and applying environmental thinking—unfortunately, however, still lacking the force of formal international law.

Although establishment of International law on water sharing still has a long way to go, customary law can function nearly as well, so long as all parties understand and are willing to apply it. We need only look to the example of the Jordan Valley where belligerent states followed un-ratified guidelines for 39 years.

Notes

1 All city populations from Wikipedia.

2 The informal arrangements were replaced with formal ones when Jordan and Israel signed a peace agreement in 1994.

3 I exclude Lebanon from comparisons here and below because it is not dependent on water from the Jordan Valley.

4 Statistics here and below from the country statistics pages of the CIA Factbook. Most national statistics as of 2007.

5 Allan, J.A. *Israel and Water in the Framework of the Arab-Israeli Conflict, SOAS Water Issues Group Occasional Paper 15*, p. 3.

6 Chapagain, A.K. and Hoekstra, A.Y. (2004) *Water footprints of nations*, Value of Water Research Report Series, No.6, UNESCO-IHE

7 *Maquiladora* is a Spanish term for the "miller's portion" of grain. Maquiladora factories are ones which partly manufacture and then re-export products; they are usually located just across a border from the country of primary manufacture.

8 The UN has decided that the Shebaa Farms belong to Lebanon and both Lebanon and Syria agree. Israel, however, fears that handing the area back to Lebanon might result in Lebanon giving control back to Syria. Thus the debate continues.

9 The reader should note that poverty lines differ in each country—with Israel setting an unusually high definition and countries like Syria and Jordan setting unusually low definitions of poverty. Many experts believe that both Syria and Jordan set their rates well below reality. If this is the case, and if the actual rates of poverty and population growth continue, the region already has many more poor, and will have a vastly higher number by 2050.

10 Guide to the Eric A. Johnston Papers 1920-1963. http://nwda-db.wsulibs.wsu.edu/findaid/ark:/80444/xv34899

11 Johnston quickly established good rapport with Stalin, much to the chagrin of the then Ambassador to Russia, Averell Harriman. As a result, Johnston became the first U.S. diplomat to travel extensively in the post-Revolution Soviet Union. See History Link Essay: The Eric Johnston Story, www.historylink.org/index.cfm?DisplayPage=pf_output.cfm&file_id=7339

12 Akmansoy, Sandra, *Southeastern Anatolian Project*, The University of Texas at Austin Department of Civil Engineering. http://www.ce.utexas.edu/prof/maidment/grad/akmansoy/gap/paper.html

13 Kiser, Stephen D. *Water: The Hydraulic Parameter of Conflict in the Middle East and North Africa*, INSS Occasional Paper 35, Environmental Security Series, p.36

14 Transnational Water Rights, General Assembly. http://docs.ucsdmun.org/ TRANSNATIONAL%20WATER.pdf, p. 2

15 The Helsinki Rules on International Uses of the Waters of International Rivers, UNESCO. http://webworld.unesco.org/water/wwap/pccp/cd/pdf/educational_tools/course_modules/ reference_documents/internationalregionconventions/helsinkirules.pdf

16 Dellapena, Joseph, *The International Law Association's Berlin Rules on Water Resources*, International Union for Conservation of Nature.

Transboundary Water Crises:
Learning From Our Neighbors In The Rio Grande (Bravo) And Jordan River Watersheds

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The Rio Grande as an international border offers great opportunity for cooperative efforts between the U.S. and Mexico but at the same time presents significant challenges. Commerce and business is enhanced with maquiladoras (or twin plants) that encourage production in Mexico for sale around the world. Agreements facilitate allocation of the limited water to the benefit of both nations. There is cooperation to protect the eco-system from invasive plants. But at the same time, relations are stressed by the US building a wall, issues with the drug trade and violence, and underserved communities on both sides.

Headwaters of the Rio Grande [River] begin in Southern Colorado, fed by snow melt (Figure 1), and continues through New Mexico and into Texas, comprising the international border between the U.S. and Mexico along the Southern border of Texas. It extends over 1,800 miles and is primarily located in the semi-arid regions of New Mexico, Texas, and Mexico. The River has been listed on the Most Threatened Rivers list by the American Rivers Group four times, more than any other U.S. river (Shozo).

Irrigated agriculture and a rapidly-increasing population, three U.S. states, four Mexican States, and two countries largely dependant on The River are all placing stress on water availability, the ecosystem, biodiversity, and indeed the physical structure of The River itself. In fact, with reservoirs and consumptive use, the Rio Grande is effectively two separate rivers today, given that flow almost ceases at Fort Quitman, Texas, with meaningful flow beginning again at the inflow from the Pecos. That is, snow pack feeds the upper Rio Grande (Colorado, New Mexico, and to below El Paso-Fort Quitman) while primarily summer monsoonal flow from the Rio Conchos in Mexico feeds the lower Rio Grande (HARC).

Figure 1. Headwaters of the Rio Grande in Colorado.
SOURCE: http://www.solihullsociety.org/wp/wp-content/snowpack.jpg

Challenges related to the Rio Grande range from the stress placed due to dependency on water and increasing demand by all that border the River to issues related to socio-economic factors. There are low income communities where services, education, health care and jobs are lacking. Invasive aquatic plants have infested the River consuming part of the water, illegal border crossings and drug trafficking have resulted in concerns related to public safety. These and other challenges as well as joint solutions are discussed.

Description

From its source to the mouth in the Gulf of Mexico, the Rio Grande drops over 12,000 feet to sea level as a snow-fed mountain torrent, desert stream, and meandering coastal river (Brand and Schmidt). It is the second-longest river entirely within or bordering the United States and is Texas' longest river. The area within the entire watershed of the Rio Grande is approximately 336,000 square miles. The Rio Grande flows for 175 miles in Colorado, 470 miles across New Mexico, and 1,240 miles between Texas and the Mexican states of Chihuahua, Coahila, Nuevo Leon, and Tamauilpas (Brand and Schmidt).

Flow And Reservoirs

The Rio Grande Basin is identified in Figure 2. The figure illustrates the path and reservoirs associated with The River. Rio Grande waters are impounded in Elephant Butte and Caballo Reservoirs (know as the Rio Grande Project) in southern New Mexico for irrigation of approximately 200 miles of valley and 135,000 acres of land, including land in El Paso County, Texas.

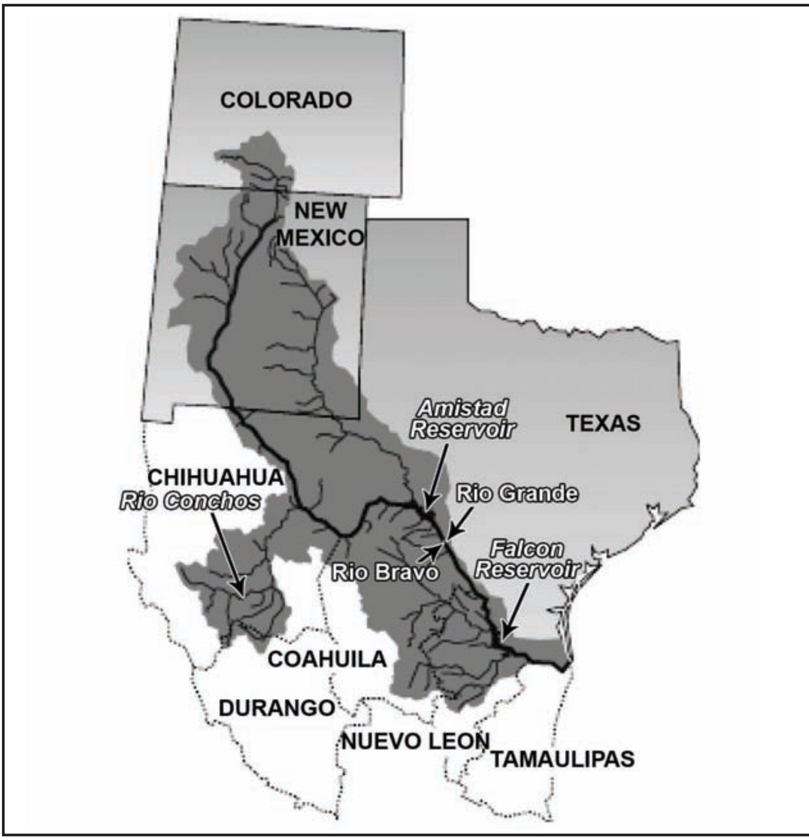

Figure 2. Map of the Rio Grande Basin.
SOURCE: Schmidt and Dean.

A few hundred miles southeast of El Paso in the Big Bend area, the Rio Grande flows through three canyons: the Santa Elena (river bed elevation of 2,145 feet and canyon-rim elevation of 3, 661 feet), the Mariscal (river bed elevation of 1,925 feet and canyon-rim elevation of 3,625 feet), and the Boquillas (river bed elevation of 1,850 feet and canyon-rim elevation of 3,490 feet). The River flows around the base of the Chisos Mountains and then comprises the southern boundary of Big Bend National Park for approximately 100 miles. From Big Bend National Park, downstream to the Terrell-Val Verde Country line, the River covers another 191.2 miles.

The U.S. and Mexico built the Amistad Dam at the joining of the Rio Grande and the Devils River, which holds 3,505,400 acre-feet of water, of which Texas' share is 56.2% (Texas Almanac). Below Amistad, there is the Falcon Reservoir, which holds 2,767,400 acre-feet of water, of which Texas' share is 58.6%. Falcon and Amistad reservoirs were formalized in the Treaty of 1944 by the International Boundary and Water Commission (IBWC) which authorized construction of the international reservoirs and provided for the division of stored waters between the two countries (HARC). Combined, these two reservoirs provide 95% of this Lower Rio Grande segment of The River with water.

Reservoir management is complex in all cases involving hydrological status, water demands, and issues of risk related to drought and/or flooding. The situation is further complicated by competing factors across states and countries. There are several international, federal, state and municipal institutions, the International Boundary and Water Commission (IBWC), and water agencies which have a regulatory role, as well as multiple users of reservoirs (HARC). Approximately 80% of withdrawals from the Rio Grande are for irrigation (HARC). At the mouth of the Rio Grande, where it joins the Gulf of Mexico, a fertile delta has been created, typically termed the Lower Rio Grande Valley (Stubbs *et al.*). This is a large area for vegetable, fruit, and commodity production heavily dependant upon irrigation. The Rio Grande drains 48,259 square miles of Texas, with the principal tributaries flowing from the Texas side being the Pecos and Devils rivers. On the Mexican side, the Rio Conchos, Rio Salado, and Rio San Juan all flow into the River. Around three-fourths of flow into the Rio Grande below El Paso comes from the Mexican side (media-2.web.britannica).

Population And Socio-economic Characteristics

Concentrating on the Transboundary section of the Rio Grande (U.S. and Mexico border separated by The River), the 43 Texas border counties are currently home to over 4.6 million Texans (Shapleigh). This population is projected to be almost 9 million by 2010 and 13 million by 2020—just on the U.S. side of The River (United States-Mexico Border Health Commission). A review of the 2000 population for the major twin cities (U.S. and Mexico cities across The River from each other) indicates a population in excess of 3.6 million (Table 1). These population values do not include some of the communities located between larger cities such as between McAllen and Brownsville, Texas.

City	Borderplex Population
El Paso, TX Ciudad Juárez, Chihuahua	679,622 1,218,817 1,090,439
McAllen, TX Reynosa, Tamaulipas	569,463 420,463 989,926
Brownsville, TX Matamoros, Tamaulipas	569,463 420,463 989,926
Laredo, TX Nuevo Laredo, Tamaulipas	193,117 310,915 504,032
Total	**3,337,765**

Table 1. U.S. Mexico Twin City population: 2000.

SOURCE: Federal Reserve Bank of Dallas, El Paso Branch.

Along the Rio Grande, the rate of growth in population of El Paso-Cuidad Juárez was 38%, compared to 48% for Laredo/Nuevo Laredo and 38% for McAllen-Reynosa during the decade of the 1990's. This rapid growth rate is projected to continue through 2050 along the Texas-Mexico border (Texas State Data Center and Office of the State Demographer). Both on the U.S. and Mexico side of the Rio Grande, the average age is very young. Over 43% of the population of El Paso is 25 years old or younger (Shapleigh). On the Mexican side of the border, the average age is even younger; 35% of the Mexican Border population was under 15 years old in 2000 (Shapleigh).

There is a high level of poverty along the Rio Grande in the U.S., suggesting a cycle of poverty that is not being addressed (Shapleigh). Socioeconomic challenges extend to education, income levels, health access, workforce skills, and basic infrastructure (Shapleigh). Among the critical issues facing the Rio Grande, the need to address socio-economic ills is one of the most pressing. In ranking the 43 border counties of Texas portion of the border, if it were hypothetically to be the 51st state in the U.S., this border state would rank last in per capita personal income, first in poverty, and fifth in unemployment. The border regions of the U.S. and Mexico are characterized by a mix of very poor and affluent areas. Interestingly, the Northern part of Mexico including the border area along The River is among the wealthier regions of the country, while the opposite is true for the U.S. side of The River.

The Economy

Agriculture comprises a large part of the economy along The River. Crops are very diverse, ranging from potatoes and alfalfa in Colorado; cotton, pecans, dairy, vegetables, and grapes in southern New Mexico and El Paso; to citrus fruits, sugarcane, corn, sorghum, cotton, and vegetables in the Texas Lower Rio Grande Valley (Brand and Schmidt). Some examples of crops grown along The River are shown in Figure 3.

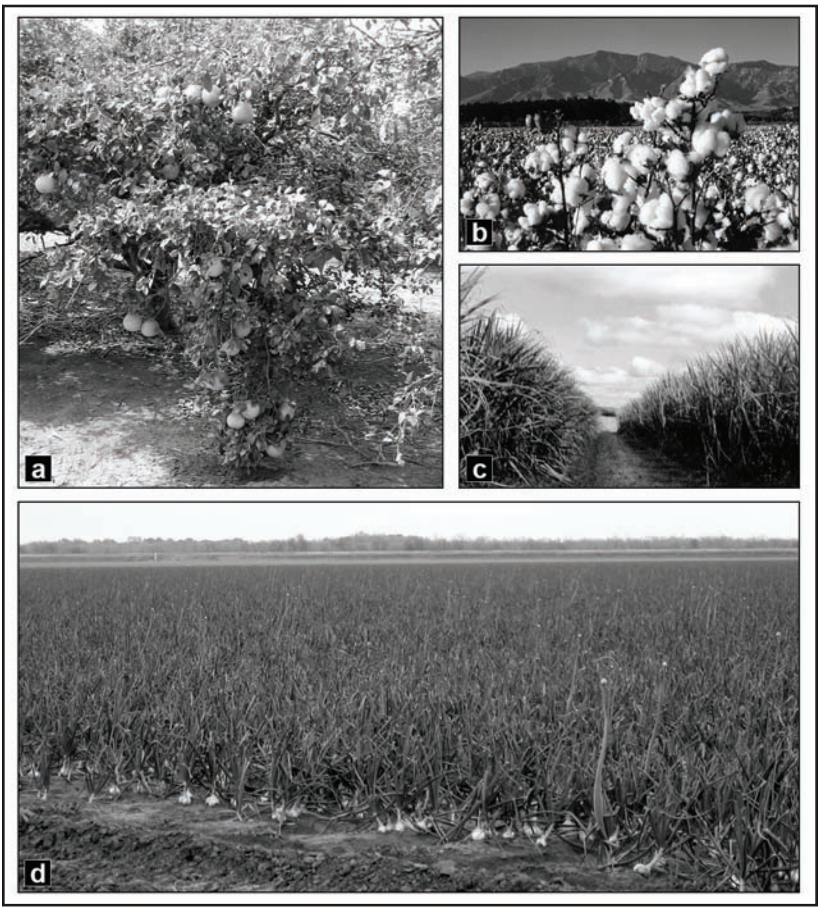

Figure 3. Representative irrigated grapefruits (a), cotton (b), sugarcane (c), and onions (d). PHOTOS: Lacewell.

Also, for the Rio Grande basin, cattle and livestock are a significant part of the economy. Agriculture provides employment opportunities, but often at relative low wages. In 2005, manufacturing in the border region accounted for $6.25 billion worth of private earnings. Trade with Mexico accounts for one of five manufacturing jobs in Texas, while exports make up 14% of Texas' gross product, 36% of that going to Mexico. In Texas alone, over 65 million legal pedestrians, trucks, autos, and rail cars crossed the border in 2007 (Brand and Schmidt). Often the border crossings become very congested as shown in Figure 4.

Figure 4. Traffic at a Texas-Mexico border crossing.
SOURCE: http://latimesblogs.latimes.com/photos/uncategorized/2008/03/12/ysidro.jpg

Other leading industries include mining (petroleum, natural gas, coal, uranium ore, silver, lead, gold, potash, and gypsum), along with recreation (national and state parks and monuments, rafting, fishing and hunting, and summer and winter resorts). In addition, the introduction of maquiladoras along the Rio Grande in the US and Mexico (twin manufacturing plants) has generated significant economic activity.

Maquiladoras

A maquiladora (or maquila) is a Mexican Corporation which operates under a maquila program approved by the Mexican Secretariat of Commerce and Industrial Development (SECOFI). Preferential tariff programs established by the U.S. and Mexico governments encourage the development of industry in Mexico (Twin Plant News). Maquilas are usually established along the U.S./Mexico border co-located in both countries in close proximity. However, a maquila can be located anywhere in Mexico with the exception of Mexico City, Guadalajara, or Monterrey urban areas (Baz).

"A maquila program entitles the company, first, to foreign investment participation in the capital—and in management—of up to 100% without need of any special authorization; second, it entitles the company to special customs treatment, allowing duty free temporary import of machinery, equipment, parts and materials, and administrative equipment such as computers, and communications devices, subject only to posting a bond guaranteeing that such goods will not remain in Mexico permanently. Ordinarily, all of a maquiladora's products are exported, either directly, or indirectly, through sale to another maquiladora or exporter. The type of production may be the simple assembly of temporarily imported parts; the manufacture from start to finish of a product using materials from various countries, including Mexico; or any conceivable combination of the various phases involved in manufacturing, or even non-industrial operations, such as data-processing, packaging, and sorting coupons" (Baz). Basically, any product can be manufactured, assembled, packaged, processed, sorted, transformed or rebuilt in a maquila (Baz).

NAFTA (North American Free Trade Agreement) led to a rapid increase in trade among U.S. and Mexico, as well as a growing number of maquiladoras (Shapleigh). Due to the maquila industry's demand for labor, population along the U.S./ Mexico border has increased dramatically. Principle maquila industries include electronics, transportation, textile, and machinery. About 90 % of the maquilas trace their ownership to the U.S. The maquila sector is the second greatest source of jobs in Mexico (Twin Plant News). By 1985, maquiladoras had become Mexico's second largest source of income from foreign exports, behind oil. Since 1973, they have accounted for nearly half of Mexico's export assembly. Between 1995 and 2000, exports of assembled product in Mexico tripled and growth of industry equaled about one new factory per day. In the late 20th century, they accounted for approximately 25% of Mexico's GDP (Gross Domestic Product) and 17% of total Mexican employment (The Free Dictionary). In 2002, approximately 529 maquiladoras shut down and investment decreased by 8.2% due to competition from other offshore assemblies (e.g., China, Latin America). Currently, over 3,000 maquiladoras still operate along the 2,000 mile-long border between U.S. and Mexico, providing employment for approximately 1 million workers and importing more than $51 billion in supplies into Mexico. As of 2006, they account for 45% of Mexico's exports. The majority of employees are women, working for approximately one-sixth of the U.S. hourly rate. Employee turnover is high, reaching up to 80% annually in some maquiladoras due to stress and health issues (HARC).

There is an allegation that maquilas contribute to major environmental problems due to growth of industrial manufacturing plants and need to dispose of wastes. Hazardous waste and pollution are serious concerns (HARC). The La Paz Agreement, signed both by Mexico and the U.S. in 1983, requires waste created by U.S. corporations to be transported back to the U.S. for disposal. However, it is suggested that many companies seek to avoid this requirement due to cost to dispose of toxins and other waste compared to ease of releases into Mexico's rivers and deserts (HARC). Hence, an issue related to wastes created along the border but with an agreement that provides a solution. Unfortunately, a lack of enforcement has delayed implementation.

Treaties

With increasing population and reliance on river water for irrigation and growth of industry, several water treaties were developed. This section is only an overview and not intended to describe or include all treaties and compacts, but rather provides an overview of the number of treaties and their complexity (Brand and Schmidt).

- 1906 Convention between U.S. and Mexico—U.S. shall deliver 60,000 acre feet of water to Mexico each year at El Paso/Juárez except during extraordinary drought.
- 1938 Rio Grande Compact among Colorado, New Mexico, and Texas to equitably apportion the waters of the upper Rio Grande above Fort Quitman, Texas.
- 1944 Treaty between U.S. and Mexico—divides the flow of the Rio Grande and its tributaries below Fort Quitman; also sets the quantity of water to be delivered annually from the Colorado River by the U.S. to Mexico.
- 1948 Pecos River Compact between New Mexico and Texas concerning the Pecos above Girvin, Texas and water delivery by New Mexico to Texas.

With these agreements, treaties, and compacts, essentially all of the 3 million acre feet in the Upper Rio Grande is fully allocated and consumed in this sub-basin. Many stretches of The River from New Mexico-Colorado border to below Brownsville, Texas have no surface flow during some periods of the year. For example, during the off season of irrigation, typically November through February (Michelsen), The River has no flow between Elephant Butte Reservoir and El Paso (Brand and Schmidt). Figure 5 is a picture of the Rio Grande above El Paso illustrating there are those that actually drive on the dry river bed.

Figure 5. Rio Grande river bed above El Paso, January 2004.
PHOTO: Michelsen.

Transboundary Issues

With the Rio Grande listed as among the "Most Threatened Rivers" (Shozo), the future of The River is indeed challenging. There are large population centers along The River with growing demands for water combined with increasing disposal of wastes and the need for wastewater treatment. Coupled with increasing salinity, global climate change implications, endangered species, immigration issues, and diverse interests, there is an urgent need for an accelerated multinational response related to the Rio Grande.

Global Climate Change Implications

An overview of Global Climate Change for the Southwest was prepared by the Southwest Regional Assessment Group for the U.S. Global

Change Research Program (Sprigg and Hinkley). The report basically suggested the Southwest would be subject, in the future, to a slight increase in rainfall during the winter, resulting in an increase in the number of floods with greater soil erosion and threat to property and life. However, less rainfall during the summer was projected. In all cases, an increase in temperature is expected. Higher temperature results in more evaporation, placing stress on available water supplies. Further, rainfall is projected to be more erratic, occurring as storm events more often than slow precipitation. Such phenomena suggest a greater threat of flooding.

The water supply for the upper Rio Grande basin is fully allocated. The system of engineered storage and delivery requires precipitation at the right time, right place, over time, and with adequate quantity in order to function properly. Changes in the timing and amount of rainfall with a change (increase) in temperature puts the system in a vulnerable situation (Sprigg and Hinkley). The potential impact of such changes extends beyond surface water to groundwater supplies since aquifers will be used to offset any shortfall related to The River. To ensure municipal supplies during drought and for anticipated growth, El Paso Water Utilities completed construction in 2008 of a 27.5 million gallon per day (mgd) brackish groundwater desalination plant (Figure 6).

Figure 6. El Paso Water Utilities, Kay Bailey Hutchison Desalination Plant, 2008.
PHOTO: Michelsen.

The El Paso County Water Improvement District #1 has also developed 60 shallow (100 foot depth) wells to supplement irrigation supplies during drought, but this water has elevated salinity and cannot be used on a continuing, long-term basis (Figure 7) (Michelsen *et al.*). Hurd and Coonrod identified several climate change scenarios and conducted an analysis of the expected impacts for the upper Rio Grande Basin. They used an optimizing model in conjunction with a hydrologic model to develop implications for the future.

Figure 7. El Paso County water improvement District #1 groundwater well pumping for supplemental drought supply, 2008.

PHOTO: Sheng.

Among the anticipated effects of climate change, this study identified streamflow and runoff being altered, reservoir evaporation rates changed, agriculture water consumptive use shifted up due to higher temperatures, and urban water demand changes with population increases. Summarizing results of the Hurd and Coonrod study identifies the following expected responses associated with climate change:

- A shift of some agricultural water to urban uses and associated loss of environmental services of green spaces, food for wildlife and fragmentation of land.
- Concerns relative to inter-basin transfers due to drier conditions which can exacerbate reduced flow in some periods.
- Potential of increased flooding associated with greater frequency of short duration, high rainfall events.

- Water quality is expected to suffer due to reduced streamflow, suggesting issues with contaminants and greater salinity load.
- Ecological impacts can be expected as a result of the changes in the natural hydrograph, further threatening endangered species dependant on The River.

Additional summary reflections from the Hurd and Coonrod study include (1) less snowpack in Colorado, with earlier snow melt and higher evaporative demands; (2) disruption in agricultural and rural economies; (3) serious economic, social, and ecological disruption associated with water transfers and increasing costs associated with water; and (4) negative impacts on ecological and social services related to irrigated agriculture and flowing water in the riparian systems. For the upper Rio Grande Basin, the implications of global climate change suggest serious vulnerability which will impact the Rio Grande region to Fort Quitman. This potential susceptibility suggests that the issue of endangered species will be even more serious as the impacts of climate change are encountered. Institutions are sure to be tested between states and between the U.S. and Mexico as the impact of climate change begins to be expressed on the Upper Rio Grande.

Extrapolating impacts of climate change to the Lower Rio Grande Basin, flow is mostly from the Mexico watershed and relies on rainfall, not snowpack. However, the outlook is similar in that some increase in moisture during the winter, reduced rain during the summer, and overall higher temperatures are likely to occur. In addition, the expectation of more intense rainfall events implies less soaking rains for the soil. Mexico has a rapidly increasing population that also will be facing the impacts of climate change. Water that falls in Mexico will be subject to storage in reservoirs which can disrupt the flow to the Rio Grande. With reduced flow to the Rio Grande, the Lower Rio Grande region (U.S. and Mexico) will be faced with increasing stress on water supply while evaporation is increasing and consumptive use by crops is increasing. As in the upper Rio Grande, the institutions will be put under added stress within each country and across countries. An example of drought on reservoir level is shown in Figure 8.

With the studies of climate change directed to much of the Rio Grande Basin, it was useful to relate to a potential challenge of the future. However, the science and a consensus related to climate change generally, and certainly for the Rio Grande Basin, is not resolved with conflicting concepts, results and theories.

Figure 8. Elephant Butte reservoir storage reduced following several years of drought, 2003.

PHOTO: Michelsen.

For example, Singer stated in a lecture in 2007 that perhaps the concerns of man-made global warming are misplaced. His contention, as well as that of others, is that scientific evidence does not support the perception of man activities being the cause of global climate change (global warming). This point holds that climate has changed in the past and will continue to change in the future with warming and cooling on different time scales for many reasons. Singer discusses natural changes that have occurred over time with descriptions of natural causes of warming. Therefore, the challenges facing the Rio Grande Basin extend to the uncertainty related to outlook of global climate change. However, whether man-made or natural, if indeed there is a warming trend facing this region then it means more pressure on an already stressed system.

A study by Booker, Michelsen, and Ward (2005) may hold some insight for addressing the issues of water management and allocation. The study looked to policies that efficiently and equitably allocated water among competing uses as well as political and institutional jurisdictions. The study took a water marketing approach where any reallocations (and losses) among users were offset by payments made by higher value users. They found that through market exchanges, drought economic impacts could be reduced by almost one-third compared to existing allocation policies. The model operates to the extent permitted by constraints of hydrology, compact allocations, and Treaty deliveries. This application was done for the upper Rio Grande basin. In considering an increase in frequency of high rainfall events, there is significant risk related to flooding along the Rio Grande. It is certainly a joint U.S. and Mexico issue when looking to levees for flood protection. If one side of The River has a levee that is higher than the other side, then the flood waters will be pushed to the side with the lower levee. The benefits of the International Boundary and Water Commission levee system were estimated to be over $500 million dollars for just the United States (Sturdivant *et al*., 2004). However, this is for protection of the 100-year frequency flood when there are storms exceeding this frequency.

Shown in Figures 9 and 10 is just how destructive flooding can be along the Rio Grande with the El Paso region flooding of 2006. This occurrence suggests a joint program would be advantageous where both countries work together to assure that not any particular group is subject to greater damage than another.

Figure 9. El Paso 2006 flood on Sunland Park Drive.
PHOTO: Sheng.

Figure 10. Rio Grande flood above the Texas-New Mexico state line, Sept. 2006.
PHOTO: Michelsen.

Endangered Species Protection

With the increasing demand for water and extensive engineering works along the river for storage and distribution, there have been impacts on fish, plant, animal, and bird species that rely on The River. For example, the number of native fish has declined by 70% in last few decades (Harris). Species that are now extinct include shovelnose sturgeon, the American eel, the pained redhorse, and the Rio Grande chub, to name a few. Those species that are in jeopardy include the Rio Grande silvery minnow, Rio Grande sucker, and the Rio Grande Cutthroat Trout (Harris). Migrating water fowl and neotropical songbirds have also declined, where 170 species have declined and 20 are threatened or endangered (Harris).

According to Davis, the silvery minnow lives only in the Rio Grande, from Cochiti Dam to Elephant Butte Reservoir. It is said that the cause of this decreasing number of the silvery minnow is due to erosion of The River's sediment caused by cattle overgrazing. Silvery minnow feed off of the forage that falls to the bottom of The River. The Endangered Species Act has come to bear related to the silvery minnow with actions developed for restoration (Davis). The proposal for recovery and survival of the silvery minnow relates to a need for at least 50 cubic feet per second flow in the San Acacia reach of the upper Rio Grande. Ward and Booker (2003) evaluated the economic implications of maintaining this flow. Interestingly, the New Mexico users as a whole do not incur damages due to maintaining this flow (but some irrigators do incur damages) while downstream users actually benefit. Agriculture users in Texas see about a $200,000 benefit with El Paso municipal and industrial users incurring over $1 million in benefits.

Invasive Plant Species

Non-native species of the Rio Grande such as Saltcedar are now taking over the cottonwood-willow space. It is estimated that saltcedar uses 3-4 acre-feet of water per acre annually. The plant was originally planted to reduce erosion along streams but the Saltcedar began to out compete native vegetation creating a major issue. Both chemical and biological control are being applied to control the plant (Seawright). Shown in Figure 11a is Salt Cedar infestation along the Pecos River with Figure 11b showing the spraying for control of Salt Cedar. In addition, in the Lower Rio Grande region, Arundo donax (giant reed) is invading thousands of acres of the riparian (Goolsby).

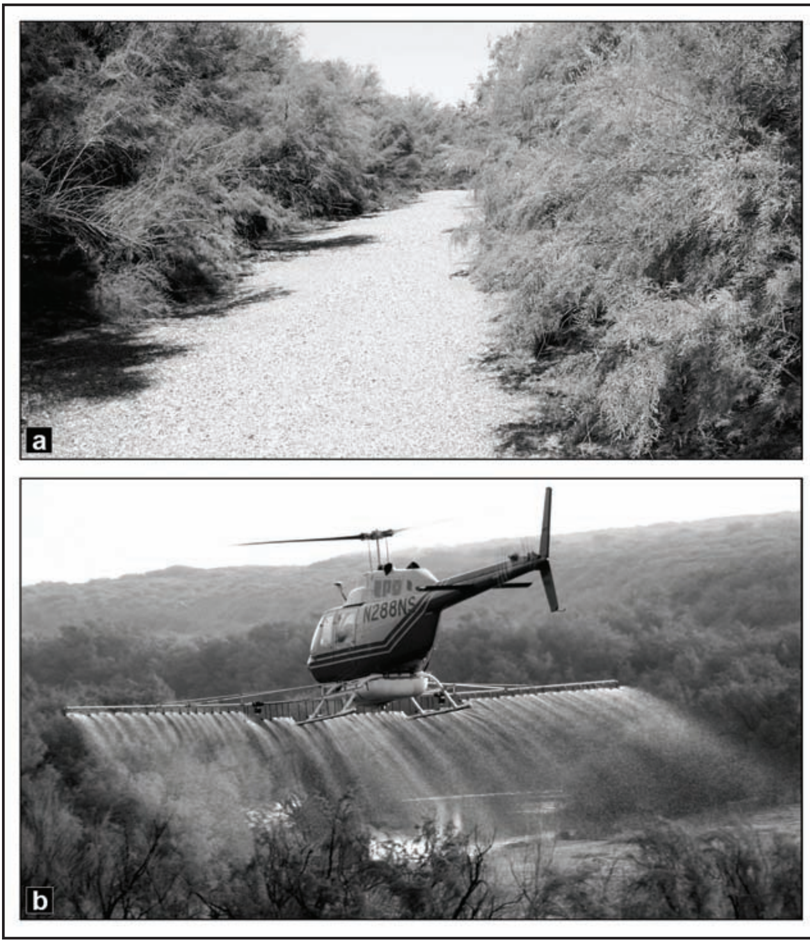

Figure 11. Salt Cedar invading eco-system (a); Spraying for Salt Cedar (b).
PHOTO: Texas AgriLife Agriculture Communications.

This water-thirsty plant (i.e., water use exceeds four acre feet per acre of infestation) robs The River of water, reducing the flow, impacting the eco-system, and creating issues for all users. Arundo donax grows to 20–30 feet tall and consumes an estimated 4.37 acre-feet of water each year, precluding beneficial productive use of that water (Seawright). Further, it is increasing in the area infested. This invasion is not only consuming large amounts of water, but since the plant has grown to such a high density, the Border Patrol is experiencing safety and security problems, as infrared sensors cannot detect any heat beneath the plant canopy.

Due to Arundo being on an international river, control is complicated. Use of chemicals is not a favorable option so the U.S. Department of Agriculture, Agriculture Research Service in cooperation with the Mexican Government is working on use of biological control agents. There are encouraging results from the tests and, with cooperation of Mexico, release of a wasp is underway. This initial control step will be followed with release of these additional insects (Goolsby).

Because the Rio Grande below El Paso is the international border between the U.S. and Mexico, both countries suffer as a result of these water intensive plants and both enjoy benefits from control of the plants. Cooperation is essential to protect water for users along The River. Arundo is only one example, but it serves to illustrate the co-dependency on The River and joint responsibility for management. Illustrated in Figure 12 is an example of the density of Arundo along a segment of The River.

Figure 12. View of Arundo in the Rio Grande Riparian, 2007.
PHOTO: Lacewell.

The present value of each acre foot of water conserved due to control of Arundo (or any water-intensive plant) along the Rio Grande, ranges from $1,400 to $2,700 or more depending on supply and demand (Seawright). There are many other invasive plants that plague both the U.S. and Mexico, including Russian olive and tarmarisk. Water hyacinth and hydrilla are examples of water plants in the Lower Rio Grande, consuming water and creating problems for pumps located along The River (Jones). These water plants have impacted pumps, slowed water flow, and reduced available water. Control strategies range from chemicals to mechanical to releasing sterile grass carp.

Water Supply

Many issues and concerns related to water supply in and along the River are discussed above. However, other factors illustrate cooperation between the U.S. and Mexico to address opportunities for increasing quantity. For the lower part of the Rio Grande, a bi-national effort was undertaken to improve efficiency of irrigation districts with emphasis on canals. Resources were partially provided through the North American Development Bank, with a companion program in Mexico (Rister *et al.*, 2009). The primary methods for improving water efficiency (accomplish water conservation) was to reduce seepage, spills, and evaporation in raw-water conveyance systems.

To reduce losses in conveyance systems, the partnership between Irrigation Districts, Texas Water Development Board, North American Development Bank, and U.S. Government (i.e., U.S. Bureau of Reclamation) engaged in lining of canals, installing pipelines, building or renovating pumping plants, and application of advanced management technologies (e.g., telemetry) (e.g., Rister *et al.*, 2002, Rister *et al.*, 2003). For the conservation-rehabilitation projects on the U.S part, total acre feet of water saved (conserved) since 2002 is an estimated 407,729 acre-feet (i.e., 7 years at 58,247 acre-feet per year). The cost per acre foot of water saved on a annuity-equivalent basis ranges from $12 to $427 per acre-foot, per year, with an average of $45 per acre-foot, per year (Sturdivant *et al.*, 2007). Although a Mexican engineering and economic analysis comparable to what has been conducted in the U.S. has not been done, it is anticipated that significant savings also were accomplished in Mexico.

Another opportunity for addressing water supply rests in desalination. Several brackish groundwater desalination plants have been installed in the U.S. portion of the lower part of the Rio Grande. Groundwater is a source of water other than the River, hence an added water supply. To estimate the total costs of desalination, a financial and economic study was done for the Southmost Plant located near Brownsville, Texas (Sturdivant *et al.*, 2009) and for the La Sara plant (Boyer 2008, Boyer *et al.*, 2009). The Southmost desalination plant was designed for 7.5 million gallons per day capacity. Using the records of construction and operating costs for the desal plant, an annuity equivalent cost estimate (Sturdivant *et al.*, 2009) was developed based on actual operation. Based on this single plant, the estimated annual costs to produce and deliver water to a point in the municipal delivery-system infrastructure are $615/acre-foot or $1.89/1,000 gallons (Sturdivant *et al.*, 2009). These costs are actually less than those for about the same size traditional conventional treatment plant of surface water, estimated to be $668/acre-foot, or $2.05 per 1,000 gallons by Rogers in 2008 (also Rogers *et al.*, 2009).

A last point related to issues of water supply relate to legislation passed by the 2007 Texas Legislature. Studies suggest that desalination is economically competitive with conventional treatment of surface water as indicated above. However, the apparent competitive relationship between conventional and desalination treatments was impacted in the 2007 Texas Legislative Session due to Floor Amendment 60 of Texas Senate Bill 3. This legislation was an attempt to meet the increased demand for municipal water. This legislation established the price at which irrigation water in the Lower Rio Grande Valley of Texas can convert to municipal water, as a result of urban/residential development of agricultural land, at 68 percent of the market price, effective January 1, 2008 (Yow, Yow *et al.*).

The economic and financial implications, both intended and unintended, of Floor Amendment 60 on the Valley water market and the resulting incentives impacting adoption of alternative technologies for producing potable water include a shift in the slight cost advantage from desalination to conventional surface water treatment after implementation of Floor Amendment 60 with a corresponding increase in the supply of potable water produced by this method. For the desalination facility discussed above compared to the same size conventional surface water treatment facility, the final result provides benefits to consumers and municipalities, while adversely affecting irrigation districts selling converted municipal rights. The cost per 1,000 gallons was constant for desalination at $1.89 while conventional treatment of surface water declined from $2.05 to $1.87 (Yow, Yow *et al.*).

Water Quality

Issues throughout the basin arise with salinity, nutrients, and fecal coliform bacteria (Flores). Salinity concentration is caused both by human activities and natural conditions and affects those downstream, especially around Amistad reservoir. Fecal coliform contamination is due to untreated and poorly-treated discharges through inadequate wastewater treatment facilities, mainly in Mexican cities. The water quality issues are further impacted by non-point sources on both sides of The River traced to malfunctioning septic systems and/or pet animal wastes not properly managed plus all kinds of natural sources such as wildlife.

Toxic discharges are evident below population centers, mostly near the maquiladora industrial parks (HARC). Certainly population, economic growth, irrigated agriculture, and reservoir construction have dramatically impacted the Rio Grande ecology. Grassland and brush have mostly been cleared. Irrigation impacts water quality due to nutrients and salinization, soil modification, and loss of habitat. There is also the concern of toxic chemicals making their way to the Rio Grande from warehouses built along the banks of creeks that feed The River (TX Peer). Edible fish tissue requirements have been found to be exceeded for arsenic, mercury, chlordane, and other chemicals at numerous points along The River. Further, studies of fish tissue found 12 toxic chemicals that exceeded screening levels. Levels of copper, zinc, and mercury in carp and bass were also dangerously high (TX Peer).

A prime example of the issues facing the Rio Grande is demonstrated by the changes in the "Forgotten River" section (Teasley, McKinney, and Patiño-Gomez as well as Environmental Defense Fund). The Forgotten River extends downstream from El Paso, Texas to the confluence of the Rio Conchos near Presidio, Texas. It is named the Forgotten River because little data is available for this region when compared to the rest of the Rio Grande/Bravo basin.

Additionally, much of the section is remote and at times very little water flows in The River. Large cottonwood and willow bosques once flourished in this reach. Thousands of migratory ducks, geese, and songbirds thrived in this sliver of green, and game such as deer, turkey, quail, and rabbit, as well as large fish, eels, and turtles, were plentiful. Between Fort Quitman and Presidio, The River has dwindled to a trickle of salty water, bordered by acre on acre of invasive salt cedar, a nonnative plant that has choked and obliterated the river channel and every year consumes thousands of acre-feet of water. In April 2003, The River dried up through Big Bend National Park's Mariscal Canyon, halting recreational rafting and stranding fish and aquatic species. Shown in Figure 13 is the location along the Rio Grande of the Forgotten River.

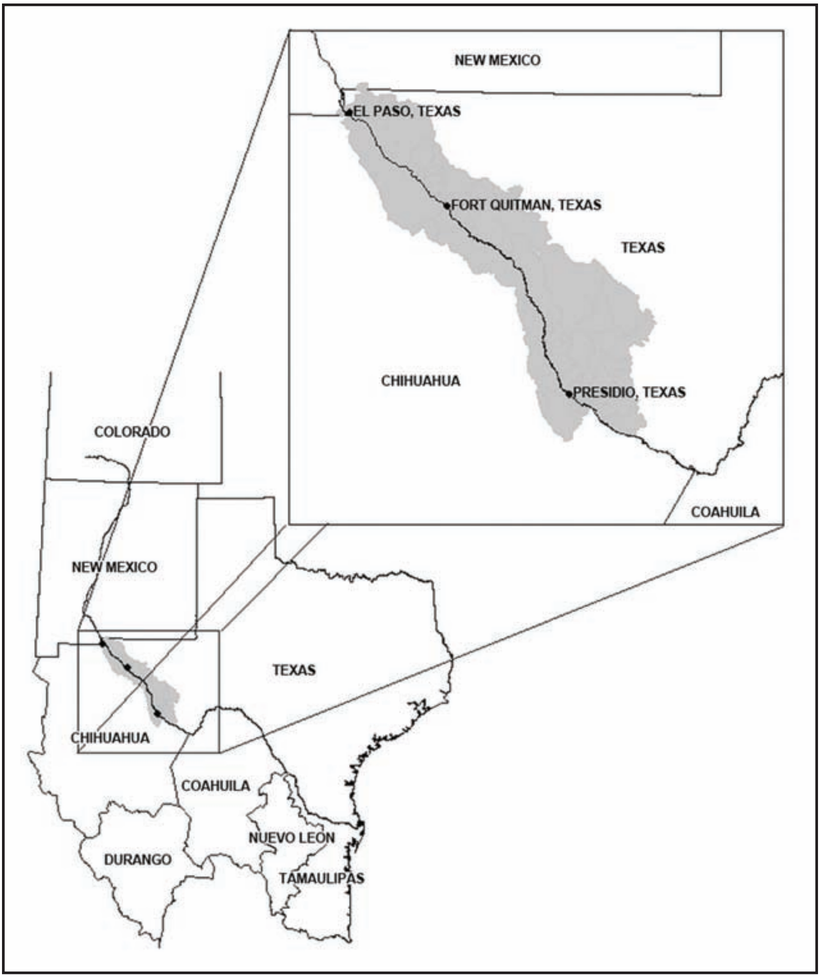

Figure 13. The "Forgotten River" segment is between Fort Quitman, Texas where the Rio Grande Compact ends and Presidio, Texas.

SOURCE: Teasley, McKinney, and Patiño-Gomez.

One excellent example of a joint effort to control salinity entering the Rio Grande is emphasized by the El Morillo Drain which is located in Mexico and captures runoff from irrigated fields in Mexico sending the high saline water to the Gulf of Mexico (Lacewell *et al.*). Today, approximately 300,000 tons of salt is diverted from the Rio Grande by the El Morillo Drain each year, resulting in a 30% reduction in salinity concentration in the Rio Grande. Over the years, the Drain has worked well; in fact, it has worked so well that many residents and entities do not know it exists. If the Drain were to fail, however, the Lower Rio Grande Valley would suffer several consequences, including: (1) the standards of the Clean Drinking Water Act would not be met by cities with traditional water treatment facilities and (2) irrigated agriculture would be impacted with reduced yields, loss in product quality, and even adjustments in cropping patterns.

A study by Lacewell *et al.*, estimated the benefits (i.e., damages averted) attributable to the El Morillo Drain including U.S. municipalities, industry, and agriculture. It is conservatively estimated that the annual direct benefits to residents of South Texas ranges between \$20.1 and \$31.6 million. Including the potential costs to agriculture from crop losses of about \$20.5 to more than \$68.3 million, the total annual impact of the El Morillo Drain for South Texas is between \$40.6 and more than \$99.9 million. Such annual economic impact assessments are indicative that operation and maintenance of the Drain are highly-beneficial activities. As the South Texas population and associated demand for high-quality water increase, the value of the El Morillo Drain to the public and regional water-industry stakeholders will also increase. In the Upper Basin, a Salinity Coalition has been established by the three Rio Grande Compact Commissioners, state agencies, university scientists and local stakeholders. A first phase assessment of the salinity conditions and preliminary economic impacts was initiated in late 2008 (Rio Grande Compact Commission).

Immigration

Although trade across the U.S. Mexico border is valuable to both countries, there is an issue related to movement of people and illegal drug trafficking. The total illegal alien population in the U.S. was estimated by Secretary of Homeland Security Tom Ridge at 8 to 12 million in December 2003 (Global Security Org.). As long as the per-capita income differential between the U.S. (over \$30,000) and Mexico (less than \$4,000) continues to be so wide, it will be difficult to deter the flow of illegal immigrants. By one estimate (Global Security Org.), between 400,000 and 1 million undocumented migrants try to cross the rivers and deserts on the 2,000-mile (3,200-km) US-Mexico border each year.

In 2005, over 1.2 million illegal immigrants were apprehended by the Border Patrol. It is estimated that the Border Patrol catches 1 out of every 4 illegal border crossers, and this is typically the estimate public officials use in discussing the problem. Official Border Patrol statistics are that 1 in 5 illegal aliens are apprehended and arrested (Global Security Org.). Tunnel passages across an international border into the United States have become a real problem. There are 40 such tunnels that have been discovered since September of 2001, and the great bulk of them are on the southern U.S. border. Large-scale smuggling of drugs, weapons, and immigrants takes place today through these tunnels. In response to pressure on the border, there was a temporary deployment of up to 6,000 National Guard troops, two new surveillance aircraft, and five helicopters (Global Security Org.).

This brought forth the concept of a wall or fence to provide an obstacle to those that might be planning to enter the U.S. illegally (Meyers). The wall includes a double set of steel walls. Costs for a wall that would run the entire length of the border might be as low as $851 million for a standard 10-foot prison chain link fence topped by razor wire. For another $362 million, the fence could be electrified. A larger 12-foot tall, two-foot-thick concrete wall painted on both sides would run about $2 billion. Alternative configurations could cost at least $3 million per mile (i.e., $568 per foot). At $3.7 billion, the 700-mile fence would cost $5.28 million per mile—or an astounding $1,000 per foot. In addition to the wall, the plan includes floodlights, surveillance cameras, and motion detectors—along 700 miles of the 1,952-mile border. An example of construction of the “wall” is shown in Figure 14.

Figure 14. Example of construction of the border fence in El Paso between the U.S. and Mexico, 2009.

PHOTO: Michelsen.

This investment will certainly create economic impacts due to the inflow of materials and dollars as well as jobs. However, to date, the authors have not seen any estimates of effectiveness expected from construction of the wall. Figure 15 is a picture of a portion of the wall being constructed in El Paso, Texas, illustrating workers and machinery involved.

Figure 15. Example of construction of the border fence with workers in El Paso between the U.S. and Mexico, 2009.

PHOTO: Michelsen.

Summary And Conclusions

As suggested above, there are challenges related to the Rio Grande both within the U.S. and shared between the U.S. and Mexico. Highlights of the positive cooperative activities include the El Morillo Drain to control salinity from reaching The River, bi-national programs for control of invasive water consuming plants, multiple U.S. States and Mexico working to characterize binational aquifers in order to develop more sustainable management strategies, paired plants (maquiladoras) providing jobs and economic activity, and a healthy trade between the nations as well as other cooperative activities. Major issues relate to rapidly increasing population along the border and associated water quantity and quality factors, as well as preserving the eco-system associated with the Rio Grande. New technology and advances in desalination as well as developing salt tolerant crops offers opportunity for the future. The socioeconomic problems facing both nations, and certainly the border region, suggest the more difficult side of the equation where there are not easy solutions.

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Governing The Jordan River System: History, Challenges, And Outlook [1]

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In spite of years of turmoil and conflict, the riparian states sharing the Jordan River system have undertaken several attempts at negotiating an accord to govern their international basin. Although the first attempt was multilateral and involved basin-wide negotiations, all future efforts have been bilateral. This paper analyzes the various attempts to govern the Jordan River system, such as the Eric Johnston Mission, the Israeli-Jordanian Picnic Table Talks, the Israeli-Jordanian Peace Treaty, and the accords between Syria and Jordan. As a result of these negotiations, the riparian states have also established both informal and formal institutions to manage the Jordan River system, which are also analyzed. Since all formal accords regulating the sharing of the Jordan River have been bilateral, the causes and consequences of fragmented governance of the Jordan River are also considered, along with the necessary changes need to arrive at a basin-wide agreement that promotes the river's optimal and sustainable development.

> "We met to share a few drops of water, to place and move sandbags in the river, for our mutual survival."[2]

In comparison to other international rivers, "the Jordan [River] is a small stream" (Lowi, 1993, 28). Yet in this parched region of the world, this stream is critical for the survival of several of its riparians. Although shared by the Lebanese, Syrians, Israelis, Jordanians, and Palestinians, for the latter three societies this hydrological system is the only perennial river. Despite a history of animosity and conflict, the Jordan River riparians have participated in negotiations over several unsigned and signed accords.[3] During this period, they have also established both informal and formal institutions in attempt to manage the Jordan River system. Although the first attempt at reaching an accord was multilateral (involving three or more states), all future efforts have been bilateral (between two states). The objective of this article is to review and analyze these various attempts at cooperation over the Jordan River system and examine the shortcomings of fragmented governance.

The Jordan River system is perhaps one of the most examined cases in the field of managing international river disputes.[4] Due to the declassification of government documents, we have extensive knowledge of the first effort to reach a multilateral agreement (Lowi, 1993; Wolf, 1995; Haddadin, 2002). Yet, there is a paucity of data on the formation and working procedures of both the informal and formal commissions established to manage the Jordan River system (Jagerskog, 2003). Moreover, although scholars have been discussing the forces influencing the prevalence of fragmented governance of multilateral rivers in general (Just and Netanyahu, 1998), there has been a paucity of in-depth examinations of this issue as it relates to the Jordan River system. Through field interviews and an analysis of classified documents, this article contributes to our knowledge of the operation of the informal and formal commissions. Drawing on the international relations literature, the article also contributes to our understanding of the causes and consequences of bilateral agreements over this multilateral river system, along with a consideration of the structural changes needed to arrive at a basin-wide accord.

Before discussing the attempts at cooperation, the following section considers the river's geography and the available freshwater supplies within the riparian states. Section two examines the first attempt at a multilateral accord under the mediation efforts of Ambassador Eric Johnston, while section three considers the consequences of the 1967 Arab-Israeli war on the region's borders. The informal institution along the picnic table is examined in section four, followed by an analysis of the 1994 Israeli-Jordanian Peace Treaty. Section six discusses the various bilateral accords between Syria and Jordan over the Yarmouk River. After considering the causes and consequences of fragmented cooperation along the Jordan River system, the article concludes with suggestions for future research.

Providing The Jordan River And Its People With Freshwater

The upper Jordan River originates from springs that receive their water from melting snow along Jebel el-Sheikh (in Hebrew, Mount Hermon). These springs feed the Dan, Banias, and Hasbani Rivers, whose confluence forms the head of the Jordan River. The largest is the Dan River, which contributes 50 percent of the water in the upper Jordan River and originates in Israel. The Hasbani River originates in Lebanon at the confluence of the Hasbaya and Wazzani springs, while the Banias originates in Syrian territory, which has been under Israeli control since the 1967 Arab-Israeli war. These three tributaries form the upper part of the Jordan River. The river then flows through the Huleh Basin, which until 1959 was covered by swamps and fed by minor tributaries. The Jordan River begins its descent in height, flowing through a narrow gorge until it reaches Lake Tiberias (Lake Kinneret or Sea of Galilee). As Figure 1 shows, upon its departure from the lake the lower Jordan River is fed by the relatively freshwaters of the Yarmouk tributary and begins to flow through the Jordan Valley until it reaches its terminus in the Dead Sea.[5] Several minor wadis feed the Jordan River between its confluence with the Yarmouk River and the Dead Sea (Naff and Matson, 1984; Kliot, 1994).

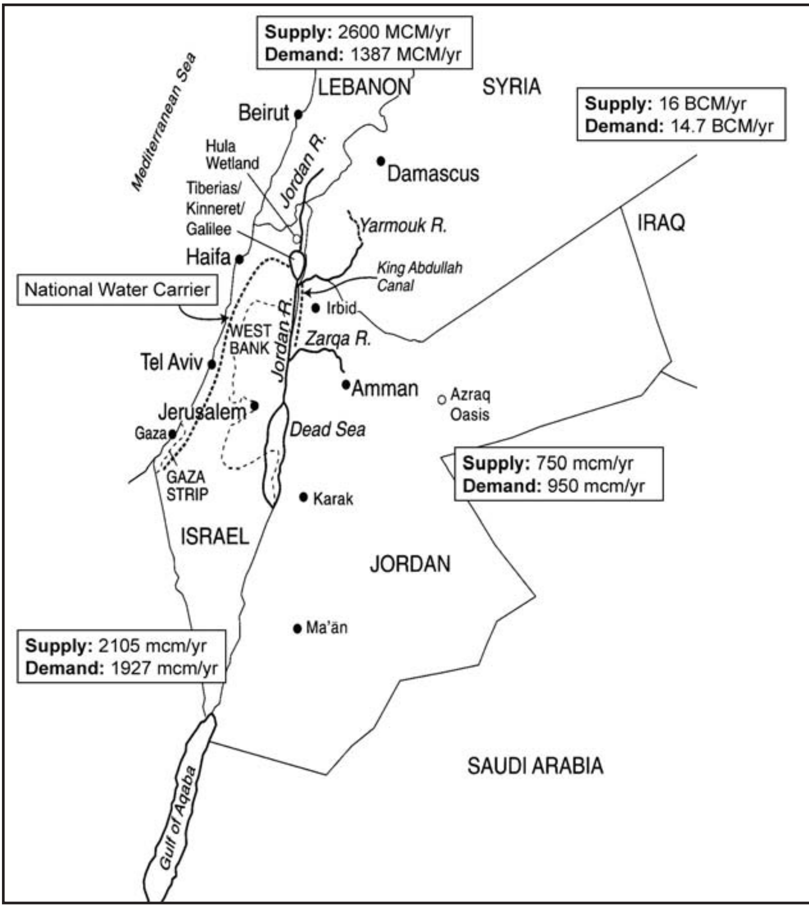

Figure 1. The Jordan River System.

SOURCE: Map is adopted from the Committee on Sustainable Water Supplies for the Middle East. (1999). *Water for the Future, the West Bank and Gaza Strip, Israel, and Jordan*. Washington, D.C.: National Academy Press. Data for water supply and demand comes from: Lithwick, 1998; El-Fadel, Zeinati, and Jamali, 2000; Author's interview with Syrian Government Officials, Damascus June 12, 2001; and Author's interview with Hazim El-Naser, Secretary General, Ministry of Water and Irrigation, Amman, April 17, 2001.

Since the 1920s, it was well known that the Jordan River system failed to carry sufficient water to meet the domestic needs of its riparian states (Wolf, 1995; Haddadin, 2002). It is generally believed that the upper and lower portions of the Jordan River contain between 1,400 to 1,600 million cubic meters per year (mcm/yr). In comparison to other river systems within the Middle East, the Jordan River carries the annual flow of 1.5 percent of the Nile River and 4.3 percent of the Euphrates River (Salameh and Haddadin, 2006). Due to population growth, industrialization, and climate change the Jordan River riparians face ever-increasing demand on a limited supply of freshwater (World Bank, 2007). To meet these growing demands the riparians have over-exploited all internal renewable and non-renewable sources of freshwater and they are looking towards alternative sources, such as desalinization and treated wastewater. As will be evident shortly, the water crisis is the strongest in Jordan and Israel (Swain, 2004).

Israel's estimated domestic water consumption is 1,927 mcm/yr. Aquifers contribute 1,250 mcm/yr, the upper Jordan River and Lake Tiberias contribute 640 mcm/yr, the lower Jordan and Yarmouk contribute 85 mcm/yr, streams and springs contribute 130 mcm/yr, and treated wastewater contributes 460 mcm/yr (Lithwick, 1998). This constitutes a complete development of all internal water resources. In fact, a commission studying Israel's water resources concluded, "Natural resources of water are currently fully exploited. Presently the use of treated sewage effluents is the main source of additional supplies for the irrigation sector, as a substitute for fresh water supplies, which are diverted for urban and industrial consumption" (Arlosoroff, 1997, 1). This recommendation constitutes a change of Israeli water policy, which has involved mining of aquifers to meet growing domestic demand.

While Israel is able to meet its domestic demand for water, Jordan runs on an annual deficit of about 200 mcm, which is expected to increase because of high population growth rates and a diminishing supply of freshwater. Jordan's renewable water resources are estimated at 750 mcm/yr.[6] In 1995, its domestic demand was 882 mcm/yr. By 2001, this demand had increased to 950 mcm/yr (World Bank, 1997). The Jordanian government compensates for this deficit by setting substantial domestic rations on water, transferring water away from the agricultural sector, mining non-renewable fossil water, and appealing to neighbors for a drop of water.

Unlike Israel and Jordan, Syria and Lebanon have access to alternative river systems that permit them to meet their domestic demand for freshwater. Total domestic water demand in Syria is 14.7 billion cubic meters annually (bcm/yr). The Euphrates and Orontes (Asi) Rivers contribute 50 and 20 percent respectively to Syria's water budget, while the Yarmouk River contributes three percent.[7] Perhaps one of the richest states in the Middle East in terms of precipitation and rivers is the state of Lebanon, which has about 17 perennial rivers, 40 streams, and substantial ground water. Due to an unstable domestic political system, Lebanon has not been able to make full use of its water resources, most of which flow largely unused into the sea or neighboring states. Although an upper riparian to the Jordan River system along the Hasbani River, Lebanon has not significantly developed the springs feeding this tributary and consequently the majority of this water flows unused into Israel (El-Fadel, Zeinati, and Jamali, 2000). Having described the water balance of the Jordan River riparians, the following section considers the attempts at sharing this river system.

Eric Johnston's Mission

After the 1948 Arab-Israeli war, the Jordan River riparians began to plan unilateral development of the river system. As they initiated these separate projects, sporadic fighting ensued (Wolf, 1995). Fearing the outbreak of war over the river, then United States President Dwight D. Eisenhower sent Eric Johnston to the region to negotiate a settlement to the water dispute. From 1953 until 1955, Ambassador Eric Johnston shuttled between the capitals of Egypt, Israel, Jordan, Lebanon, and Syria in an attempt to negotiate an agreement. Although not a direct riparian to the surface water of the Jordan River system, the support of Nasar's Egypt was perceived as essential to reaching a final settlement.[8] From the beginning of these negotiations, the riparians had difficulty reaching agreement on the following issues:

1. The proportional allocation of the river's water;
2. The incorporation of the Litani River into the negotiations;
3. The use of Lake Tiberias as a natural storage reservoir and construction of dams along the Yarmouk;
4. The transfer and use of the Jordan River's water out-of-basin; and
5. The establishment of an institution to oversee the treaty's allocations.

The quantitative allocation of the river system was one of the most contentious issues to mediate. In an attempt to augment the supply of water within the river system, Israel insisted on including the Litani River (Amery, 1993). Since the Litani originates and flows entirely within Lebanon and it is not connected to the Jordan River system, the Arab states rejected the proposal. After persuasion from the United States, Israel agreed to focus the negotiations on the Jordan River system and exclude the Litani. The second option to augment the existing supplies was to collect and store the Yarmouk River's floodwaters by constructing dams and using Lake Tiberias for storage. Fearing that its sovereignty over the lake might be compromised, Israel refused to agree to use the lake as a natural storage reservoir. Pointing to different concerns, mainly the fear of dependence on Israel, the Arab states also rejected the use of the lake. After four rounds of mediation efforts by the United States, however, both Israel and the Arab states agreed to use Lake Tiberias and to construct dams along the Yarmouk to collect the tributary's floodwaters.

As for the individual quantitative allocations, Israel sought all the waters in the upper Jordan River, with minor allocations to Lebanon and Syria—25 mcm/yr and 30 mcm/yr respectively. In exchange, the Yarmouk River would be given to Jordan, with some allocations to Israel—40 mcm/yr (Wolf, 1995). The Arab states sought the majority of the Jordan River—911 mcm/yr—for the state of Jordan. Under this plan, Syria would receive 120 mcm/yr, Lebanon 32 mcm/yr, and Israel 270 mcm/yr (Lowi, 1993, 90). After several rounds of shuttle diplomacy between the region's capitals, the states agreed to the following compromise. Jordan would receive 100 mcm/yr from the Jordan River. Lebanon's share of the upper Jordan River was fixed at 35 mcm/yr, while Syria received 42 mcm/yr from the Jordan River and 90 mcm/yr from the Yarmouk tributary. Israel's share of the Yarmouk River was fixed at 25 mcm/yr. Jordan was allocated the residual of the Yarmouk tributary, while Israel received the residual of the Jordan River (Wolf, 1995).

Although the Arab states insisted on giving priority to using the Jordan River's water within the basin, after intensive negotiations they agreed that Israel would unofficially use the water out-of-basin (Lowi, 1993). Finally, after mediation efforts to overcome initial apprehension by Israel, the states agreed to form an institution. The commission was expected to oversee water withdrawal, gather hydrological data, and prevent the construction of projects outside of the agreement (Naff and Matson, 1984). An Israeli and an Arab, along with a third member selected by them constituted the commission. Decisions within this commission were to be made on a unanimous basis (Reguer, 1993).

Israel and Jordan were anxious to accept the final plan reached by Ambassador Eric Johnston so that they may proceed with developing the river system. Lebanon, which had little to gain from the agreement because of its internal water wealth, was less interested in its endorsement (Lowi, 1993). Due to political turmoil in Syria and the availability of alternative sources of water, it was similarly less interested in an agreement. Nevertheless, after gaining approval of the Arab and Israeli technical committees and the Egyptian leadership, Johnston's agreement was sent to the Arab League for confirmation in October 1955. The Arab League refused to accept the proposal without further technical studies. The plan was returned to the Arab League in March 1956, but again it could not reach an agreement. Despite the failure to accept and ratify the Johnston Plan, the two riparians most dependent on the river, Israel and Jordan, have tended to comply with the agreement. In exchange for their compliance, the United States funded projects that conformed to the Johnston Plan (Lowi, 1993; Reguer, 1993). The Johnston Plan has also been the baseline for Lebanon and Syria in all their future negotiations over the Jordan River system (Wolf, 1995).

After the failure to formalize the Johnston Plan, Israel and Jordan proceeded with the development of the Jordan River system within their respective territory. In 1955, Israel undertook construction of its National Water Carrier (NWC), which involved the transfer of water from Lake Tiberias to the coastal region and the Negev. The NWC constituted the first out-of-basin transfer of water in the Jordan River system (Wolf, 1995). As for the state of Jordan, it undertook construction of the East Ghor Canal (later renamed the King Abdullah Canal (KAC)), which transported water from the Yarmouk River to the Jordan Valley.

Alterations To International Borders

The 1967 Arab-Israeli war not only changed the region's borders, but it also secured for Israel control of the Banias River and Lake Tiberias. Israel also gained greater access to the lower Jordan River and the Yarmouk River. Prior to the war, Israel's direct contact with the Yarmouk River was a six kilometer stretch. After gaining control of the Golan Heights, Israel's contact increased to almost 50 percent of the Yarmouk River (Lowi, 1993). Israel also came into control of highly fertile land located at the confluence of the Yarmouk and Jordan Rivers. The gain of the West Bank from Jordan secured Israel's access to the lower Jordan River. Due to this shift in the international border, the interdependence[9] between Israel and Jordan increased because during the winter the Yarmouk River carries sediments that settle and clog the river during the summer season. To ensure the continued flow of water, it was essential to dredge the river. The failure of Jordan and Israel to communicate and coordinate a dredging operation resulted in years of sediment accumulation that eventually formed a sand bar, a small island with wild plants in the center of the river (Haddadin, 2002). The sand bar not only obstructed the river's flow, but it also began to choke the drop inlet of the KAC. In time, this situation culminated in the formation of an informal institution between Israel and Jordan, which was born out of necessity.

The Israeli-Jordanian Picnic Table Talks

In 1979, Jordan turned to the United States to mediate a meeting with Israel in order to dredge the Yarmouk River. The American embassies in Amman and Tel Aviv coordinated the first meeting, which led to the formation of an informal institution that then began to meet on a regular basis (Lowi, 1993; Wolf, 1995; Haddadin, 2002). Meetings of this informal institution were held every summer to dredge the Yarmouk and divide its water. Members met in the field to measure and allocate the water, and arrange for upcoming meetings. Four or five people from each side attended these meetings, along with a member of the international community.[10] Those in attendance included members of the military of both sides, a representative from the states' Ministries of Foreign Affairs, a team of engineers, and a representative from the United Nations or the United States.[11] Outside of these meetings, there was no direct communication between Jordanian and Israeli members of this informal institution. All communication was through the third party. After the initial meeting between the technicians, a second meeting was usually arranged to dredge the river. At the second meeting, trucks and workers were brought to clean the silt (Haddadin, 2002). Sandbags were brought to divide and divert the river. With time, the technicians began to set around a picnic table to negotiate, as the military surrounded them.[12] All sides took notes, but minutes of the meetings were not prepared. During the meetings, decisions were made on a unanimous basis and a handshake sealed the outcome.[13] After the meetings, members of the institution briefed their respective governments on their activities in the field (Haddadin, 2002).

Israel and Jordan's informal institution lacked the capacity to monitor its member states' development of their shared river system. Members were restricted to a small triangle along the Yarmouk River where they met to dredge the river and divide the water. Unable to tour the river to collect information in order to overcome their fear of cheating, members relied on intelligence gathered from their military posts to discern any changes. Because of the interdependent relationship rivers impose, any development is likely to be noticed. If Israel noticed a change, a helicopter was sent to take pictures and satellite photographs were examined to document the change. Military binoculars also permitted both Jordanian and Israeli engineers to look into their riparian neighbor's territory to discern any potential cheating (Haddadin, 2002). These attempts by each state to gather information regarding their riparian neighbor's development of the shared river were insufficient to overcome fear of cheating. Suspicion of cheating was responsible for precipitating political flare-ups on several occasions (Zawahri, 2008a).

What saved these states from open military conflict was the presence of third party mediators and the evolution of some conflict resolution mechanisms within the informal institution. Initially, the United States and the United Nations were very active in mediating water disputes between Israel and Jordan (Haddadin, 2002). With the passage of time, members of the informal institution developed some conflict resolution mechanisms and became less dependent on a third party to mediate their disputes. As one participant noted, "During the meetings, we agreed by a handshake, if in later meetings there was a disagreement on the interpretation, we sat and talked it through, 'a do you remember.' A handshake was a very strong commitment."[14] Another participant confirmed the evolution of some conflict resolution mechanisms within the informal institution: "Many times problems arose and were resolved in the field, without the knowledge of the upper government officials."[15] This informal institution continued to operate until its replacement with a formal one in 1994.

A Bilateral Accord To Govern Shared Waters

Throughout the 1970s and 1980s, the United States continued its efforts to mediate an agreement between Israel and Jordan over their shared river system. However, it was not until October 26, 1994 that these riparians "would settle [their water disputes] on their own without outside intervention" (Hof, 1995, 48).

Article 6 and Annex II of the Israeli–Jordanian Peace Treaty focus on managing all their shared water systems, which include the Yarmouk tributary, lower Jordan River, and Wadi Araba/Arava (Treaty of Peace between the State of Israel and the Hashemite Kingdom of Jordan (Peace Treaty), 1994). Article 6 of the Peace Treaty acknowledges the rights of Israel and Jordan to the Jordan River, Yarmouk River, and Wadi Araba/Arava waters, and secures their existing consumption from these shared hydrological systems. Because existing water resources are insufficient to meet the growing demands of the riparian states, Article 6 calls upon the riparians to cooperate in the search for additional sources of water (Peace Treaty, 1994).

Annex II of the Peace Treaty details the allocation of the shared hydrological systems and identifies projects for developing additional resources. Prior to the treaty, the states divided the waters in the Yarmouk River according to a ratio, but the treaty establishes a fixed quantitative division. In the summer months, Israel pumps 12 mcm/yr and Jordan gets the rest of the flow. In the winter months, Israel pumps 13 mcm/yr for itself and an additional 20 mcm/yr it pumps and stores for Jordan. The stored 20 mcm/yr is returned to Jordan in the summer. Jordan is entitled to the rest of the winter flow. However, Israel and Jordan share the floodwaters. As for the lower Jordan River, the state of Jordan is permitted to construct storage facilities to secure for itself 20 mcm/yr and three mcm/yr to Israel from periodic floodwaters. Jordan is also entitled to 10 mcm/yr of desalinated water from salt springs that Israel diverts to the Jordan River. In exchange for this water from the salt springs, Israel is permitted to pump 10 mcm/yr from wells located inside Jordan's Wadi Araba/Arava territory. Finally, the states were expected to cooperate to find an additional 50 mcm/yr of drinkable quality water for Jordan (Peace Treaty, 1994). The likely source of this water remains a complete mystery, even to the riparian states themselves (Zawahri, 2008b).

The Israeli-Jordanian Peace Treaty established the Joint Water Commission (JWC) (Peace Treaty, Annex II, Article VII, 1994) to implement the Treaty, facilitate cooperation in the river's development, and manage the interdependent relationship between the riparian states (Zawahri, 2008b). Three members from each country comprise the JWC. The commission has the ability to "specify its work procedures, the frequency of its meetings, and the details of its scope of work," but only with the prior approval of its member states (Peace Treaty, Annex II, Article VII, 2, 1994). The JWC consists of high-ranking government officials, whose assigned task is to also manage their respective government's domestic water resources.[16] Since its inception in 1994, the commission has succeeded in accomplishing several tasks. The JWC negotiated the design and construction of the Deganya pipe, which transports water from Lake Tiberias to the KAC. The pipe was designed and constructed in a remarkably short period of time.[17] After several years of negotiations and with some assistance from their national leaders, the JWC was able to build a weir to replace the sandbags previously used to divide the Yarmouk's water. Commissioners were also able to improve the method by which they collected their hydrological data. To survive droughts that plague the region, they established their own accounting system to deliver water.[18]

The JWC has been less successful in implementing the treaty in other areas. The Peace Treaty identified the construction of a desalinization plant that was expected to be completed by 1995 (Peace Treaty, Annex II, Article I, 3, 1994). Commissioners are still negotiating the source of water to be desalinized and how to finance the plant's construction, operation, and maintenance costs (Fischhendler, 2008). Storage facilities to collect floodwaters in the lower Jordan River have not passed the feasibility study stage (Zawahri, 2008b). The Jordanians expected to gain approximately 150 mcm/yr of water, but they gained only 55 mcm/yr from the Peace Treaty after intense negotiations.[19] Israel gained the right to an additional 10 mcm/yr of water from wells in Jordan's Wadi Araba/Arava (Peace Treaty, Annex II, Article IV, 3, 1994) but it is still negotiating the building of additional wells to collect this water. Finally, contrary to the treaty's requirement that the quality of water in the lower Jordan River be cleaned (Peace Treaty, Annex II, Article III, 1994), it remains a dumping ground for Israeli and Jordanian farmers.[20] Due to its relatively weak capabilities, the JWC's struggle to manage its member states' water disputes has not prevented periodic flare-ups and deterioration in bilateral relations (Zawahri, 2008b).

Members of the JWC have the capacity to communicate directly with one another and they hold regular meetings, but the treaty bequeathed the commissioners with weak monitoring capabilities and inadequate conflict resolution mechanisms. Commissioners can monitor Israeli wells inside Jordan's Wadi Araba/Arava (Peace Treaty, Annex II, Article IV, 4b, 1994). The southern subcommittee tours these wells on a regular basis. Meetings of the northern subcommittee can be held in the field, but commissioners depend on government permission for their field meetings, which have taken place in the Jordan Valley, Beit Shean/Beasan, Lake Tiberias, and Adasiyya. During the JWC's tenure, member states have postponed or refused to grant permission to inspect sites (Zawahri, 2008b).

The treaty does not directly stipulate conflict resolution mechanisms for the JWC, but some have suggested that commissioners may draw on the general conflict resolution mechanisms specified in Article 29 of the Peace Treaty (Shamir, 1998). According to this Article, disputes arising from the treaty's implementation should be settled via negotiations, conciliation, or arbitration (Peace Treaty, Article 29, 1 and 2, 1994). Commissioners have sought to negotiate settlements to disputes as they arose during their meetings and as they attempted to implement the treaty. When disputes occur between technicians in the field or members of the subcommittees, they attempt to resolve them. If they fail, the disputes are sent to the JWC for further discussion. The JWC's inability to manage disputes has contributed to deterioration in relations that led to emergency meetings between the states' national leaders. Examples include the attempt to build the Adasiyaa weir and desalination plant and the attempt to manage droughts that prevented meeting the treaty's fixed allocation commitments. As these disputes arose, commissioners attempted to resolve them. When negotiations failed, a telephone call or an emergency meeting between the Israeli Prime Minister and Jordan's monarchy often succeeded in resolving issues (Zawahri, 2008b).

Bilateral Accords To Govern The Yarmouk

In contrast to the Israeli and Jordanian negotiations, Jordan and Syria have signed several bilateral agreements to develop the Yarmouk River as it flows between their borders. The riparians reached their first agreement in 1953, to construct several dams along the Yarmouk in attempt to store irrigation water and generate hydropower. The Maqarin dam was the largest of the planned hydrological structures with the capacity to store 300 mcm and generate hydropower. The stored water was intended to irrigate lands in Jordan and Syria, while 75 percent of the generated hydropower would go to Syria and 25 percent to Jordan. Jordan was responsible for financing 95 percent of the construction costs and the majority of the operation and maintenance costs. The treaty failed to specify a fixed quantitative allocation of the Yarmouk's waters between Jordan and Syria, but it did acknowledge Syria's right to use springs feeding the tributary and the main branch of the Yarmouk below Maqarin (Agreement Between the Syrian Arab Republic and the Hashemite Kingdom of Jordan Concerning the Utilization of the Yarmuk Waters, 1953). Some suggest that this quantity equaled 90 mcm/yr, which was Syria's share in the Johnston Plan (Hof, 1998).

To implement the treaty, oversee construction of the planned infrastructure, and address disputes, the Joint Syro-Jordanian Commission was established. The commission was given monitoring capabilities and conflict resolution mechanisms. Commissioners and their assistants had the capacity to tour the study areas without prior permission from government officials. Should the commissioners be unable to resolve a dispute, they could send the issue to an arbitration committee consisting of three individuals (Agreement Between the Syrian Arab Republic and the Hashemite Kingdom of Jordan Concerning the Utilization of the Yarmuk Waters, 1953).

Israel's control of the Golan Heights after the 1967 Arab-Israeli war, which increased its access to the Yarmouk, and renewed mediation efforts by the United States to assist in constructing the Maqarin dam necessitated the negotiation of a new accord. As a result, in 1987 Jordan and Syria signed their second agreement on the Yarmouk River, which focused on the construction of the Maqarin dam (now known as the Unity or Wahdah dam). Unlike the 1953 agreement, the new treaty required Jordan to bear the entire cost of planning, studying, constructing, operating, and maintaining the dam. The total height of the dam was fixed at 100 meters, but the treaty did permit the states to raise the height in the future (Agreement Between the Syrian Arab Republic and the Hashemite Kingdom of Jordan Concerning the Utilization of the Yarmouk Waters, 1987). The storage capacity of the Wahdah dam decreased from 300 to 225 mcm to reflect the decreasing flow of the Yarmouk (Hof, 1998).

Once again, the treaty did not provide for a fixed quantitative allocation of the Yarmouk between Syria and Jordan. Rather, it simply secured Syria's right to use springs feeding the Yarmouk and to fill over 20 of its small dams prior to filling the planned Wahdah dam. The accord established the Joint Syria-Jordan Commission,[21] which consisted of three members from each state. Unlike the previous agreement, the 1987 accord decreased the commission's capabilities, especially its conflict resolution mechanisms and monitoring capacity. If commissioners were unable to resolve disputes, their only option under the new treaty was to send the issue to their respective governments for settlement. Use of an arbitration committee consisting of three experts to resolve a dispute was purged. Furthermore, the commissioners were no longer authorized with the autonomy to travel within each state to collect information. Rather, commissioners were permitted to travel through the construction site only with prior permission (Agreement Between the Syrian Arab Republic and the Hashemite Kingdom of Jordan Concerning the Utilization of the Yarmouk Waters, 1987).

In 2001, Syria and Jordan reached a third bilateral agreement over the Yarmouk River and construction of the Wahdah dam (Rosenberg, 2006). The dam's size and storage capacity decreased further from the previous agreement. Due to the decrease in the Wahdah's size, its hydropower generating capacity was deferred. Under the 2001 accord, Jordan compensated Syrian farmers $8 million USD for their land that was to be flooded by the dam. As with the previous accords, Syria secured its use of the river to fill its dams prior to filling the Wahdah dam (Rosenberg, 2006). After years of planning, negotiating, and waiting, on February 9, 2004, Jordan's King Abdullah and Syria's President Bashar Assad celebrated the initiation of construction on the Wahdah dam (United Press International, 2004). The dam was completed in 2006, with a smaller storage capacity, 110 mcm. Yet, due to increased upstream consumption in Syria and consecutive droughts, the dam's reservoir remains unfilled.

Causes And Consequences Of Fragmented Governance

As the foregoing analysis has demonstrated, with the exception of the Johnston Plan, all accords over the Jordan River have been bilateral. What are the potential consequences and causes of these fragmented attempts at cooperation?

There are several negative consequences, because fragmented cooperation can contribute to inefficiencies in the management of multilateral rivers, complicate the implementation of existing bilateral accords, and increase the possibility for future instabilities. Scientists, engineers, and hydrologists have argued that the sustainable and efficient approach towards managing an international river is to develop it as an integral system that respects the hydrological interdependencies within the basin and among the various users (Global Water Partnership, 2000). Consider the need for states to manage floods or droughts that tend to affect the entire basin. To minimize the potential social, economic, and political losses that these natural hazards can inflict, it is necessary for riparians to communicate and share hydrological data. Failure to transmit timely data can contribute to direct and indirect losses among riparian states. To manage natural hazards most effectively, multilateral agreements are needed because bilateral accords can weaken states' collective ability to respond effectively by complicating the coordination and sharing of hydrological data.

Implementation of several bilateral agreements on a single multilateral river may challenge the long-term attempts at cooperation because exclusion of riparians that can affect the quantity and quality of water within the river can complicate attempts at compliance (Kliot and Shmueli, 1998). Consider the bilateral accords governing the Yarmouk tributary. Due to increased upstream consumption of the tributary by Syria and consecutive droughts, the Wahdah dam's reservoir remains unfilled. Yet, midstream Jordan must fulfill its treaty commitment to deliver to Israel 25 mcm/yr from the Yarmouk River. An empty reservoir may undermine or complicate Jordan's ability to comply with its treaty commitments. The failure to establish a multilateral accord between Syria, Jordan, and Israel over the Yarmouk is likely to continue to challenge the ability to comply with the commitments in two separate bilateral accords. Challenges to existing bilateral treaties are also likely to surface once the excluded riparians sign accords over the Jordan River. The Palestinian Authority, Syria, Lebanon, and Israel have yet to reach an accord over this shared hydrological system. Any future accord between these riparians over the Jordan River system is likely to be influenced by and in turn influence all existing accords.

To account for the forces influencing the rise of fragmented governance, scholars have tended to use either interest or power based arguments. Drawing on interest based arguments some experts have suggested that compared to bilateral negotiations there are inherently higher transaction costs associated with multilateral negotiations that may complicate their success (Hopmann, 1996; Just and Netanyahu, 1998; Waterbury, 2002). As the number of negotiating parties increases, so does the various interests that have to be accommodated, which can reduce the possibility of reaching an agreement (Hopmann, 1996; Waterbury, 2002). Furthermore, multilateral negotiations decrease each state's ability to secure its own interests in an accord and they enable less interested states to complicate the negotiation process. Combined, these factors can prevent the successful conclusion of negotiations and the formation of a treaty.

Anticipation of the sanctioning problem that often plagues multilateral cooperation can also decrease states' interest in conceding to this form of collaboration. In bilateral cooperation cheaters can be identified and punished, but as the number of cooperating states rises the potential for free-riding increases because of the difficulty in identifying and punishing defection (Axelrod and Keohane, 1989). To overcome fear of free-riding, the moral hazard problem, and the inefficiencies associated with multilateral negotiations, states have an interest to break up multilateral interactions into bilateral ones.

Some scholars have also suggested that fragmented attempts at cooperation can possibly lead to future multilateral accords (Just and Netanyahu, 1998). This possibility is especially present for the Jordan River riparians because the macro-political environment of the Arab-Israeli dispute increases the cost incurred from multilateral collaboration and decreases states' interest in the formation of a basin-wide accord.

Using power-based arguments other experts have attributed the presence of fragmented cooperation to the relative distribution of power within a basin. A powerful riparian prefers bilateral negotiations and bilateral treaties because they minimize the formation of coalitions between weaker riparians, which might upset the distribution of power and weaken the hydro-hegemon's capacity to secure its own interests (Lowi, 1993; Crow and Singh, 2000; Salman and Uprety, 2002).

Relying on quantitative analysis, Zawahri and Mitchell (2009) argue that it is necessary to combine interest and power based arguments to account for the rise of fragmented governance. Through an empirical analysis of 404 bilateral and multilateral treaties covering bilateral and multilateral basins, they discover that the combination of state interest, transaction costs, and distribution of power influence the type of treaty governing international rivers. Multilateral accords are more likely to occur when there is parity of power among riparian states and they are dependent on the international river. Transaction costs in multilateral negotiations are lowered when riparians are democratic, they share similar legal systems, and they are economically interdependent. Bilateral accords in multilateral basins are likely when the riparians are dependent and a hydro-hegemon is willing to pay the sunk costs of dividing multilateral negotiations into bilateral interactions (Zawahri and Mitchell, 2009).

Combined, the foregoing analysis of the causes and consequences of fragmented cooperation lead us to conclude that there are real structural impediments to the formation of a basin-wide accord to govern the Jordan River system. The riparians confront high transaction costs because they differ in regime type and domestic legal system, along with a lack of strong economic interdependence. There is also an asymmetry in interests, because some riparians are much more dependent on the Jordan River system than other riparians. Within the basin there is asymmetry in power, with Israel possessing much more military capabilities than the other riparians. The macro-political Arab-Israeli conflict overshadows issues of low politics, such as sharing the Jordan River system (Lowi, 1993). Given these structural impediments, what are the variables that can contribute to the formation of a basin-wide accord?

A basin-wide accord can arise once the overall Arab-Israeli conflict is settled or is close to settlement. Given the asymmetry in interest and power among the riparians along with the high transaction costs, a third party mediator is needed to overcome these potential obstacles. The single mediator, such as the World Bank, can use the carrot and stick to facilitate compromise. The mediator can draw on financial incentives, issue linkages, and side-payments to overcome the asymmetry of interest and power between the riparians. The high transaction costs confronting these riparians may be minimized with a mediator and the formation of an effective river basin commission. Scholars have suggested that the free-rider and sanctioning problems confronting multilateral collaboration may be minimized through the formation of effectively designed institutions (Martin, 1992). Consequently, there is a possibility that a basin-wide accord to govern the Jordan River system in attempt to minimize inefficiencies and prevent sub-optimal outcomes can arise, despite the potential structural impediments.

Conclusion

Several conclusions may be drawn regarding the various attempts at governing the Jordan River system. First, contrary to an extensive history of animosity, some of the riparians have managed to find informal and formal methods to manage their shared hydrological system. Although the Johnston Plan was never signed or ratified, some riparians sought to comply with the agreement while others have used it as a baseline from which all future negotiations begin. Israel and Jordan, the two riparians most dependent on the river system, used informal and later formal means to manage the interdependent relationship within this river system. To coordinate their development of the Yarmouk River and store floodwaters, Syria and Jordan also reached several accords. Second, with the exception of the Johnston Plan, bilateral agreements have been the selected path towards governing this multilateral river system. Although bilateral agreements might be easier to negotiate, they can result in inefficiencies in the management of an international river and complicate the ability to comply with existing or future accords.

Several questions for future research arise from this analysis. Climate change is expected to increase the occurrences of natural hazards, such as floods and drought, and decrease freshwater supplies along the Jordan River (Evans, 2009). Research can consider the capacity of fragmented governance and existing river commissions to manage the anticipated variability in freshwater supplies. Second, there is no questioning the fact that the Jordan River carries insufficient water to meet the current and future demands of its riparians. Future research can consider whether political and economic incentives increase or decrease the efficiency by which existing supplies are used.

Notes

1 Field research was conducted in Israel, Jordan, and Syria from November 2000 through September 2001. In the Middle East, information on water is considered integral to national security. At times, the names of experts are withheld to protect their identity.

2 Author's interview with Meir Ben Meir, former Israeli Water Commissioner (1977-1981 and 1996-2000), Kfar Massaryk, February 7, 2001.

3 The Palestinian Authority and Palestinian officials do not participate as independent actors in the negotiations over water resources until after the Oslo Accords. Furthermore, after 1993, all negotiations between Israel and the Palestinian Authority over their shared water resources have focused on aquifers. Consequently, the Palestinian-Israeli negotiations are not included in this analysis.

4 A sample of the work examining the Jordan River system includes: Wolf, 1995; Lowi, 1993; Amery & Wolf, 2000; Haddadin, 2002; and Amery, 2002.

5 The Dead Sea, at 395 meters below sea level, is the lowest point on earth.

6 Author's interview with Hazim El-Naser, Secretary General, Ministry of Water and Irrigation, Amman, April 17, 2001.

7 Author's interview with Syrian government official, Damascus, June 12, 2001.

8 Egypt is included within the entire basin of the Jordan River system (Wolf *et al.*, 1999).

9 For more information on the interdependent relationship between riparians and the national security threat it produces, see Zawahri, 2008c.

10 Author's interview with Noah Kinarty, Chief Adviser to the Prime Minister on Water Affairs, Jerusalem, February 5, 2001.
11 Author's interview with Moshe Yzraeli, consultant to Water Commissioner, Tel Aviv, February 21, 2001.
12 Because of this picnic table, this informal institution is known as the Picnic Table Talks.
13 Author's interview with Meir Ben Meir, former Israeli Water Commissioner (1977-1981 and 1996-2000), Kfar Massaryk, February 7, 2001.
14 Author's interview with Meir Ben Meir, former Israeli Water Commissioner (1977-1981 and 1996-2000), Kfar Massaryk, February 7, 2001.
15 Author's interview with Moshe Yzraeli, consultant to Water Commissioner, Tel Aviv, February 21, 2001.
16 From the time spent with both Israeli and Jordanian water officials, it was obvious that members of the JWC are overworked.
17 Author's interview with Moshe Yzraeli, consultant to Water Commissioner, Tel Aviv, February 21, 2001.
18 Author's interview with George N. Silbey, Regional Environmental Officer, US embassy in Amman, April 25, 2001.
19 It is important to note that in Jordan the public was led to believe that Jordan's water gains would be 215 mcm/yr and not 150 mcm/yr.
20 Author's interview with Yeshayahu Bar-Or, Director of Division of Water and Streams, Ministry of the Environment, Jerusalem, January 23, 2001.
21 Note that the name of this commission does change from the previous treaty, see Article IX of the 1987 treaty.

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Future Solutions:
Research Needs In The Mexican Section Of The Rio Grande (Bravo) Watershed

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This paper discusses technical water issues in regard to research needs in the Mexican portion of the binational Rio Grande watershed. It describes tasks for efficient watershed management and suggests water research topics that should be addressed. These research needs will require expertise in many disciplines and the resources to support multidisciplinary teams. This paper suggests that future research needs will be related to initiatives requiring the earth sciences along with the use of applied geospatial technologies.

Holistic approaches to administering and managing water resources have gained attention from world governments and from international water experts interested in the preservation of watersheds. In the next 20 years water resources research will become the most important topic on the international agenda, with technologies from hydro-informatics required to support this research, (MacKay and Band, 2009). However, many developing countries, including Mexico, lack a long-term strategy for improving scientific knowledge of water resources to support improved water resource management and policy application.

The present long-term plans in Mexico for water conservation and management are limited to real-time challenges such as water demands, sewage demands, leaks, water treatment plants, and conservation-maintenance of present water infrastructure. Long-term challenges are not presently seen as priorities for water resource managers or the government. The challenges in Mexico for improved water management and policy in the long term will require an investment in water resources research.

Studies are needed in the areas of groundwater recharge, watershed mapping, understanding aquifer formations, efficient water use for food and fiber production, transfer of water technologies, demographics and future water demands, climate change effects on water resources, water resources quantity and quality, transboundary water resources, environmental demands for ecosystems, ecohydrological conditions, and an evaluation of homeland security.

The Mexican state of Chihuahua provides a case in point. In this border state, intense population growth, expansion of irrigated areas, depletion of groundwater resources, potential point and non-point contamination areas, and climate change risks are threatening the normal functioning of the state's water resources. Of particular concern is the transboundary nature of Chihuahua's watersheds, many of which are located in arid and semi-arid areas. In recent years, the holistic approach to hydrologic understanding of the Paso del Norte region of the Southwest U.S.-Northern Mexico border, an area that includes portions of Chihuahua, has identified the importance of a systematic study of the hydrological processes including the approach to tasks and water challenges based on a watershed approximation, implementing actions along basins and sub-basins located within these transboundary territories, (Creel *et al.*, 2007; Granados, *et al.*, 2006; Hurd *et al.*, 2006; Carabias *et al.*, 2005; Brown *et al*, 2005 and Brown *et al.*, 2005).

Worldwide the study of hydrologic processes in arid and semi-arid regions has received limited attention and few details are available to interpret the hydraulic phenomena within ecohydrological dry regions, (Wheater, *et al.*, 2008). In Mexico watersheds have been delineated at a low-scale resolution for the whole country. Approximately 1,829 watershed regions have been identified where all administrative and conservation actions take place, (Fig. 1). Out of the total water uses in the country, primary applications have been identified: agriculture (69%), domestic (25%) and industrial uses (6%) out of the total volume of water used. Little consideration is given for other uses such as environmental or natural flows.

In regard to groundwater, official Mexican data identify only 653 aquifer formations in the nation's watersheds. The aquifers have been mapped-delineated without a systematic methodology. Out of the 653 aquifer formations official data identifies 102 over-pumped aquifers. Nonetheless, a thorough understanding of these aquifer formations remains limited, (Chavez, *et al.*, 2004; Chavez & Sancion, 2006).

From significant hydrological geodata generated under a GIS environment, Mexico has identified the surface hydrology network density which has been classified by lengths of the main tributaries and rivers, as well as areas of aquifer formations defined under three classification scales: a low, medium or high potential for groundwater resources reservoirs. However, these delineations and their related water potentials are uncertain since the scale of analysis is limited to a 1:250,000 approximation. Efforts to enhance the scale of the analysis and acquire greater knowledge of these water resources have been undertaken by water resource experts from the north-central region of Mexico and the southwest U.S., (Creel *et al*, 2008; Eastoe *et al*., 2008; Hawley & Granados, 2008; Hibbs *et al*., 2007; Granados, 2000; Granados & Monger, 1998). Despite these efforts there remains a need to evaluate and characterize the different water resource assets in Mexico.

Figure 1. Mexican watersheds mapped at scale 1:250,000.

To summarize, Mexico has limited understanding of the physical and chemical characteristics of these water resources and little information about the dynamics of the system. A thorough understanding of water resources basic science, efficient administration, technology transfer and the variables of space and time is required. Groundwater resources research along the border region remains a task that requires government attention and will be needed to thoroughly comprehend the transboundary dynamics of this natural resource in this transboundary region.

This paper addresses some of the most relevant research needs for the U.S.-Mexico region along the Rio Grande (Bravo) as part of an effort to define possible future solutions for a holistic approach to transboundary water resource management. A secondary purpose of this paper is to advance the bilateral agenda on water resources between Mexico and the United States. The discussion will concentrate on case studies related to the topic under consideration with examples of the outcomes of different water policies and their implications on bilateral relations for improved water management between Mexico and the United States.

Demographics And Socio-economic Issues In The Mexican Section Of The Rio Grande (Bravo)

In order to understand the research needs on the Mexican side of the Rio Grande (Bravo), we need first to address the drivers for the water requirements in the region. The region of interest is sited at one of the most important deserts in North America: the Chihuahuan Desert Ecosystem with more than 350,000 km^2 and a total geospatial distribution of ¾ in Mexico and ¼ in the United States (Figure 2).

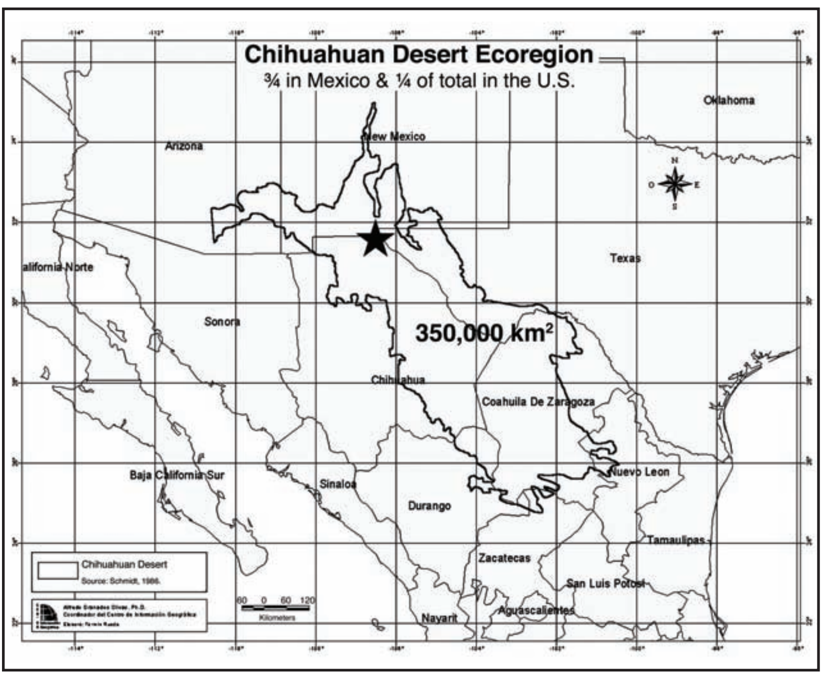

Figure 2. Chihuahuan desert ecoregion with > 350,000 km^2
(Modified from Schmidt, 1986)

There is a common understanding that one of the most important natural resources in the region is water. Its conservation is one of the most important action items for the area (Carabias *et al.*). Some of the most industrialized and populated cities within Mexico are Ciudad Juárez (population > 1,300,000) and Ciudad Chihuahua (Population >700,000), all within Chihuahua, while the total population of the state is estimated at more than 3,200,000, (INEGI, 2000). These two cities concentrate more than two-thirds of the total population of the state. They are where water demands are most intense and where water infrastructure is needed as cities grow.

The two cities provide water for domestic and industrial uses from groundwater since this is the only available water resources at these regions. In the case Ciudad Juárez (star in figure 2), the surface water allotment per year from the Rio Grande (Bravo) international treaty (75 Mm^3) is a potential source for future domestic and industrial requirements. However, this is a matter of debate between the city and the farming community of Irrigation District 009-Valle de Juárez, located to the southeast of the major metropolis. Because the waters were intended for agricultural uses, the farming communities defend their water rights and have not agreed to the redistribution of these waters for domestic purposes.

The debate over the region's future water allocation has broadened in scope. Under Mexico's National Water Law (http://www.oas.org/usde/environmentlaw/waterlaw/documents/M%C3%A9xico-Ley_de_Aguas_Nacionales_(2004).pdf), the umbrella law for water disputes, domestic water use is considered a priority over other uses, including agriculture. In other locations, the Mexican federal government is evaluating the potential for establishing water markets to support greater economic benefits from scarce water. Under this plan, the final decision on water allocation will be based on the highest economic valued uses of water within a watershed. Hence, in the near future, it could be that water rights in the Mexican section of the Rio Grande (Rio Bravo) region will have an economic factor to consider in which the allocation of water resources will be influenced by the most economically valued activities.

The need to evaluate and study these different water market activities is important. Furthermore, this is a binational region. An action plan on how best to reach a sustainable approach to water resource use and meet the demands of binational water users in a shared watershed remains a significant issue. Demands on the region's water resources remain equally high on both sides of the border. Further, there is a concern for the needs of the natural environment and the needs to understand the requirements for natural flows within the region's ecosystems. Regional recreation requires attention as well as the question of quality of life standards relevant to water resources.

Hydrometeorological Network And Gage Stations In Paso Del Norte

Basic hydrometeorological data are important for the understanding of the hydrological system. Information on temperature, wind speed, and direction, and, measurements on precipitation intensity are important for hydrologic models. They also are important for estimating potential hydrometeorological risks within the Rio Grande Watershed, particularly for border communities at these transboundary watersheds, (Rojas, *et al.*, 2008; Granados, *et al.*, 2007).

Weather stations located at the Paso del Norte Region (star in figure 2) are sited around the junction of the Rio Grande (Bravo), at the international border between Mexico and the United States. These were originally established as part of a research project developed by the Department of Civil and Environmental Engineering at the Universidad Autónoma de Ciudad Juárez (UACJ). The weather stations were sited over a broad area for the purpose of covering the largest area possible within the region of interest, (Figure 3). The weather stations were equipped with instruments to measure and digitally store climatic data including data related to storm duration and intensity captured from precipitation.

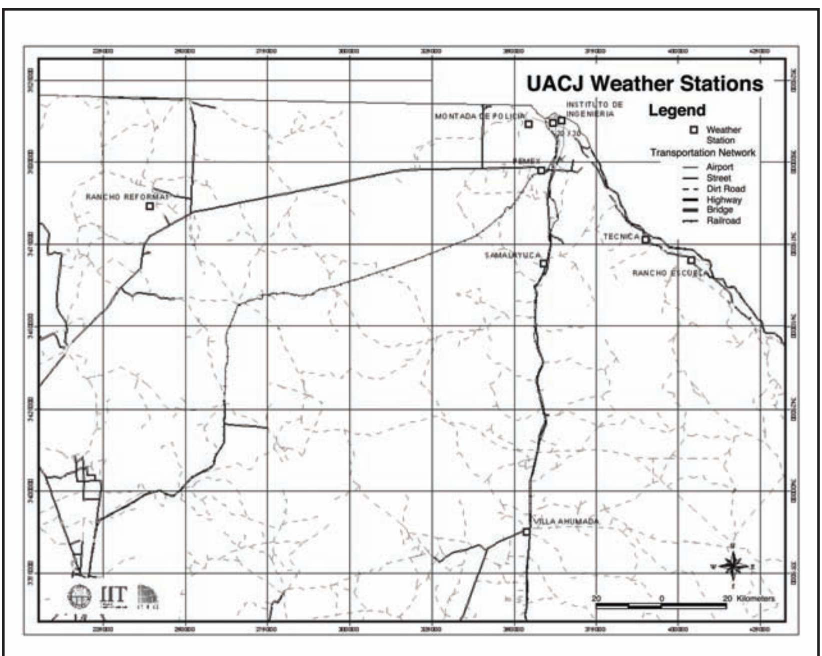

Figure 3. Location of UACJ weather stations at Paso del Norte.

From this effort, nine weather stations were eventually installed at permanent locations within a radius of 120 km with a centroid at the city of Juárez. The climatic stations are important to the region due to the strategic locations at which they were installed. Regional climatic data is now available via Internet (http://www.uacj.mx/clima/) where information is captured on a real time basis for consultation and to populate climatic data for the region.

A more detailed network with 9 stations located within a radius of <10 km with a more dense approach was recently created to evaluate potential hydrometeorological risks on the Sierra de Juárez. These were established to record intense precipitation which is the dominant Type II precipitation for these desert regions. This type of precipitation is characterized by intense and short duration precipitation, which generates flooding in urbanized areas within the city. Similar infrastructure to this is needed at other locations within the binational watershed along the Rio Grande (Rio Bravo) region on the Mexican side.

Although more such stations are needed for data collection, few economic resources are available to address this research requirement. Several Mexican federal agencies have been approached to include such equipment in their budgets for future years. This and other similar data collection efforts will be needed in the near term to enhance our ability to conduct research that allows for future water resource assessments and decisions. Actions to enhance water resources infrastructure for monitoring and data generation will help support the evaluation of potential impacts by climate change as well. Climate change is estimated to have several negative effects due to more frequent punctual torrential rains that could increase hydrometeorological risks at these binational watersheds (Weather, 2008).

Hydrocensus And Wellhead Protection Programs

Efforts to generate a hydrocensus while applying GPS technology to locate and georeference water wells are urgently needed in the Mexican section of the Rio Bravo (Rio Grande) region. While the Comisión Nacional del Agua (can) has the authority to manage water resources in Mexico, it is also evident that lack of funding, minimum technology updates and old protocols reduce the ability for the agency to apply the Mexican water law and to reach groundwater sustainability within the watersheds. There is presently a recognized fact that not all water wells have been located or georeferenced within the Mexican section of the binational Rio Grande-Bravo watershed. This is a crucial need since all plans and projections of available groundwater inventories will be in error when calculating efficient water management and volume availability.

In Mexico water well permits, which by law have a total volume of groundwater attached to them, are awarded based on estimated total groundwater availability within the different aquifer systems. However, a rough calculation of water volume in storage, plus average recharge, is considered before awarding groundwater permits. The permit is given or new drilling of water wells and for other uses depending on a positive calculation of available groundwater supplies within the specific aquifer. Since the regional hydrocensus has not been actualized in many areas, including the Paso del Norte region, is remains unknown if the total number of existing wells has been accounted for, including wells without permits. Under this circumstance, the total volume of allowable extractions from the aquifer becomes an unknown factor that limits the accuracy of acceptable pumping volumes and the total number of suitable new water well permits that should be issued.

Environmental issues in regard to potential groundwater contamination are also important to address in order to have a complete perspective on strategies and policies to reach groundwater sustainability. Potential point and non-point contamination sources to groundwater resources are largely unknown within the Mexican section of the Rio Grande (Rio Bravo) transboundary watershed. Despite the fact that Mexico has not mapped potential risks to groundwater resources and these limitations have been acknowledged under the present Mexican water law, no actions are planned to address these risks.

Within the Rio Grande (Rio Bravo) watershed, only those wells drilled in urbanized areas for domestic and industrial users have wellhead protection plans. No wellhead protection plans or projects are in place to prevent contamination for agricultural wells, which are the most abundant in Rio Grande (Rio Bravo) watershed area. Return flows from irrigation and infiltration flows generated at irrigated areas pose potential contamination from nitrates and other used fertilizer compounds, putting at risk the groundwater supplies in these areas. Furthermore, the interactions of surface water and groundwater are important to consider when evaluating potential sources of contamination since urban development and expansion are constantly putting at risk the available groundwater, Hence, a complete program to monitor and prevent groundwater contamination is needed on the Mexican side of the Rio Grande (Rio Bravo) watershed.

Summary

In this paper we have addressed some of the most important water issues along the Mexican side of the international Rio Grande (Bravo). It is important to recognize that in regard to water management and sustainability, society and hydro-informatics will be major players for informed decision-making in the next 20 years. Action items for the transboundary water agenda need to be holistically addressed by the two federal governments and multiple state and local governments to initiate a bilateral working agenda on which scholars and water research should be focused. Some of the most relevant future research within the Mexican section of the transboundary Rio Grande (Bravo) watershed is related to climate change and impacts on availability of water resources, efficient use of water on food and fiber production, socio-economic implication on water management, water quality and quantity, and real-time hydro-informatics. There is also the identified need that official authorities, such as water agencies and governments, should assume responsibility for defining a modern water agenda in which the private sector, academia and researchers should be included. Also, an ongoing urgency for monitoring water resources in the transboundary watersheds between Mexico and the United States should be addressed as a main effort for evaluating water vulnerability.

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A Descriptive Overview Of The Rio Grande-Rio Bravo Watershed

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The Rio Grande ranks twentieth in length of the world's rivers, is the fifth longest river in North America, and defines 1,276 miles of the international boundary between the United States and Mexico. Due to over allocation and the arid climate, the river discharge of the Rio Grande tends to shrink in size as it flows downstream, presenting a major challenge to manage transboundary water resources between the two countries of Mexico and the United States. This paper describes the physical environment, land use changes, and anthropogenic structural modifications to the Rio Grande basin based on five unique subareas. The concluding discussion describes various binational data sharing activities and joint research projects focused on developing technical solutions and increasing conservation awareness to enhance the preservation of one of the most important watersheds in North America.

The Rio Grande-Rio Bravo ranks twentieth in length among the world's rivers and is the fifth longest river in North America at an approximate length of 3,059 kilometers (Patiño, 2005; Reid, 2004). The headwaters in the United States are fed from snowmelt in the San Juan Mountains in southern Colorado before entering into New Mexico and flowing towards the border between the United States and Mexico 12 kilometers northwest of El Paso. The Rio Grande, as known in the United States, or the Rio Bravo, as known in Mexico, forms the international border between the two countries for the 2,053 kilometers of river boundary.

The two main tributaries, the Rio Conchos and the Pecos River, revive the surface flow of the Rio Grande-Rio Bravo after the river passes through the Forgotten Reach south of El Paso, Texas. The Rio Conchos flows from the Sierra Madre in Mexico contributing about 35 to 40% of the surface flow in the lower basin (Texas Center for Policy Studies, 2002). The entire Rio Grande-Rio Bravo Basin encompasses 924,300 square kilometers of land in the U.S. and Mexico (Tables & Figures, Figure 1) (Patiño, 2005). The contributing watershed is divided almost in half between the two countries, with 231,317 square kilometers in Colorado, New Mexico, and Texas and 227,149 square kilometers in Chihuahua, Nuevo León, Coahuila, Durango, and Tamaulipas.

Except for the snowmelt at the headwaters in Colorado and the subtropical climate at the mouth near the Gulf of Mexico, most of the river flows through arid regions, including North America's largest desert, the Chihuahuan Desert. Because of over allocation of water and arid climate, the Rio Grande-Rio Bravo tends to shrink in size as it flows downstream, presenting a major challenge in managing the transboundary water resource for the United States and Mexico. The collective physical features of an arid climate, with an average rainfall in the basin ranging from 200 to 900 millimeters (Patiño, 2005), an evaporation rate exceeding water gained from precipitation, and a landscape dominated by agriculture with limited surface-and groundwater supplies, present a major challenge to manage this transboundary water resource for a growing population along both sides of the international border.

The transboundary resource of the Rio Grande-Rio Bravo is governed by the binational agency of the International Boundary and Water Commission-U.S. Section (IBWC) or Comision Nacional de Limites y Aguas-Seccion Nacional de Mexico (CILA). The role of the IBWC is to administer and provide sensitive, timely, and fiscally responsible boundary, water, and environmental services along the international border. To govern water allocation, United States and Mexico have two treaties, signed in 1906 and 1944, and various cooperative regulations referred to as Minutes.

Population growth along the U.S.-Mexico border follows the world trend from a rural to a more urban environment (14-percent urban in 1900, almost 50-percent urban in 1990) (Douglas, 1994), with most of the population growth occurring in the major transboundary cities. These transboundary "sister" or "twin" cities are communities where a city in one country borders a city in another, creating a large urban area separated by administrative boundaries (Tables & Figures, Table 1).

Rapid population growth and consequent economic development and land-use changes are pushing the limits of environmental sustainability and quality. Infrastructure development has lagged behind the rapid growth of the region, resulting in a shortage of water for municipal, agricultural, and industrial uses. Rapid economic growth as a result of the Border Industrial Program (a program to create duty-free industrial zones in a 3,000- kilometerwide, 20-kilometer deep strip on the Mexican side of the border) with the United States created a lack of affordable housing (Parcher & Humberson, 2007). New migrants in the United States began to purchase rural homestead lots from developers through a contract-for-deed program with little or no down payment and to construct the permanent housing when funds became available (Parcher & Humberson, 2007). Because these settlements were established outside of the formally sanctioned governance of nearby cities, developers did not always fulfill verbal agreements to follow through with public utility infrastructure needs (Parcher & Humberson, 2007).

These substandard unincorporated subdivisions are commonly called *colonias* in the United States.[1] The lack of public infrastructure in the colonias and the extreme poverty of the residents, forces many colonia residents to rely on unsanitary sources for water and wastewater disposal. These stressors threaten the quality of life in the region and raise concerns about the interdependence of environmental quality and human health (Buckler & Strom, 2004).

The Five Major River Sections

For the purpose of this paper, the Rio Grande-Rio Bravo Basin will be described on the basis of these five major river sections (Tables & Figures, Table 1):

1. The Rio Del Norte, from the headwaters to Elephant Butte Reservoir
2. From Elephant Butte Reservoir to the Rio Conchos
3. From the Rio Conchos to Amistad Reservoir
4. From below Amistad Reservoir to Falcon Reservoir
5. From Falcon Reservoir to the Lower Rio Grande Valley

River Section 1: The Rio Del Norte, From The Headwaters To Elephant Butte Reservoir

The headwaters of the Rio Grande-Rio Bravo begin high in the Sangre de Cristo and the San Juan Mountain range of the Rocky Mountains in southern Colorado and the river flows for 950 kilometers to Elephant Butte Reservoir in New Mexico. At this stage, the river is narrow and fast-flowing through the mountainous forest landscape, resembling a pristine trout stream able to support 800 fish per kilometer (Reid, 2004) before reaching the alluvial San Luis Valley. Average annual snowmelt runoff is about 76 centimeters and average precipitation within the watershed ranges from 1120 millimeters near the headwaters to 200 millimeters in the southern end of the watershed (Schimdt *et al.*, 2004). The northern portion of the watershed provides 70% of the precipitation.

The short Conejos River tributary, known for white-water kayaking, joins the Rio Grande-Rio Bravo after the Conejos flows through the Rio Grande National Forest and before the Rio Grande-Rio Bravo crosses into New Mexico. In northern New Mexico, the Rio Grande-Rio Bravo is known for its spectacular gorges that contrast with the broad mesas of the Basin and Range section. After the river passes through Taos and Santa Fe, it drops down and meanders through the gentle sloping flood plains near Albuquerque and broadens out to a slower flowing river. This southern portion of the watershed from Albuquerque to Elephant Butte Dam is the driest and warmest of the Rio Del Norte as annual potential evaporation can exceed 1,000% of annual precipitation (Levings *et al.*, 1998).

Modifications to the flow of the river began with the construction of the Rio Grande Reservoir at 2,749 meters in elevation near the headwaters. The reservoir was constructed to keep floods in check and to capture water for irrigation for farming in the San Luis Valley of Colorado. The next major water storage structure along the river is the Cochiti Reservoir located on Cochiti tribal lands 80 kilometers north of Albuquerque. The Cochiti Reservoir regulates flood control and sediment management (Cochiti Pueblo of New Mexico, 2003). More water is diverted for agriculture as the river reaches the flood plains near Albuquerque. Beginning within the Rio del Norte river section, appropriated surface-water rights on the Rio Grande-Rio Bravo in Colorado and New Mexico usually exceed mean annual flow (Levings *et al.*, 1998).

The major population centers in the Rio del Norte river section include Alamosa in Colorado, and Santa Fe and Albuquerque in New Mexico before the river reaches the small town of Truth or Consequences near Elephant Butte Reservoir. The river passes through various national forests and Indian tribal lands. Except for the diverse manufacturing economy of Albuquerque, the main economic activities in the river section are agriculture and tourism.

River Section 2: From Elephant Butte Reservoir To The Rio Conchos

The Rio Grande-Rio Bravo river section extending from Elephant Butte Reservoir to the Rio Conchos is an interconnected group of 14 hydrologic basins in the Basin and Range physiographic province.

The area extends about 515 kilometers along the international boundary between New Mexico and Texas in the United States and Chihuahua in Mexico. Most of the river section is located in the Rio Grande rift zone of the Chihuahuan Desert and also in the Tularosa Basin north of El Paso, Texas. The Franklin Mountains along the southwestern boundary of the Tularosa Basin stretch from north of El Paso to south of Ciudad Juárez in Mexico. Elevations range from about 760 to 3,200 meters. The climate is characterized by hot summers and cool winters; annual precipitation generally is less than 150 millimeters per year.

Under the 1906 Binational Convention for the Equitable Division of Waters of the Rio Grande for Irrigation, Mexico agreed to the construction of Elephant Butte Reservoir in southern New Mexico (Turner, 2000). Under this treaty, the United States is committed to providing to Mexico 74 million cubic meters of water annually, which is delivered through Mexico's Acequia Madre near Ciudad Juárez. Elephant Butte Reservoir was completed in 1916; in 1938, Caballo Reservior was built downstream of Elephant Butte to capture and store winter power generation releases from Elephant Butte Reservoir (Turner, 2000). Construction of these reservoirs, combined with the Chamizal agreement, to channelize the river as it runs through the international border near El Paso and Ciudad Juárez, results in more than 320 kilometers of the river being engineered into a water conveyance stream (Stolz, 2000).

The combined effects of channelization, diversion of large amounts of water to support irrigated agriculture in the arid region from Las Cruces to south of El Paso, high evaporation rates, and mandatory water deliveries to Mexico, result in only 5% of the water released from Elephant Butte reaching Fort Quitman, Texas, located 90 kilometers south of El Paso (Wilson, 1999). This area south of Fort Quitman to the confluence of the Rio Conchos is known as the Forgotten Reach of the Rio Grande-Rio Bravo. The Forgotten Reach is choked with invasive salt cedar that clogs the river channel and alters the ground- water flow, resulting in difficulty in determining the location of the U.S.-Mexico international boundary.

The El Paso-Ciudad Juárez sister city area is the second largest population center along the U.S.-Mexico border. For El Paso the 2006 estimated population was 609,415 and for Ciudad Juárez was 1,313,338. With five major border crossings and significant manufacturing and commercial centers, the sister cities of this binational metropolitan area are closely linked economically, politically, and socially.

The El Paso economy relies on telecommunications and military support for Fort Bliss. Ciudad Juárez's growth is based on maquiladoras, which are foreign-owned industries that assemble goods for sale in the United States. Scarcity of water resources is a limiting factor for growth in the area, as Ciudad Juárez relies solely on ground water from the Hueco Bolson with new expansion into the Mesilla Bolson. El Paso now operates the largest inland desalinization plant as a joint venture between the El Paso Water Utilities and Fort Bliss. Within this river section, the next largest population center is Las Cruces, New Mexico. The area southeast of El Paso and Ciudad Juárez is sparsely populated and lacks roads and border crossings until the junction of the Rio Conchos with the Rio Grande-Rio Bravo near Ojinaga, Chihuahua, and Presidio, Texas.

In this river section the major U.S. Department of Interior Federal land holdings include: Elephant Butte and Caballo Reservoirs (Bureau of Reclamation); White Sands National Monument, Chamizal National Monument, and Guadalupe Mountains National Park and Wilderness Area (National Park Service); San Andres National Wildlife Refuge (Fish and Wildlife), and various Bureau of Land Management holdings.

River Section 3: From The Rio Conchos To Amistad Reservoir

The Rio Conchos to Amistad Reservoir river section extends about 635 kilometers along the Rio Grande-Rio Bravo international border. This sparsely populated river section is predominantly open range and is divided between the Basin and Range and the Great Plains physiographic provinces. The Basin and Range province, from Big Bend National Park westward, is characterized by isolated mountain ranges, such as the Chisos Mountains, separated by desert basins characteristic of the northern Chihuahuan Desert and deep, steep-walled canyons of limestone (Tables & Figures, Figure 2). The Rio Grande-Rio Bravo flows through three main canyons, the Santa Elena, Mariscal, and Boquillas. Tributaries above Amistad Reservoir include the Rio Conchos, Alamito Creek, and Langtry Creek. The Pecos River, with headwaters beginning in the Sangre de Cristo Mountains in New Mexico, and Devils River contribute flow directly to Amistad Reservoir.

Under the U.S.-Mexico water treaty of 1944—Cooperative Regulation and Apportionment of the Rio Grande from Fort Quitman to the Gulf, two international reservoirs were established along the Rio Grande-Rio Bravo: Amistad Reservoir in 1968 with 6.5 billion cubic meters of capacity, and Falcon Reservoir in 1953 with 4.9 billion cubic meters of capacity (U.S. Department of Interior, 2002). Both of these shared binational reservoirs were created to control the downstream flooding of homes and farms. Under the treaty, each country receives one half of the water from the mainstem Rio Grande-Rio Bravo and full use of the tributaries, except for one-third of the flow coming from the Mexican tributaries of the Rio Conchos, San Diego, San Rodrizo, Escondido, Salada, and LasVacas, which is allocated to the United States (Patiño, 2005).

The combined Chihuahuan Desert protected areas of Big Bend National Park in the United States and Maderas del Carmen and Canon de Santa Elena in Mexico create one of the largest transboundary protected areas in North America at more than 80,937,128 hectares (National Park Service, 2008). Within Texas, the National Park Service manages the Big Bend National Park, the Rio Grande Wild and Scenic River, and the Amistad National Recreation Area. These protected areas cover river, desert, and mountainous regions and support an extraordinary richness of biodiversity for this ecoregion, including more than 1,200 species of flora, 450 species of birds, and 75 species of mammals (National Park Service, 2008). Major vegetation types within the protected areas include Chihuahuan Desert scrub, grassland, oak-juniper-pinyon woodland, pine-oak forest, and riparian communities (Loring, 2009).

Along the banks of the Rio Grande-Rio Bravo just north of Big Bend National Park, the once thriving mining towns of Lajitas and Terlingua, Texas, currently suffer from the lack of an official border crossing. Within the U.S. portion of the river section, the small rural population centers of Alpine and Marathon, Texas cater to tourists, whereas in Chihuahua, Mexico, the remote cattle ranching and mining activities make the Mexican side even more desolate.

A large subset and extremely critical portion of this river section is the Rio Conchos watershed, located entirely in Mexico. The Rio Conchos watershed at 64,000 square kilometers accounts for just over 14% of the larger Rio Grande-Rio Bravo watershed (Kelly, 2001; Patiño, 2005). The river is a critical lifeline to the arid Chihuahuan Desert ecosystem and to the replenishment of surface flow to the Rio Grande-Rio Bravo. The headwaters are fed from heavy rainfall and snowmelt from the Tarahumara Mountains of Chihuahua and Durango, Mexico, in the Sierra Madre Occidental Range. The perennial flow begins high in the pine and oak forests and is replenished from five major tributaries, the Rio Florida, Rio San Pedro, Rio Bachimba, Rio Chuviscar, and Rio Parral. Irrigation for agriculture accounts for 90% of the water use in the basin (Kelly, 2001).

The debate over water use rights within the Rio Conchos Basin have greatly intensified due to the increased competition between municipal and industrial uses for the state of Chihuahua, recent droughts, and the need to fulfill the requirements of the Binational Treaty (Kelly, 2001). Seven major reservoirs, with Boquillas the largest, have been constructed to provide surface water for agricultural and municipal uses (Kelly, 2001). In the three largest irrigation districts, Rio Florida, Delicias, and Bajo Rio Conchos, agriculture water use efficiency is about 40%, whereas per capita municipal water use is about 50%, of the average for Texas (Kelly, 2001).

River Section 4: From Below Amistad Reservoir To Falcon Reservoir

From below Amistad Reservoir to Falcon Reservoir river section is an interconnected group of 13 hydrologic basins that drain either to the Rio Grande-Rio Bravo or to the lower reach of the Rio Salado. The area extends about 480 kilometers along the international boundary between Texas and Coahuila, Nuevo León, and Tamaulipas, Mexico, beginning just south of Amistad Reservoir and ending at the upper reach of Falcon Reservoir. The northernmost part of the river section, near Del Rio, Texas, and Ciudad Acuña, Mexico, is located in the Edwards Plateau, an area underlain by massive limestone deeply cut by arroyos and canyons. Most of the river section south of Eagle Pass, Texas, is in the Rio Grande plain.

Elevations range from about 96 meters at Falcon Reservoir to 891 meters in Val Verde County. The climate is subtropical-subhumid with average annual precipitation of 430 to 480 millimeters. Droughts with annual precipitation less than 150 millimeters are common. Plant communities include desert shrub savanna, scattered mesquite and live oak woodlands, and irrigated agricultural lands. Less than 1% of the Texas land in the river section is considered prime farmland. Wildlife living in the area includes javelina, bobcat, coyote, white-tail deer, muskrat, beaver, and opossum; sandhill crane, various ducks, geese, and doves; various frogs, turtles, and lizards; snakes, and a host of invertebrates.

In this river section, water in the Rio Grande-Rio Bravo is used for irrigation and municipal use. Many municipalities rely completely on surface water for municipal use, except for Del Rio, Texas, which pumps ground water. Unfortunately, surface-water quality exceeds the standards for bacteria below Del Rio, and there is a high level of nitrates and dissolved oxygen in the river. The principal sister city population centers of Del Rio, Texas-Ciudad Acuña, Coahuila; Eagle Pass, Texas-Piedras Negras, Coahuila; and Laredo, Texas-Nuevo Laredo, Tamaulipas are connected economically and socially, with each Mexican sister city having at least double the population of its U.S. sister city. The entry port of Laredo and Nuevo Laredo are strategically located nearest to Mexico's third-largest city, Monterey. The Laredo entry port supports more than 50% of the truck crossings through all Texas border crossings and is the largest inland port in the United States (Anderson & Gerber, 2008).

River Section 5: From Falcon Reservoir To The Lower Rio Grande Valley

The Falcon Reservoir to the Lower Rio Grande Valley river section is physiographically characterized as the Gulf Coastal Plain. The river section contains 10 basins that drain either to the Rio Grande-Rio Bravo, to the lower reaches of the Rio San Juan, or to the Arroyo Colorado in southern Texas. This river section extends about 450 kilometers along the international border between Texas and Tamaulipas and Nuevo León terminating in the coastal Gulf of Mexico wetlands, marshes, and the Laguna Madres of Texas and Tamaulipas.

The landscape is characterized by a wide deltaic floodplain, interspersed with abandoned river channel meanders, locally referred to as resacas (Tables & Figures, Figure 3) (Parcher, 2003). These resacas provide multiple benefits, such as collection and storage of local storm runoff, conveyance channels for Rio Grande-Rio Bravo waters, irrigation and drinking water sources, wildlife habitat, and recreational opportunities (Parcher, 2003). Falcon Reservoir is owned and operated by the IBWC. The reservoir provides flood control, recreation, water conservation, and hydroelectric power. Mexico's Rio Salado is a major contributor to Falcon Reservoir. The Rio San Juan, after supplying water to Monterrey, Mexico, provides additional tributary flow to the Rio Grande-Rio Bravo entering south of Falcon Reservoir.

Surface flow below Falcon Reservoir is highly controlled by anthropogenic modifications which results in less than 10% of the water withdrawn for irrigation being returned to the Rio Grande. The two main floodways on the U.S. side, the Arroyo Colorado and the North Main Drain draw irrigation and floodwaters to the Laguna Madre, not to the Rio Grande-Rio Bravo. On the Mexican side, the

Anzalduas Dam is the major water diversion structure for delivering irrigation water to the Mexican portion of the river section. With minimum topographic relief in the area, water of many of the hydrologic features flows in both directions (Brown *et al.*, 1980).

U.S. Department of Interior Federally owned or managed areas include the Santa Ana, Lower Rio Grande Valley, and Laguna Atascosa National Wildlife Refuges, administered by the U.S. Fish and Wildlife Service, and the Palo Alto Battlefield National Historic Site administrated by the National Park Service. Native Tamaulipan brush land characterized by dense, woody, and thorny vegetation and a high degree of biological diversity is the dominant land cover. This taller and more lush vegetation in riparian areas provides not only important nesting and feeding habitat, but also serves as corridors for animal movement. The subtropical humid climate, with an average annual rainfall of about 660 millimeters at the mouth of the river and about 410 millimeters at Falcon Dam is strongly influenced by Gulf-related weather activity.

The major metropolitan areas of McAllen, Harlingen, and Brownsville, Texas, and Reynosa and Matamoros, Tamaulipas, support more than a million inhabitants through tourism, manufacturing, and agriculture. This river section contains more than 75% of the documented colonias within the Texas counties adjacent to the international border (Parcher & Humberson, 2007). As in other border river sections, the water resources and associated plant, fish, and wildlife communities of the Lower Rio Grande Valley are increasingly subject to the pressures of human activities. A high%age of surface water is allocated to agriculture (U.S. Department of Interior, 2002); the saline ground water is not a suitable source of drinking water for these urban areas.

Discussion

Major structural impoundments, increased population growth, and over allocation of water for agricultural and industrial development in the Rio Grande-Rio Bravo watershed have drastically changed this transboundary river. The anthropogenic changes in streamflow, such as reservoir impoundments, affect the seasonal timing and magnitude of peak flows and can drastically alter the stream channel and riparian vegetation. These deviations are greatly compounded during drought conditions. In 2002, the reduction of flow in the Rio Grande-Rio Bravo resulted in the mouth of the river being blocked by a sand bar deposition, resulting in closure of flow to the Gulf of Mexico(Tables

& Figures, Figure 4). The reduced flow of the river led to the formation of masses of hyacinth, an invasive species, in the vicinity of Brownsville. Current predictions of climate change include less snowpack and the resulting in lower spring runoff, more intense localized precipitation events, and warmer conditions for the Rio Grande-Rio Bravo watershed (Kerr, 2008). These climatic changes, combined with the current anthropogenic water needs, will most likely result in increased challenges for transboundary water management and the ability to comply with the existing international treaties.

At the current population, per capita water availability in the Rio Grande-Rio Bravo watershed is estimated to be 1,467 cubic meters per person per year, which is between the acceptable limit (1,700 cubic meters per person per year) and the water scarcity limit (1,000 cubic meters per person per year) as calculated by the Swedish hydrologist Malin Falkemark (Patiño, 2005). Climate change and increased population will force both the Federal and local governments to search for innovative solutions to manage the scarce water resources. Because of the transboundary nature of the river, open sharing of environmental, demographic, and economic data will be needed to allow decision makers to successfully manage the water resources for both U.S. and Mexican inhabitants along the entire river course of the Rio Grande-Rio Bravo.

Recommendations provided by Mexican and U.S. federal, state, and local authorities who convened at the Binational Rio Grande Summit in November of 2005, advocate collaborative technical solutions; strengthening of binational institutions focused on conservation, planning, and monitoring; and the development of publicly available binational information systems. The recommendations acknowledged the importance of aquifer recharge, binational research concerning ground water storage, and accounting for the concurrence of droughts which may occur as often as every seven years. The importance of maintaining sufficient environmental flows to provide a native riparian buffer along the river were some of the important environmental issues discussed in the recommendations.

Providing both U.S. and Mexican scientists with the data and modeling tools to develop binational solutions is the first step to develop these alternative solutions. Since the Binational Rio Grande Summit convened, the implementation of several federally funded binational information and research collaborations are currently laying the groundwork for improved water management of the Rio Grande–Rio Bravo Watershed. These include the U.S. Geological Survey's

Border Environmental Health Initiative and U.S.-Mexico Border Geographic Information System, the Transboundary Aquifer Assessment Program, and the Physical Assessment of the Rio Grande-Rio Bravo watershed.

The U.S. Geological Survey (USGS) U.S.-Mexico Border Environmental Health Initiative (http://borderhealth.cr.usgs.gov) recognized the need for development of transboundary datasets, standards, and Web mapping services under the guidance of multidisciplinary researchers, using documented methodology, for various themes along the U.S-Mexico border. The decision to use watersheds for study-area boundaries instead of the administrative 1983 La Paz agreement, 100-kilometer boundary delineation, was based on the need to undertake an environmental approach to the problem instead of an administrative approach.

The U.S.-Mexico Project Annex between the USGS and the Instituto Nacional de Estadística y Geografía (INEGI) provides the legal framework for full public access to the best available harmonized binational geospatial datasets along the U.S.-Mexico border that now constitute the United States-Mexico Geographic Information System (USMX-GIS) (Tables & Figures, Figure 5) (Parcher, 2008). The binationally harmonized data layers from the USMX-GIS that support environmental management activities include: land use and land cover, watershed boundaries, geology, hydrologic networks, international and local boundaries, urban areas, named features, aerial imagery, medium- and high-resolution elevation models, and contaminant databases. These consistent databases provide a temporal baseline to analyze changes and predict scenarios for the future and to provide needed information to facilitate joint planning activities, sustainable development practices, and conservation of natural resources.

The United States-Mexico Transboundary Aquifer Assessment Act which was signed into law in December, 2006, authorizes the Secretary of the Interior to cooperate with U.S. Border States and other appropriate entities to implement a program of hydrogeologic characterization, mapping, and modeling for priority transboundary aquifers. The objectives of the Act are to evaluate available data and publications, prioritize transboundary aquifers for further analysis, enhance existing geospatial databases to characterize the spatial and temporal aspects of the aquifer, implement field studies, develop ground-water flow models that include ground-water/surface-water interactions, and develop or expand existing agreements with Mexico for joint scientific investigations.

The priority aquifers are the Hueco Bolson and Mesilla aquifers, Santa Cruz River Valley aquifers, and San Pedro aquifers. Within the Rio Grande-Rio Bravo watershed, scientists from two universities (New Mexico State University (NMWRRI) and Texas AgriLife Research-Texas A&M University System (TWRI), the USGS, and state agencies and organizations will work together to develop a binational hydrogeologic framework for the Hueco Bolson and Mesilla aquifers.

The Physical Assessment of the Rio Grande-Rio Bravo Basin was launched in 2001 by a consortium of U.S. and Mexican nongovernmental organizations and government agencies to explore water management options for this binational watershed and to respond to the growing pressure on this important resource. The objective of the project is to examine the hydro-physical opportunities of expanding the beneficial uses of water supply within the basin to satisfy a variety of water management goals. Led by the University of Texas and the Natural Heritage Institute, and in collaboration with the Instituto Mexicano de Tecnología de Agua (IMTA) and the Instituto Tecnológico de Estudios Superiores de Monterrey, the project has developed a binational water resources database and a system wide analytical capability to model both the natural and anthropogenic flow of water within the basin.

By jointly sharing federal databases, surface water modeling information, and technical exchange of advanced modeling techniques the binational team have characterized the water intakes and returns, the flow of water between the major dams, irrigation needs, the surface and groundwater characteristics, and the anthropogenic changes to the basin. This model provides a binational and collaborative technical approach to develop alternative scenarios for water allocation in the Rio Grande-Rio Bravo Watershed.

Joint collaboration and data sharing between U.S. and Mexican scientists are critical in the development of transboundary solutions for this significant transboundary watershed. Alliance between both U.S. and Mexican scientists and government officials in developing technical solutions and greater conservation awareness are critical steps toward preserving one of the most important watersheds in North America.

Notes

1 In Mexico the word *colonias* refers to neighborhoods. Substandard settlements in Mexico are referred to as *comunidades marginales*.

2 Source of population information for the United States is U.S Census Bureau Quick Facts 2006 estimates, http://quickfacts.census.gov/qfd/states/48.html. Source of population information for Mexico is Instituto Nacional de Estadística y Geografía (INEGI) 2005 estimates, http://www.inegi.org.mx/inegi/default.aspx?s=est&c=10394

3 Source of population information for the United States is U.S Census Bureau Quick Facts 2006 estimates, http://quickfacts.census.gov/qfd/states/48.html. Source of population information for Mexico is Instituto Nacional de Estadística y Geografía (INEGI) 2005 estimates, http://www.inegi.org.mx/inegi/default.aspx?s=est&c=10394

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Tables & Figures

Watersheds	Physiographic Province	Vegetation	Annual Precipitation	Urban Areas & Sister Cities (population)
Rio Del Norte	Rocky Mountains	Coniferous forest, oak-juniper-pinyon woodlands	Snowpack -760 mm precipitation -200 to 1120 mm	Alamosa, Col. (15,225) Santa Fe, NM (72,056) Albuquerque, NM (504,949)
Elephant Butte Reservior to Rio Conchos	Basin and Range, Chihuahuan Desert, Franklin Mountains	Chihuahuan desert, oak-juniper-pinyon woodlands, coniferous forests	150 mm	Las Cruces, NM (86,268) El Paso, TX (609.415) - Ciudad Juárez, Chih. (1,313,338)
Rio Conchos to Amistad Reservoir	Basin and Range, Great Plains	Chihuahuan desert, badlands, shrub forest,	280 to 480 mm	Alpine, TX (5,786)
Below Amistad Reservoir to Falcon Reservoir	Edwards Plateau - limestone	Desert shrub savanna, mesquite, live oak	430 to 490 mm	Del Rio, TX (36,491) - Ciudad Acuña, Coah. (126,238) Eagle Pass, TX (22,413) - Piedras Negras , Coah. (169,771) Laredo, TX (215,484) - Nuevo Laredo, Tam. (355,827)
Falcon Reservoir to Lower Rio Grande Valley	Gulf Coastal Plain	Tamaulipan brush, riparian zones	660 to 410 mm	McAllen, TX (146,411) - Reynosa, Tam. (633,730) Brownsville, TX (172,437) -Matamoros, Tam. (462.157), Harlingen, TX (64,202)

Table 1. Physical and demographic characteristics of the main river sections along the Rio Grande-Rio Bravo watershed.

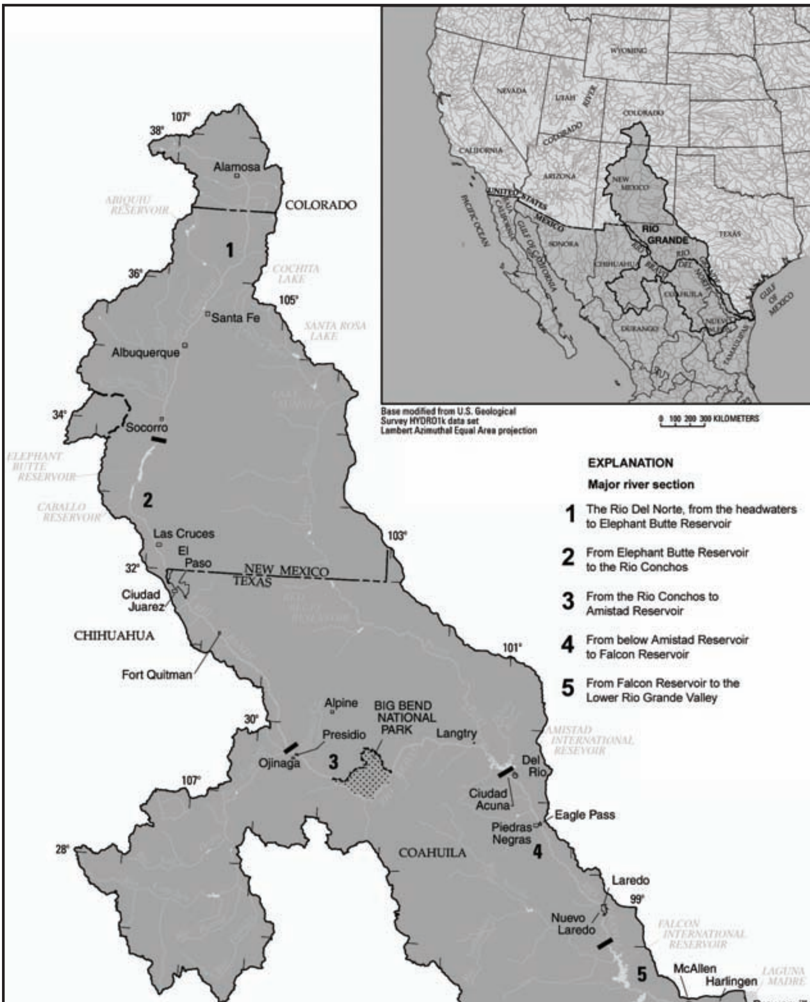

Figure 1. The five major river sections of the Rio Grande-Rio Bravo watershed.

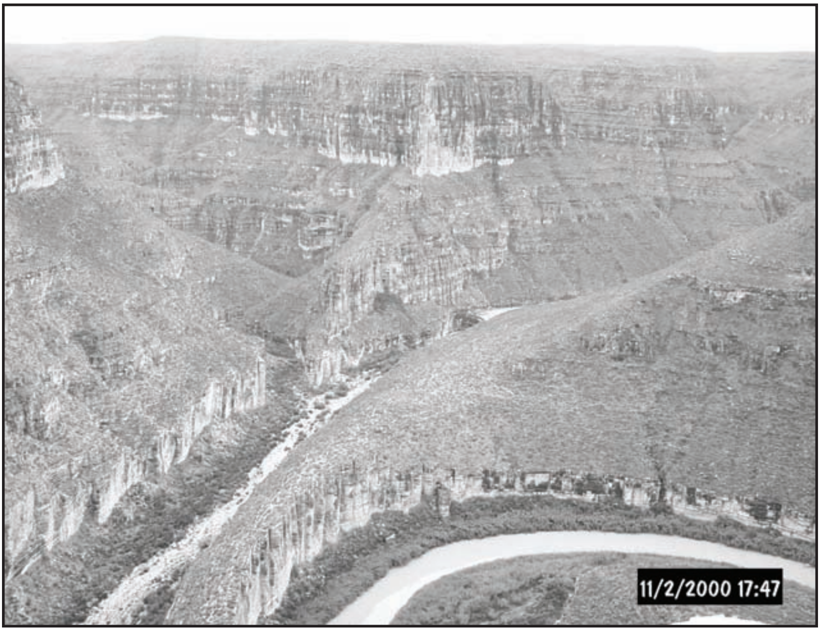

Figure 2. Aerial photograph of the Rio Grande Wild and Scenic River near Big Bend National Park.

Figure 3. Photograph of a resaca (abandoned riverbed channel of the Rio Grande-Rio Bravo) near Brownsville, TX.

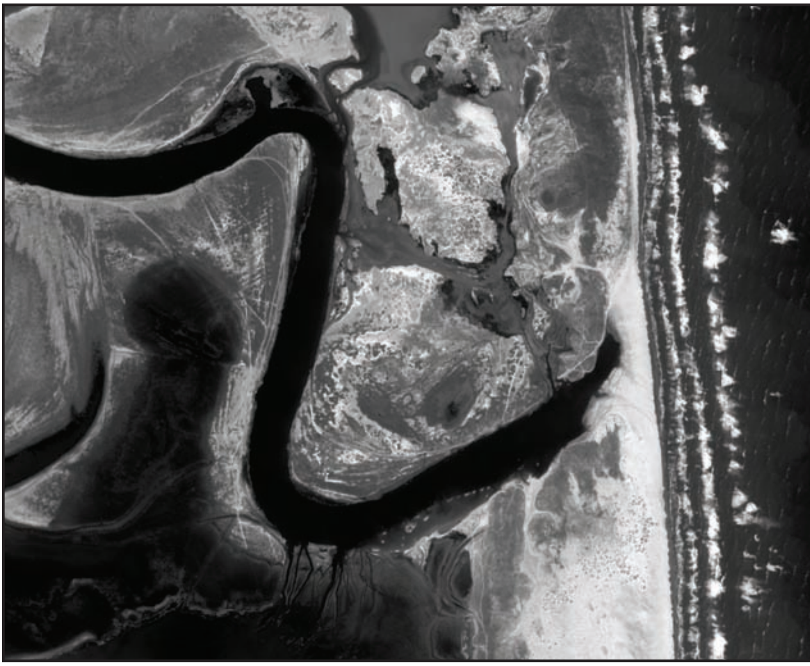

Figure 4. A high resolution SPOT satellite image taken May 2, 2002, showing the sandbar sedimentation blocking the flow of the Rio Grande-Rio Bravo into the Gulf of Mexico (courtesy of University of Texas, Center for Space Research).

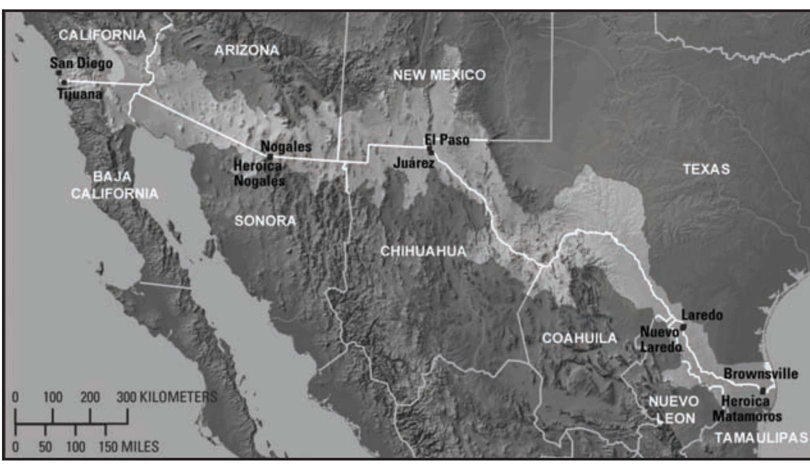

Figure 5. The major watersheds along the U.S.-Mexico border compose the current project area for the U.S.-Mexico Border Geographic Information System.

Future Solutions:
Research Needs In The Jordan River Watershed *

MAC McKEE
Utah State University

Water-related technical issues within the Jordan River basin are interesting research topics and, for the most part, not terribly difficult to address. They include a standard range of research options and can be accomplished if the required resources are available. In short, technical water issues can be addressed fairly easily. The chief obstacles to resolving the region's water issues rest instead with the failures of the water management institutions and with regional politics. These issues will have to be addressed if the solutions provided through research are ever to benefit the people of the Jordan Basin.

Water is politics, and politics is water in the Middle East. Anything you say about water, even what research might be proposed, will be interpreted by many in the region to have political connotations. Consequently, this paper is presented in a way that the facts about of water resources problems in the region, and hence on research needs in the Middle East, while avoiding issues that might foster political misunderstanding or discord. I should add as a disclaimer that the opinions stated here are mine alone and are based on my personal experiences and work in the region over a period of many years.

Research topics discussed:

- Economics vs. politics
- Environmental concerns
- Water and energy
- Water and strategic planning
- Water institutions

* This paper is a written version of a presentation delivered Jan. 23, 2009, during the conference "Transboundary Water Crises: Learning from Our Neighbors in the Rio Grande (Bravo) and Jordan River Watersheds" held on the main campus of New Mexico State University in Las Cruces.

Economics Vs. Politics

An ample body of economic and political research exists for the Middle East. Among the best work in the realm of economics has been done by Franklin M. Fisher and his colleagues who together have provided us with information on the value of water, how water should move from one place to another and from one sector to another.[1] Fisher's work and that of other economists can be distilled and summarized:

Separate water ownership from water usage. Current research shows that maximizing the value of water can be done with amazing economic gains for the region as a whole. In order to maximize gains, however, the region must first separate issues of ownership from issues of how and where and by whom water is being used. If the separation can be accomplished, it would allow for the transfer of water for value with benefits for all parties. On a practical level, it should be noted that separating ownership from usage in the Middle East might be politically impossible, at least in the current highly politically charged climate.

Monetize and de-emotionalize water conflicts. The connection of water to emotions in the region continues to foster mistrust and conflict. This emotion-charged connection to water issues has cast a confrontational pale over the debate. This masks the economic opportunities that could be realized by all sides if discussions about water allocation could be on the economic benefits that could be achieved by allowing water to move across boundaries and between uses.

Value of water in dispute by Palestinians and Israelis. Research has shown that the value of disputed water between the Palestinians and Israelis is actually very small, so small as to negate the value of water as a cause for war. Water can be taken "off the table" very quickly and for a very low cost. If done correctly, this action along could address one of the major stumbling blocks for resolving international difficulties quickly.

Water models. Research is still required in terms of economic modeling. The available models are essentially steady-state and cannot handle multi-year and dynamic situations. The economic effects and options for responding to changes in natural water availability are issues that require modeling support. Extensions to existing models that address these issues would move the research forward.

Also, our current models do not have a water quality component. This is a significant issue. In addition, economic models could tell us more about subsidies and the real cost to the region of subsidized water.

Political buy-in. Fisher and others have sought political acceptance of their work from the top of the political chain of command. Unfortunately, they have received little mileage in terms of implementation of the results of their research. Political buy-in for economic research and water efficiency modeling is a challenge for the Middle East and will need to be overcome if the region is to see the benefits of putting economic research into operation.

Environmental Concerns

The Red-Dead plan. The effects of importing Red Sea water into the Dead Sea poses water quality concerns. Problems are associated with changes in salts with the mixing of different kinds of brine. Also, the Jordanians and Israelis have expressed concern about the potential impact that such a diversion plan would have on Red Sea resources, such as the corals and marine life, and what this might mean for the region's tourism industry. These are tough questions that many believe have not been fully answered[2] and that pose an opportunity for research.

Wastewater treatment and disposal. Wastewater treatment and disposal is a problem in virtually all the Arab countries of the region and is not an insignificant problem in Israel. In most Arab communities, if there is a waste treatment plant, it is likely overloaded. Municipal treatment plant loadings often exceed the design hydraulic capacity, and waste concentrations are often an order of magnitude greater than in U.S. cities. The region also has limited human resources and institutional capacity for addressing wastewater operations. The most serious problems of which I am aware exist in the West Bank and Gaza Strip.

As an example of this problem, the wastewater treatment plant in the northern part of the Gaza Strip is very difficult to maintain under the conditions that have existed on the ground for the last few years. One, perhaps more cynical research recommendation might be a project to improve plant capacity in order to withstand military bombardment.

Figure 1. North Wastewater Treatment plant in Beit Lahiya, Gaza Strip under bombardment with dust cloud billowing up.

At the same Beit Lahiya Wastewater Treatment Plant in the northern Gaza Strip untreated wastewater is pumped to a large lake, which in March 2007 exceeded its capacity and flooded a nearby Palestinian village. Six people drowned in the disaster, including two children and one teen. This is probably the worst wastewater story I know. Though an extreme case, this wastewater treatment plant is indicative of the others in the region. The large pond into which the plant discharges is not an engineered facility. It was created as a recharge pond for treated wastewater, but is serving as a holding system for raw sewage with no outlet.

Wastewater reuse. Wastewater reuse is practiced extensively and very successfully in Israel. In Arab countries, lack of infrastructure and limited institutional capacity pose obstacles for wastewater reuse and, to a lesser extent, cultural prohibitions against use of wastewater. Currently, Jordan is engaged in experimentation with wastewater re-use and has extended its ability in this arena. Projects are under way in Amman and Aqaba, Jordan's only seaport, which are largely pilot in scale. The Palestinians are interested in water reuse and have good potential for its implementation, but lack the basic infrastructure.

Water quality. Within the region, all parties are contributing to deterioration of Jordan River water quality. In terms of groundwater there is a great deal to be learned that we do not know. Inadequate treatment and improper disposal of wastewater threatens groundwater in some locations. Drainage from agricultural is also a problem. According to recent research by Khalil Ammar, nitrate concentrations in a portion of the northeast aquifer in the West Bank pose a serious issue.[3] This type of research is necessary if we are going to get out in front of the problem of protecting groundwater in the region.

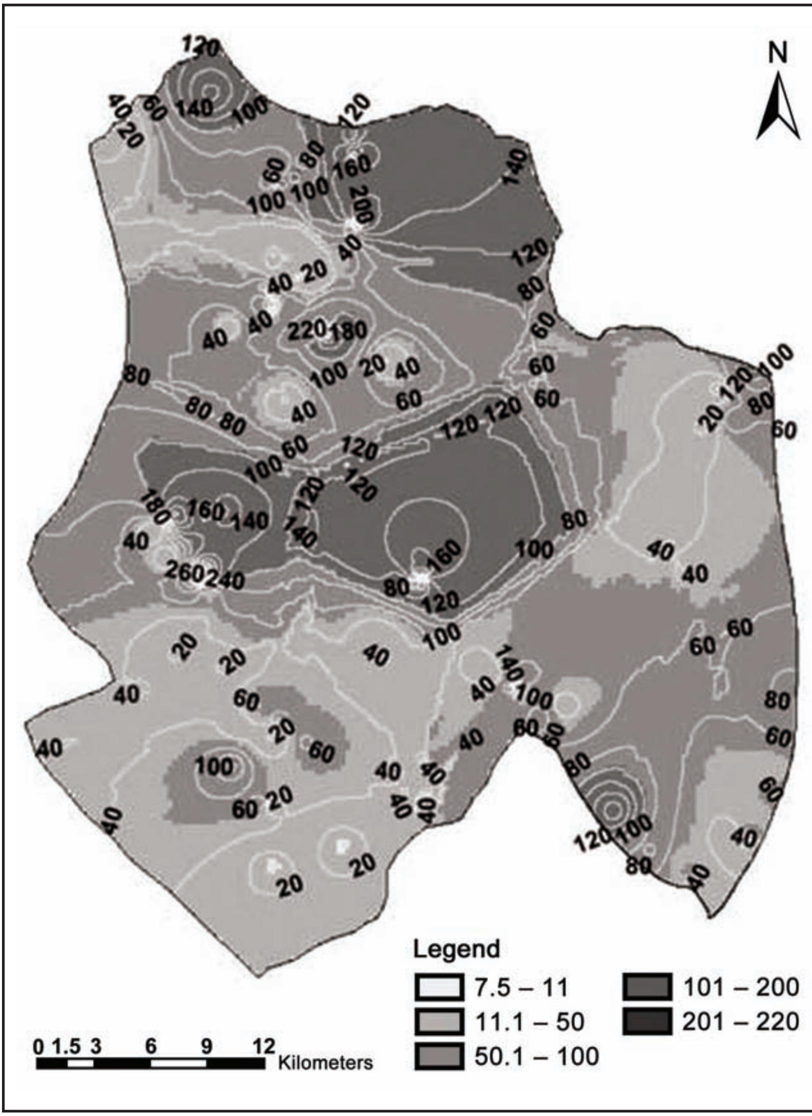

Figure 2. Nitrate concentration (portion of the northeast aquifer, West Bank).

For improvement in water quality, the region will require implementation of effective monitoring and enforcement of water quality protection requirements. Water quality problems from Israeli settlements in the West Bank may be an overlooked issue.

Water harvesting. Small-scale water harvesting, i.e., the capture and storage of rainfall in buried cisterns, has been in use in some areas within the region for more than 2,000 years. In some areas, it may still be the only source of water. This is expensive water, $6 to $7 per cubic meter, in some cases. This method also raises issue of water quality if the cisterns are not properly maintained or if the area over which water is harvested is exposed to contaminants. However, when this is the only water you have, you use it.

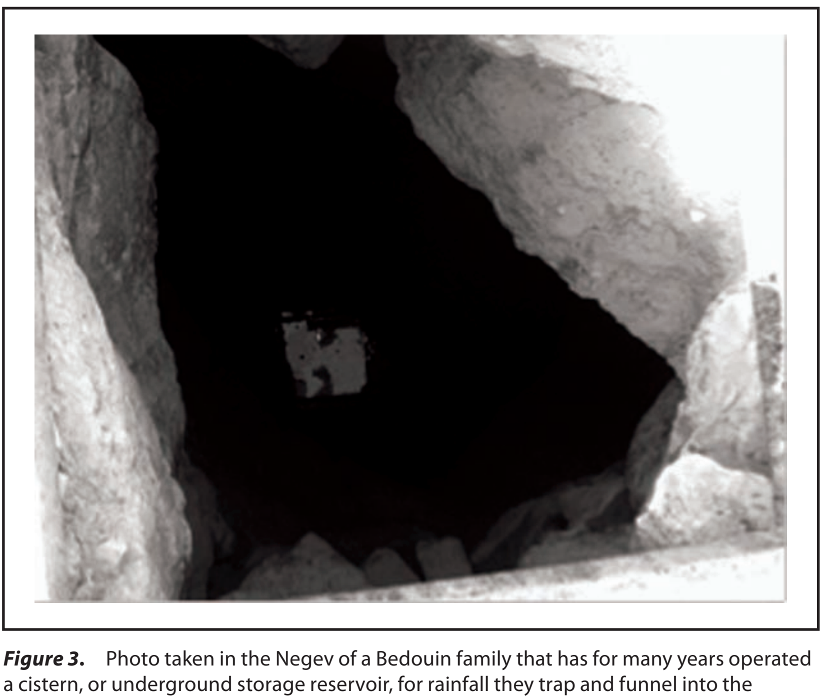

Figure 3. Photo taken in the Negev of a Bedouin family that has for many years operated a cistern, or underground storage reservoir, for rainfall they trap and funnel into the reservoir. In a good year, the family may get 50-70 cubic meters from this.

Water And Energy

Desalination appears to be a potential solution to water in the Middle East. However, the region is not "energy rich" and desalination requires a great amount of energy for facility operation. Research conducted by Said Ghabayen indicates a regional uncertainty in water production costs within the region, driven in most part by uncertainties in energy costs.[4] In most locations there will also be the unresolved issue of brine disposal.

Strategic Planning

Given the tremendous uncertainty in the year-to-year availability of natural water supplies, rapid population growth in most countries of the region, and desires for economic development, strategic planning in the water sector is a critical need.[6] However, as in many other places in the world, the region generally lacks the political commitment and the technical ability to actually engage in, and implement the results of, strategic planning in the water sector.

Climate change. Water research in the Middle East needs to address the impacts of global climate change. Climate models will require greater resolution in their ability to predict future precipitation distributions and temperatures. This will allow us to formulate ideas about future infiltration and groundwater recharge, and thereby better support planning and management. Regional researchers today lack the data to move forward in this arena in support of long-term strategic planning. This research topic could become a thorny political issue within the region, and water management institutions will have to grapple with the problem across the entire basin.

Agriculture vs. urban uses. Research may be needed as the region begins at some point to refocus from agriculture to urban water uses. Water is too scarce and so much more valuable for urban uses that it is for agriculture. This is likely to become a politically charged issue for the region's governments. Populations continue to grow and citizens expect a level of economic well being that might not be possible in the future under the current water allocation arrangements. This topic raises other issues, of course, such as food security.

Water Institutions

In my opinion, water management institutions in the riparian nations of the Jordan River are limited in capacity, lack flexibility, and are often hamstrung by entrenched politic. This is exemplified by problems in acquiring information sufficient to support water management, lack of the ability to move water toward higher valued applications, and major problems imposed on the efficient operation of the water sector through rigid focus on security.

Data and information. Measurement of the available water resource is spotty in many counties of the Middle East. In some cases, data is not shared or is not accurate. In other cases, data may be collected without thought as to what it may be used for. An example is the Palestinian case. In the West Bank, groundwater quality data is collected, probably three or four times as much as is needed, compared to the real information content or value of the information that is gained from the data. In this situation, the Palestinians might be better off thinking first why they need the data and what they might be able to do with the information.

Institutional smoothness. In the Middle East, the ability to transfer water among sectors and nations doesn't exist. This alone may be the biggest obstacle for efficient water management in the region.

Security. While the U.S.-Mexico border fence has imposed problems between those two nations with regard to water management, it remains insignificant compared to problems generated by the security measures imposed in the Middle East. The West Bank alone has 400 to 500 checkpoints. The checkpoints retard the movement of people; they retard commerce; they retard the movement of water. The West Bank is home to several hundred small villages that have no water supply and no access to piped water. The villages rely on tanker trucks filled with water as their source of supply. The trucks often have difficulty getting through the checkpoints and, at times, are rerouted and forced to drive many, many miles over harsh roads. The cost of this amounts to $4-5 per cubic meter of water, a very high cost, delivered to very poor people.

Like the border between the U.S. and Mexico where we now have a fence, a much more secure barrier, called by some the Apartheid Wall, has been constructed to separate Israelis from Palestinians in the West Bank. The barrier snakes around the West Bank and impedes the movement of people and goods, including agricultural products. It is one more barrier to deal with and presents an incredible obstacle to the movement of water. The wall now separates Palestinian farmers from their farms and farms from their water supplies. Not long after the wall was erected, a flood occurred in the Qalquilya area of the West Bank. It became apparent that the separation wall was not designed to accommodate runoff from storm water and forced a tremendous backup of debris against the fence that resulted in flooding.

Figure 4. The Apartheid Wall, West Bank.

Notes

1 Fisher, F. M., S. Arlosoroff, Z. Eckstein, M. J. Haddadin, S. G. Hamati, A. Huber-Lee, A. M. Jarrar, A. F. Jayyousi, U. Shamir, & H. Wesseling. (2002). Optimal water management and conflict resolution: The Middle East Water Project. *Water Resources Research, 38*, 25–1:17.

2 http://www.bicusa.org/en/Project.58.aspx

3 Ammar, K., Khalil, A., McKee, M., & Kaluarachchi, J. (2008). Bayesian deduction for redundancy detection in groundwater quality monitoring networks. *Water Resources Research, 44*, W08412, doi:10.1029/2006WR005616.

4 Ghabayen, S., McKee, M. & Kemblowski, M. (2004). Characterization of uncertainties in the operation and economics of the proposed seawater desalination plant in the Gaza Strip. *Desalination, 161*, 191–201.

5 McKee, M. (2005). The need for strategic planning in Palestinian water development. In: Khatib, I., Assaf, K., Claeys, D., & Daoud, A. (Eds.), *Water: Values and Rights* (pp. 507–521). Palestinine Academy Press.

Albert E. Utton Memorial Water Lecture (2003)

New Mexico Water Resources Research Institute

AMBASADOR ALBERTO SZÉKELY
Consultoría Jurídica International, México

Ambassador Alberto Székely is a Career Ambassador, since 1986, with the Mexican Foreign Service. He served as Advisor to the Mexican Foreign Minister (1976–1979), was Alternate Representative of Mexico to the OAS in Washington (1979–1980), Legal Advisor to the Mexican Delegation to the Third U.N. Conference on the Law of the Sea (1973–1982), Alternate Representative of Mexico to the U.N. in Geneva (1982–1983), The Legal Adviser to Mexican Foreign Ministry (1983–1991), Representative to the Sixth Committee of the U.N. General Assembly (1983–1990), a Member of the Permanent Court of International Arbitration at The Hague (1986 to date), and Member of the U.N. International Law Commission (1992–1996). The Ambassador has recently been appointed Judge for the International Tribunal for the Law of the Sea. He continues to be a guest/visiting lecturer on International Law at a number of U.S. Law Schools (Arizona State, University of New Mexico, Johns Hopkins) while conducting a private international legal consulting business from Mexico City specializing in International Environmental Law, the Law of the Sea, and Transboundary Resources issues including environmental zoning and land use planning, sustainable coastal development, environmental defense, water law, forestry law, protected areas, and human rights. In 1998, he coordinated the Citizens Workshop for Legislative Proposals (The Rule of Law and Administration of Justice). Ambassador Alberto Székely has an LL.B. from the National Autonomous University of Mexico School of Law (1968); M.A. and M.A.L.D. from the Fletcher School of Law and Diplomacy, Tufts and Harvard Universities (1969–1970); and Ph.D. from the University of London, College of Laws (1975). He has published extensively in English and Spanish in Mexican, American and international journals.

Introduction By Chuck DuMars

We have certainly had a wonderful lunch, we appreciate it. It's also been a great conference so far and I'm sure it will be this afternoon. I have been given the honor to introduce our luncheon speaker today, a man who I have known for 20 years, and who was if not the best friend, then close to being the best friend of Al Utton—Alberto

Székely. Alberto is a tocayo of Al, both being called Albert or Alberto. Tocayos are people who not only have the same name, but in some ways, have the same personality. Alberto certainly shares the same zest for life that Al Utton manifested throughout the time that I knew Al, and he was a very close friend.

When I was told I would get a chance to introduce the luncheon speaker, I turned it down, until I found out that it was Alberto. When he heard I was introducing him, he said, "What are you going to say Chuck?" I said, "Don't worry, I won;t tell the truth." Alberto is an amazing person. He has many degrees: from the National Autonomous University of Mexico School of Law, an LL.B and an M.A.; a M.A.L.D. from the Fletcher School of Law and Diplomacy at Tufts and Harvard universities; and a Ph.D. from the London College of Law. He has published numerous articles in English and Spanish.

He is the author of what can only be called the leading treatise on the law of the sea. He has co-published numerous articles in the Natural Resources Journal, some of which I have also contributed. He is a career ambassador since the mid-1980s with the Mexican Foreign Service. He has written at the Hague. He has been a leader in developing international water policy and transboundary issues. In the past 10 years, I can safely say, he has become one of the most famous individual authors of policy papers that are the constructs for controlling transboundary environmental pollution. Alberto is a person who has talents that not everyone knows. In addition to being fluent in English and Spanish, he speaks two or three other languages. He is an incredibly good honky-tonk piano player, and I have played duets with him. He plays other instruments as well. He's got a great singing voice, a very deep baritone—drowns you out every time. And he knows all the words to H.M.S. Pinafore's songs. Alberto is an incredible scholar, and also, on a more serious note, has had the opportunity to, because of his tremendous academic credentials, to hide in academia.

Al Utton was very fond of a very famous play called *La Vida Es Sueño*. *La Vida Es Sueño* is the story of Segismundo, a leader of a country who was locked up in a tower for basically his entire life. He was finally able to free himself and he came down and took a look at the world and he said "La vida sueño, los sueños de sueños son," meaning that life is but a dream but dreams themselves are dreams and we have to live with those dreams and build on them. Segismundo went back into the tower. Don Alberto has never gone into the tower. He has been out in the forefront in negotiations at every level for Mexico and for developing countries throughout the world.

He represents an "Albert" vision, an advocate not for government so much but for the principal of excellence in the form of what he calls "preventative diplomacy." Preventative diplomacy refers to excellence in knowledge used in advance of a problem that will result in the resolution of that problem. He and Al Utton both articulated those principles, practiced them, and have been instrumental in setting up constructs for transboundary groundwater management regimes, for example, which are being adopted throughout the world.

It is that commitment to excellence in academics, excellence in principles, and the implementation through the institutions that Alberto Székely brings to this group. I do not have a clue as to what he is going to speak about. He could speak on many topics, everything from Mexican music to classical music to Hungarian food to the most fascinating topics, what it means to plan for, predict, and dream for problem solving resolutions and implementation.

It is my great pleasure to introduce Alberto Székely.

Albert E. Utton Memorial Water Lecture

Good afternoon. I do not know how I can appear here after such an introduction. I told you that Chuck DuMars wouldn't tell the truth, and he didn't, he exaggerated on every account. But a most generous introduction. Chuck, thank you very, very much.

I have always been very proud of my association with New Mexico. There have been for the last 25 years so many things in my life that are associated with this state that I don't need to tell you how happy and honored I am that I have been invited to this forum to talk to you. In the last two years or so I have been making similar presentations in this state. I only recently went to Taos to talk to the Rotarians and I gave a presentation there that was not a very positive one because what was happening then on the water issues between our two countries did not lend itself to give happy accounts. Knowing that I was going to come here, I said to myself, I have to do better. I have to try to create something a little more positive than the last time I was in Taos. Believe me, I am going to exert myself to that end.

This is a lecture in the memory of Al Utton, and I think that to be consistent with that, I should rely mostly on his words. Al Utton did have time to leave us a legacy, a testament, a vision that is very pertinent to bring forth today at his memorial lecture. I remember that in Taos I named my presentation "Chronicle of Man's Disaster." I will try to get away from that as much as possible but it's not easy. Twenty-five years ago, back in the 1970s, Al and I had the idea of creating the transboundary resources center. At that time. Al started turning on some warning lights about the future in this area of the world. He started telling us what we should be thinking about and what kind of measures we should be taking. Perhaps he was thinking already about his grandson who is here today with us, little Daniel Albert. He was not thinking so much of our generation, but of the generations to come. I am sure that he wanted, with all the questions he started posing at that time, a brighter future to be available to future generations.

There was a very important piece of research that was published in 1982 that Al and others undertook during the 1970s called "Anticipating Transboundary Resource Needs and Issues in the U.S./Mexico Border Region." In that article, Al asked a few questions that I am going to take the liberty of reproducing now. He was talking obviously about the situation with water resources in this part of the world and particularly as they pertain to the border between our two countries, the U.S. and Mexico. We were beginning to experience some difficulty at that time. We had gone for almost a hundred years with a happy situation of great bilateral cooperation between the two countries. We had adopted several treaties, we had created an international mechanism that was a part of history, the International Boundary and Water Commission, and we had built dams all along the two main basins on the border, which is the Colorado River Basin and the Rio Grande/Rio Bravo Basin.

However, the honeymoon was almost at an end. Al asked the following questions in the 1982 article. He asked, AHow do we get from here to the year 2000? How do we cope with the fact that every drop of water in the major drainage basins is already appropriated, yet the population is projected to double by the year 2000?" I am quoting his words. He asked, "What is the institutional situation for managing water resources in the U.S./Mexico border area? How well have the institutions performed in the past? Given projections for dramatic population increases in the future, what problems should be anticipated? How should we handle them?" And finally, "What anticipatory actions should be taken?"

It was precisely on the idea of taking anticipatory action that he created the transboundary resources center that now is named for him—precisely around the concept of preventing problems. Al put those questions at the end of what he called a century of achievement. The International Boundary and Water Commission was created in 1889. So it was almost a complete century of experience that he was recapitulating on. Al asked those questions because he already saw that there were some ingredients that were beginning to change and he could see that we could not count on continuing on such a bonanza.

Ever since that time, Al's words, his questions, were the object of great analysis and they instigated the preparation of publications of great pieces of research, mostly published in the *Natural Resources Journal* here in New Mexico. Almost 20 years passed before he gave us his final words. Before he passed away, he published an article in 1999 called "Coping with Drought on an International River Under Stress: The Case of the Rio Grande/Rio Bravo." Twenty years later he was not talking about the century of achievement, he was then talking, in his words, of "The Century of the Pinching Shoe." Those of you who know that article remember those words. He said concerning the periods of drought that we had already been undergoing throughout the 1990s, "The shoe will contract, crinkle, and crack and the foot within will be subjected to sharp discomfort and perhaps traumatic dislocation." Those are the words Al used to describe the beginning of a new century.

Al dared to look into a crystal ball as to what may result from the pressures of population and economic growth. He then left us this series of questions and warnings that I am going to relay to you because it describes how wise he was, what a visionary he was in his predictions. I took those words as a testament as to the way I should conduct my work in the years ahead. He said, "...there will be much greater conservation of existing supplies because water supplies will have to be stretched by much more careful usage. Competition between users will greatly increase. Water will increasingly be switched from Albert E. Utton Memorial Water Lecture agriculture to municipal and industrial uses because many more jobs can be produced by industry with an acre-foot of water than can be produced by agriculture." Then he said, "...limits on growth will confront the region; concepts of and the means for sustainable economic development will become imperative; international and interstate apportionments, hard earned in the twentieth century, will be increasingly challenged in the twenty-first century." He had seen that scenario from the beginning of the drought that started in the 1990s and I do not think that anybody could have put it better, because the way things have been happening since have only confirmed his vision.

Al inspired us at the end of the 1970s, and after twenty years of additional work, with the words that he left us with at the end of the 1990s, he was still inspiring us for the future. I had the opportunity during the past 22 years, ending in June, to be in charge of water negotiations with the United States. These were very difficult negotiations because reserves have dwindled to such small amounts that we have now encountered the problem of not being in the position, at least on the part of Mexico, to make the kind of compliance with the water treaties that we did historically. That has irritated the relationship tremendously. It has brought to the bilateral agenda an element of discomfort, the "pinching shoe." The two countries have unfortunately not known how to deal with it; they have been bogged down in fighting about immediate water deliveries and have not been willing to look to the future.

The drought problem that started in 1992 resulted in, at least on the Mexican side of the Rio Grande/Rio Bravo Basin, a decrease of water availability by about 80 percent. That meant we did not have enough water to comply with our obligations under the treaty. But it was not enough to wake us up to the fact that we had to change the way that we use water. We continued with abusive practices. Had we stopped those abusive practices, we would have saved some water and been able to comply with our obligations under the treaty. The same is happening in the two basins. The shadow of drought has appeared already in the Colorado Basin and the questions is, how are we going to deal with it? It is the same question asked by Al Utton at the end of the 1970s and again at the end of the 1990s. We unfortunately do not know yet how to respond to those questions. For 22 years, I participated in bilateral negotiations, and inspired by some of the words that Al Utton left us, I made proposals, in the name of Mexico, that were reluctantly accepted in principle by the two governments.

The first proposal that was made and is waiting to be carried out, was something Al Utton reiterated in almost every article he wrote on the subject: the need to define when we are in an "extraordinary drought" situation so that we can say that the normal system of water delivery should be changed. Anybody who knows the literature produced by Al Utton will agree with me that he had sort of an obsession with the technical question of, or the need of, defining extraordinary drought. When a conflict eventually developed as a result of the drought, the one thing that triggered the conflict was that each of the two countries had its own version as to whether we were in an extraordinary drought situation or not.

Finally through these negotiations, at the beginning of this year, there was a proposal put on the bilateral table that we should finally do as Al Utton had advised so many times: sit down and negotiate an exquisite definition of extraordinary drought. I can only report that an agreement has been reached in which a body of experts will sit down and create that definition. Now the question is whether they are really going to sit down and do it. But at least we have advanced that far. There is a little bright light in the future.

Another proposal was made and at the time, we were thinking very much of the words of Al Utton when he said, "...concepts of, and the means for sustainable economic development will become imperative." We proposed at the negotiation table that these two countries start negotiations for a bilateral plan for the sustainable management of the two basins. That is a tremendous challenge for the two governments because preparing a plan for the sustainable water resources of the two regions, of the two basins, on both sides of the borders, means putting to question a lot of things. It means that we need to start thinking about what Al mentioned regarding limits on growth. We are doing this at a time when nobody wants to talk about limits to growth – at a time when there is wild competition to create wealth to exploit natural resources in order to participate in the market. Therefore the idea of starting to look at limiting growth does not come at the most propitious moment.

However, a proposal was made to prepare such a plan. It will require a review how we implement NAFTA on both sides of the border. NAFTA is based on the idea that we should industrialize the Gulf of Mexico as that will bring about not only the creation of trade exchanges and investment opportunities between the two countries, but it will also reduce the need for migration from Mexico to the United States. We are working with a treaty that has as its foundation, a call for much greater growth in the region where water availability has been dwindling constantly to very alarming levels. We will have to question that foundation and, as you can imagine, the federal governments are not prone to get engaged in such questions. We must look at how industry is planning to develop on both sides of the border. We must look at the urban development of all the counties and all the municipios along the border. We have seven Mexican states along the border and four U.S. states. We have 39 municipios on the Mexican side, 25 counties on the U.S. side, and 14 pairs of twin cities. We must look at how we are planning future development, urban development as well as industrial development, because so far we have been developing without any consideration to water availability. Now, as Al said, it ill be imperative.

In all this, we have a very big challenge because the attitudes of several of the actors in this story are not, as I said, very prone to engage in these activities. First of all, the institutional bilateral mechanism that we were so very proud of – the International Boundary and Water Commission (IBWC)—has been undergoing a terrible, traumatic period. We just witnessed the coming and going of the Commissioner on the U.S. side that resulted in putting the U.S. Section of the IBWC in a severe crisis to say the least. The Mexican Section is frozen in total stagnation and there is absolutely no will on the part of either of the two governments to do anything about it. So the IBWC is one of the actors we should not rely on. The IBWC will not change things. Many of those of us who are working on these issues keep harping on the idea that we should change the IBWC. I do not think that any change in the IBWC is coming and I do not think that even changing the IBWC a little is going to make a difference.

The IBWC is one actor, the institutional mechanism. Other actors include the two federal governments. However, they are too preoccupied with other things. First of all, their bilateral agenda was lost to 9/11. The Mexican Government has been making great efforts to revise some of the bilateral issues that Presidents Bush and Fox had agreed to undertake when they both came to power but 9/11 has killed that agenda and we have not been able to set it up again.

In the Mexican Government vision, migration to the United States and everything that that entails is Issue Number One; not the future of the border area, not the situation with water resources. The migration issue has its merits but I do not think that the water issue of the future of this area should be put in any place other than first place, perhaps along with the migration issue, but certainly at the top of the list. The two federal governments have not shown any interest in moving in that direction on these issues. We have been told ever since the end of the 1970s that aside from occasional droughts like the one that has been afflicting us for the past three years, we will be hit by something much worse than that, and that is the impact of global warming on these two basins. We have been told that as a result of global warming the Colorado River will lose 40 percent of its flow and the Rio Bravo will lose 76 percent of its flow by the middle of this century.

We do not want to wake up. The U.S. resists the idea that they should enter into any international engagements or obligations to address the problem of global warming. Mexico resists the idea of engaging in its own obligations hiding under the umbrella of it being supposedly a developing country that can not afford to do anything about these environmental issues. We have been told that things are going to get a lot worse, yet we do not wake up. We certainly can not rely on the federal governments to wake up and do something about it. I have counted out the IBWC. Who else should we look to?

We must look to the states. The words that Al Utton was giving us since the 1970s and all the warnings since point in only one direction given the dramatic reduction in water availability. We are going to start having conflicts and possibly even wars between the upper riparians and the lower riparians. We have to realize who those actors are. Who are the upper riparians and who are those lower riparians? In the international context, we are both upper riparians because we have water in the Conchos system that we gave to the United States under the 1944 treaty. But Mexico is lower riparian in the Colorado system while the United States is upper riparian in the Colorado but lower riparian in the Rio Bravo. That is only in the international context. So many of you know that there are upper riparians and lower riparians between states on the American side of the border – New Mexico, Texas, what else should I say? Worse than that, and we do not want to admit it, there are upper riparians in each of the states. Half the users of Rio Grande water in the state of New Mexico is upper riparian and the other half is lower riparian, all inside your own state. Who is likely to really worry about these conflicts?

The governments of the two countries have not shown any interest, and as usual, they will get there late. I think we should start looking at the states and particularly the role of the states'governors. There is an increasing role for governors in both our countries. In my own country, governors are beginning to show up as a major political force simply because they have been liberated by central control from the presidency. Thanks to the transition that Mexico has been able to make to democracy, suddenly the states of the union are sovereign states not under the control of the president as we were for the last 70 years under the previous regime. Suddenly we are hearing the voices of the governors.

On the Mexican side, we have already constituted the national governors conference. We now have a new kind of actor that was not foreseen in any part of our legislation; an actor with great political force simply because they have regained their sovereignty. They are becoming major actors on most of the top national issues. Governors in Mexico have bonded together on many issues and they meet and talk about these issues. We need a very specific effort on the part of the 11 governors. We also need an effort on the part of the seven governors of the Mexican states bordering the United States along with the four U.S. governors. The governors are going to suffer the consequences of the conflicts between upper riparians and lower riparians not only in the state vs. state conflicts and in the international conflicts, but they also are going to suffer at home when confronting conflicts between their upper riparians and lower riparians. As it so happens, anything that takes place in any part of the basin will send shockwaves to the rest of the basin.

I think it is in the interest of the governors to take a role in this issue. I do not see any other alternative. I repeat: we must discount the IBWC and I do not see the federal governments wanting to take any responsibility on this issue.

I should have finished this talk a long time ago, I think. I have a lot more to say so, if you have a couple more hours, I will go ahead. I do not want to be negative in this presentation, particularly when we are talking in memory of Al Utton, who was always so positive and such an optimist, as you all know. So where do I see hope? Where do I see the possibility of answering these questions that were posed in the positive? I am afraid that if we do not have the states moving and becoming active on this, I do not know who else will provide us with the answers.

If this Memorial Lecture should be good for something, I hope that it is as the first call on the governors of the 11 states to start acting to ensure a better future for Daniel Utton and for the other kids like him—for those of future generations. That way I will not have to come with gloomy chronicles of man's disasters—maybe we can avert those disasters. I hope this appeal to the states and their governors to move ahead on water resources issues is heard and is repeated by others. I invite you to repeat this appeal.

Thank you very much for listening to me.