67/21100

ELSEVIER

Water Policy 4 (2002) 137–155

Water Policy

www.waterpolicy.net

Bi-national water issues in the Rio Grande/Río Bravo basin

Jurgen Schmandt*

University of Texas at Austin, Houston Advanced Research Center, 4800 Research Forest Drive, The Woodlands, TX 77381, USA

Received 21 March 2001; received in revised form 23 October 2001; accepted 16 December 2001

Abstract

The Rio Grande (called the Río Bravo in Mexico) is the fifth largest river on the North American continent. The river supports extensive irrigated agriculture as well as rapidly growing cities in three US and five Mexican states. From El Paso, Texas to the Gulf of Mexico, the river marks the international border between Mexico and the United States. Treaties for sharing the water of the Rio Grande between the two countries and arrangements for joint management were concluded in 1906 and 1944. Over time, a complex system of water management institutions has emerged. Water problems are pronounced, due to intensive development in an arid environment. Over the course of the last 40 years, the population in the border communities has doubled every 20 years. Demographic projections predict another doubling of the population by 2030.

The entire Rio Grande basin is arid or semi-arid. Development has already led to a severe loss of biodiversity in parts of the basin. Development of new surface water resources is not a realistic option. The principal water management options are as follows: improved efficiency of water use, transfer of agricultural to urban uses of water, conservation and re-use of water, and treatment of brackish groundwater. Up to now, differences in law and levels of development between Mexico and the United States have made it difficult to develop basin-wide management strategies. In addition, regional differences in hydrological conditions argue in favor of developing separate but linked strategies for the sub-basins. This paper presents the key issues in two sub-basins with the largest population centers on the international border—the Paso del Norte (Las Cruces, New Mexico, El Paso, Texas and Ciudad Juárez, Chihuahua), and the Rio Grande Valley (Reynosa–Matamoros on the Mexican side, and MacAllen–Brownsville on the US side). Together, these cities will have 8 million inhabitants by 2030. The paper concludes with suggestions for improving management of river and groundwater in this bi-national growth region. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Water management; US–Mexico border; Water planning; Sustainable development

*Tel.: +1-281-363-7913; fax: +1-281-363-7924.

E-mail address: schmandt@uts.cc.utexas.edu (J. Schmandt).

PII: S1366-7017(02)00007-7

1. Introduction

The Rio Grande is the fifth largest river in North America (Fig. 1). It runs 600 miles north–south from its source in the Colorado Rocky Mountains to El Paso, Texas. From there, it turns southeast and for over 1200 miles marks the border between Mexico and the United States—the longest river border in the world between countries at vastly different levels of development (Herzog, 1990). The basin drains an area of 335,000 square miles. Of this, total 86,720 square miles form the international part of the basin—53,000 square miles in the United States and 33,700 square miles in Mexico. The climate in the entire basin is arid or semi-arid. For example, annual rainfall in El Paso, Texas, is a scant 8 in. Evaporation is high, and runoff from rainfall is minimal. Most of the border part of the basin was sparsely populated until World War II. This changed dramatically over the course of the last few decades. The population has doubled every 20 years. Juárez, El Paso and Las Cruces together will reach 3 million in 2030, and the cities in the Lower Rio Grande Valley will have a population of 4.9 million. Many reasons account for the rapid and continuing population growth. Among them the training needs of the US military, the population explosion in Mexico, the border assistance programs by the US government (most notably the tax advantages granted to assembly plants South of the border), the resulting movement of people from poorer areas in Central and South Mexico to both sides of the international border, as well as the appeal of the desert climate once air conditioning became widely available. Over the course of the last 50 years the Rio Grande basin has become a growth region.

The border region periodically suffers from droughts (International Boundary and Water Commission, 1993). However, in normal years, there used to be enough water to meet the needs of communities and irrigated agriculture. Several parts of the basin enjoy fertile soil, and can produce two or three crops a year, provided enough water is available. Until recently, few gave much attention to limits to growth due to water scarcity. As the cities grew, water quality became a serious health issue. The incidence of water-borne diseases grew steadily (Army Corps of Engineers, 1992). Many communities, mostly on the Mexican side of the border, released raw sewage in the river. For the last several years, largely because of the side agreements to the North American Free Trade Agreement (NAFTA), Mexico and the United States have begun to build the necessary water treatment facilities. Ten years from now, all large cities on the border will have primary treatment plants, and most will have the capacity for secondary treatment. Tertiary treatment is still a long way off in Mexico. So is sewage treatment in small communities.

However, coping with limited water supply is the main challenge for the future: Will there be enough water to support the water needs of the basin? So far, only some water experts and managers express concern (Sepulveda & Utton, 1984). The public does not yet recognize that water supply and demand are on a collision course. There are solutions, but they need time and resources to implement. The issue of how to manage water scarcity in a rapidly growing basin is at the heart of this paper. Possible solutions will be identified. By necessity, the political border and the differences in law, culture and level of development between Mexico and the United States make this a difficult challenge. Mastering constraints imposed by nature is difficult enough. Dealing simultaneously with constraints resulting from human actions adds complexity, delay and the risk of confrontation.

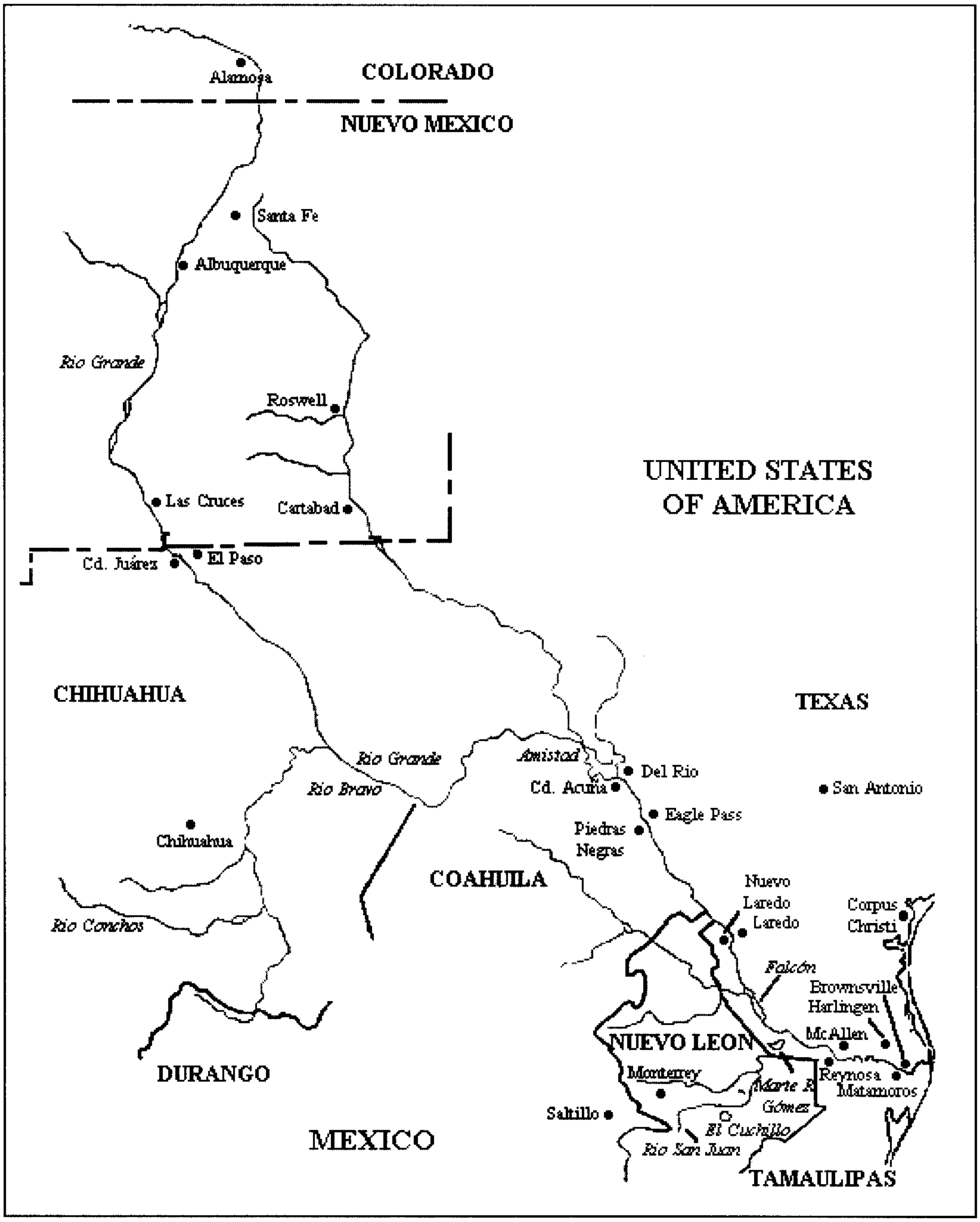

Fig. 1. Map of the Rio Grande/Río Bravo Basin.

There are two main sources of Rio Grande water: snowmelt from the mountains in Colorado and New Mexico, and tributaries from Mexico and Texas (Eaton & Hurlbut, 1992). Snowmelt feeds the *Upper Rio Grande*—from the headwaters to South of El Paso. Volume and timing of

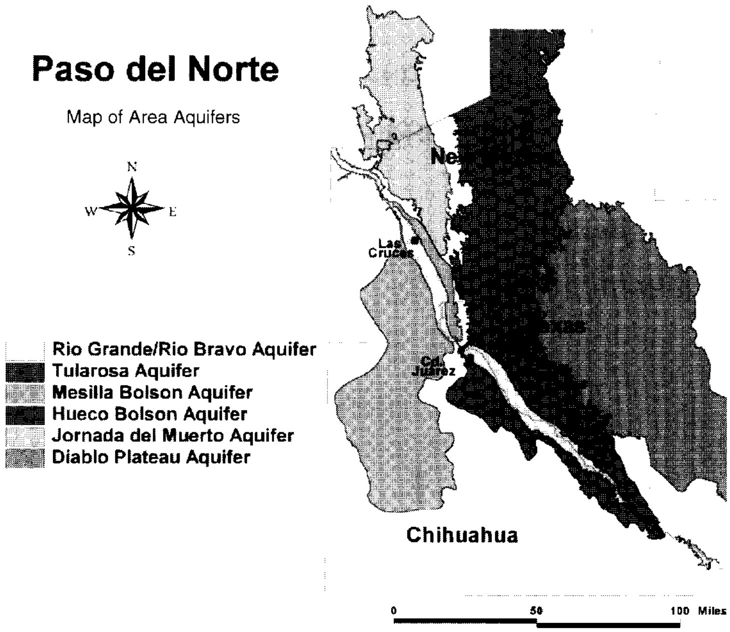

Fig. 2. (Compiled from Hibbs, B. J., Boghici, R. N., Hayes, M. E., Ashworth, J. B., Hanson, A. T., Samani, Z. A., Kennedy, J. F., Creel, B. J., 1997, Transboundary Aquifers of the El Paso/Cd. Juárez/Las Cruces Region: Joint Report of the Texas Water Development Board and New Mexico Water Resources Research Institute.)

snowmelt is critically important for irrigated agriculture in Colorado. Due to intensive agricultural use of water in Colorado, New Mexico and West Texas, coupled with increasing demand for municipal water, the river runs dry South of El Paso during much of the year. Two tributaries—the Río Conchos from Mexico and the Pecos River from Texas, as well as several minor creeks and rivers—ensure year-round stream flow in the *Lower Rio Grande* (from the confluence of the Río Conchos to the Gulf of Mexico).[1] From a hydrological perspective, therefore, Upper and Lower Rio Grande watersheds are largely independent of each other. In the remainder of the paper, I will identify water issues and response strategies in the two bi-national sub-basins with the largest irrigation and municipal water demands in the border region—the Paso del Norte in the Upper Basin, and the Rio Grande Valley in the Lower Basin.

2. Sub-basin I: Paso del Norte

The Paso del Norte is home to some of the fastest growing desert communities in the world (Fig. 2). About 2.5 million people live in the border region that includes two counties in Southern

[1] The reader must be warned that the terms *Upper* and *Lower* Rio Grande are also used, mainly in Colorado and New Mexico, to designate the upstream and downstream segments of the Rio Grande between the Colorado headwaters and Fort Quitman, Texas. In this paper, however, I use the terms to make the distinction defined in the text above.

New Mexico, five counties in West Texas and four municipalities in the Mexican state of Chihuahua. The main cities are Las Cruces, New Mexico, El Paso, Texas, and Ciudad Juárez, Chihuahua. Five million people will live there by 2030. Traditionally, the region used groundwater to meet municipal demand and river water for irrigation (Schmandt, Stolp & Rhodes, 1999). In 1906, Mexico and the United States reached an agreement to divide the waters of the Upper Rio Grande. Two provisions of this convention remain important to this date.

First, Mexico receives 60,000 acre-ft of Rio Grande water each year. In exchange, Mexico withdrew long-standing complaints about over-use of water upstream from the point were the Rio Grande becomes the common border between the two countries. The annual allotment is contingent on availability of water in any given year, and shortfalls during drought years are not made up in future years. This 60,000 acre-ft allotment represent the main source of water for the Mexican irrigation district in Juárez.

Second, the 1906 Convention expanded the authority of the existing International Boundary Commission, responsible for settling disputes over the exact location of the international border, to the management of Rio Grande waters from El Paso to the Gulf of Mexico (and to other water ways on the international border further West in Arizona and California). The International Boundary and Water Commission (IBWC) has long been the most important bi-national institution on the southern border of the United States. The agency is organized in Mexican and United States sections that work closely together in the field, and report to their respective ministries of foreign affairs. Each section head must be a professional engineer. The IBWC is responsible for the construction, maintenance and operation of international dams and other water infrastructure, water accounting between the two countries, diplomatic problem solving, flood control and technical investigation. During its long history, the IBWC has shown competence in its hydrological tasks. The agency has been criticized for not addressing new issues as they arose. Control of water quality and management of international aquifers are two cases in point. However, the formal agreements between the two countries do not cover these matters, and both countries have been reluctant to reopen negotiation of either the 1906 or the 1944 (Lower Rio Grande) treaties. As a partial remedy, IBWC can engage in joint fact-finding on new water issues and address recommendations to the two national governments. This "minute" process has been used extensively over the years but has not led to a major broadening of IBWC authority. A second criticism, made by several authors, concerns the technical orientation and lack of community involvement in the agency's work. In recent years, the Commissioners have made great efforts to overcome this limitation. Yet the structure of the agency, under which both Mexican and US sections report independently to their ministries of foreign affairs, limits flexibility in working with stake holders from both countries.

While the 1906 Convention was being negotiated, the United States acted to improve year-round availability of water in the Upper Rio Grande. In 1902, the Bureau of Reclamation had been established to assist with development in the American West. As one of the Bureau's first water projects, Congress approved funds for the construction of a large reservoir on the Rio Grande 125 miles up the river from El Paso at Elephant Butte. The reservoir was completed in 1916. At the time, it was the largest reservoir in the world. Elephant Butte provides water to farmers in Southern New Mexico where the Bureau of Reclamation developed the Rio Grande Project, a forerunner of the Bureau's even larger irrigation project in Southern California. Part of the water from Elephant Butte reservoir is passed on to downstream users in Texas, under an agreement between New Mexico and Texas, and to Mexico, under the 1906 Convention.

In 1936, the United States built a smaller reservoir downstream from Elephant Butte. The purpose was to use river water more efficiently. Elephant Butte was to produce electricity during the entire year, and the water used for this purpose was to be stored during winter months in the new Caballo reservoir. This way, farmers would be able to use the water during the growing season. As a result, however, in-stream flow downstream from Caballo reservoir was interrupted from October to February. It took decades to recognize that this arrangement lead to permanent ecological damage. New Mexico and Texas are now seeking ways to restore year-round river flow. This illustrates a significant change in priorities for water management. When Caballo was built the environmental impacts were not considered. Now a consensus is emerging in the region to undo the ecological damage resulting from this arrangement (Centre for Environmental Resource Management, 1998).

The most serious water issue confronting the Paso del Norte is water scarcity that may get pronounced as the population grows. The main source of drinking water for the cities of El Paso and Cd. Juárez, the Hueco Bolson (aquifer), has been over-pumped for decades and is expected to run dry by 2025. A secondary aquifer (Mesilla Bolson) has mostly brackish water. Both aquifers underlie New Mexico, West Texas and parts of the Mexican State of Chihuahua. However, withdrawal of water from the aquifers is not planned or managed across political boundaries.

Surface and groundwater are not managed conjunctively. The IBWC has authority over surface water. It has no authority over groundwater. As awareness of over-pumping spread, this was recognized as a serious gap in regional water management. In 1972, the IBWC conducted a technical study of the groundwater problems confronting the region. In response, the two federal governments agreed that further joint studies and planning should be organized. However, there has been strong opposition on the part of state and local governments, as well as property owners, to interfere with their groundwater rights. The laws regulating groundwater differ significantly. New Mexico requires approval by the State Engineer before a new well may be drilled. In Texas, groundwater is the property of individual landowners. In Mexico, groundwater (as well as surface water) is public property and regulated by the Mexican Water Commission, a powerful agency of the central government. In 1997, the IBWC participated in the work of state water agencies designed to map and characterize bi-national aquifers in the Paso del Norte (Hibbs et al., 1997). The study documented the exact location of border aquifers. However, a quantitative assessment of available underground water resources does not yet exist. In addition, to this day no joint planning for development and restoration of aquifers is undertaken. So far, the actions taken are limited in scope and scale. Proposals for a bi-national groundwater treaty have been developed, mainly by Professor Al Utton of the University of New Mexico (Utton, 1999), and Alberto Szekely from Mexico. (Szekely, 1991; Managing North American Transboundary Water Resources, 1993.) However, neither the IBWC, nor other federal or state agencies, have moved to authorize conjunctive water planning and management.

The City of El Paso has reduced its dependence on ground water by 40 percent, but Juárez and Las Cruces still take all their municipal water from aquifers. The strategies used by El Paso to secure the water future of their city point the way that other communities in the sub-basin will have to follow. They include conservation and water pricing, purchase of surface water rights, use of grey water, and replenishing of underground reservoirs. At present, design for a $50 million desalinization plant is also underway. However, these measures are expensive and unlikely to be implemented in Mexico.

Population growth in the Paso del Norte is expected to continue at a rapid pace. By 2030 Juárez is likely to surpass 2.5 million, and El Paso will reach 1.2 million people. Existing water plans for the future, prepared by El Paso, Las Cruces and a group of West Texas Counties reveal a startling difference in assumptions about future water needs. El Paso assumes that the demand for irrigation water will decline in response to urbanization and the sale of agricultural water rights. This will free up significant amounts of Rio Grande water for municipal use. New Mexico, on the other hand, assumes that the number of irrigated acres will remain as it is today. Similarly, Mexican water agencies do not foresee a decline in water needed for irrigation. This fact strongly supports the argument that water planning must be organized across political boundaries to avoid a major supply shortage 10 to 15 years from now.

For the last three years, a non-governmental organization—the Paso del Norte Water Task Force—has begun to lay the foundation for trans-boundary water planning in the region. The Task Force is made up of the directors of the city water utilities, the managers of irrigation districts, industrial water users, community leaders and experts from Southern New Mexico, El Paso and Juárez. The Task Force recently released its first report, *Water Planning in the Paso del Norte: Toward Regional Coordination* (Paso del Norte Water Task Force, 2001). The report brings together basic information regarding population growth, land use, water supply, water demand, and water management institutions in the Paso del Norte. The report also compares current practices by water planning agencies through an analysis of the following parameters in their water plans: planning horizon, plan updates, population projections, projections of water supply and demand, projections of land use trends, public involvement in water planning, and proposals for action. The Task Force is now undertaking a feasibility study of the legal, financial and management arrangements for cross-border water planning.

3. Sub-basin II: Lower Rio Grande

To this date, integrated data sets from Mexico and the United States, covering water supply and use, population and land use projections, economic development and ecological conditions, are hard to come by (Department of the Interior, 1995). A recent joint study by experts from both countries fills this gap for the Lower Rio Grande. In this section I summarize the results of this study (Schmandt et al., 2000; Mathis, 1999). The full report is available on the web site of the Houston Advanced Research Center (http://www.harc.edu).

There are two fundamental differences regarding water between the Paso del Norte and the Lower Rio Grande: first, while groundwater resources in the Paso del Norte are declining, in the Lower Rio Grande Basin they are of such poor quality that they are not an important source of useable water, either for irrigation or municipal use. Currently, only one water district uses groundwater. Future use would require expensive treatment. Second, the bulk of Rio Grande water in the sub-basin originates in Mexico. Therefore, international considerations are even more important than in the Paso del Norte.

Year-round stream flow in the Lower Rio Grande is only ensured by tributaries: The Río Conchos (Mexico) accounts for two-thirds, and the Pecos River (New Mexico–Texas) for one-third of water in the Lower Rio Grande. Pecos water is naturally saline, while Conchos water is of good quality. In 1944, Mexico and the United States reached agreement on the division of waters in the Lower Rio Grande (US Department of State, 1946). Each country receives half of the water in the main stem of the Rio Grande, and full use of the waters in their tributaries. However, there was an important exception to the last rule: the treaty gives the United States 350,000 acre-ft each year from the Río Conchos. In exchange, Mexico receives 1.5 million acre-ft from the Colorado River further west on the international border. In case of drought, deficits from Conchos deliveries can be made up over the following five-year period. As a result, the United States holds rights to 58 percent of Lower Rio Grande water, with the remaining 42 percent going to Mexico.

The Treaty also provided for the joint construction and management of two large reservoirs on the Lower Rio Grande. Falcón Reservoir was completed in the early 1950s, Amistad Reservoir 15 years later. Since 1972, the two reservoirs have been operated as a single system. The IBWC and its Mexican counterpart (Comisión Internacional de Límites y Aguas (CILA)) are responsible for maintenance and management of the reservoirs. The reservoirs provide 95 percent of available surface water to the Lower Rio Grande Valley, the most important economic and population center in this part of the border region. The rest comes from smaller Mexican tributaries, runoff from precipitation, and return flows from irrigation.

The two reservoirs support a number of twin cities as well as irrigation districts on both sides of the international border. The main population and economic center is the *Lower Rio Grande Valley* (*LRGV*), which encompasses the last 270 river miles (434 km) downstream from Falcón Reservoir and a stretch of 30–40 miles inland from either side of the river. This land is well suited for irrigated agriculture. Cities and agriculture in this part of the river depend entirely on river water.

Prior to the construction of Amistad and Falcón reservoirs the LRGV suffered from periodic drought as well as flooding. The largest economic losses were caused by occasional storms, often the remnants of hurricanes moving in from the Gulf of Mexico. Major floods in the main stem of the river have not occurred after Amistad and Falcón reservoirs were completed. The drought of record occurred during the 1950s, before the reservoirs existed. However, since 1994, a serious drought has reduced water supplies in the region causing serious economic losses on both sides of the border. This continuing drought is the most severe test yet of the Amistad–Falcón reservoir system. The region has experienced major water shortages during the drought (Acosta Ramirez, 1997).

Population: The LRGV, in Texas as well as Mexico, has seen rapid population growth since the 1950s. From 1950 to 1995, population rose from 680,203 to 2,146,601—an increase of 216 percent. Much of the increase is the result of in-migration from the interior of Mexico. This trend is likely to continue into the future. The total population in 2030 is estimated to rise to 4.9 million—2.6 million in Mexico and 2.3 million in Texas.

Regional economic development: In the Mexican part of the LRGV the largest economic sectors are services, commerce and manufacturing. Agriculture has declined from 15 percent of total output in 1970 to 10 percent in 1993. Total employment was 196,000 in 1994. Unemployment is low at about 3 percent of the labor force. Maquiladoras represent 12 percent of all companies in the state of Tamaulipas. Matamoros is home to 4 percent of all maquiladoras (assembly plants) in Mexico. Reynosa follows with 3.9 percent and Nuevo Laredo with 2 percent. Together, the three cities have 265 maquiladoras that employ 123,000 workers. Foreign investment is growing in Nuevo León (7 percent of Mexico as a whole), while Tamaulipas receives only 1 percent (Aguilar Barajas, 1993, 1995).

In Texas, the border counties have experienced rapid growth in personal income in recent years. Even so, they still have the lowest per capita income both within Texas and the United States. In 1994, average per capita income ranged from $6583 in Starr County to $11,346 in Cameron County. This compares with a per capita personal income of $19,716 for Texas and $21,696 for the nation. Historically, irrigated agriculture played an important role in the development of the LRGV. Yet the share of total earnings from farm income and related services has declined to 3.3 percent in all counties except Willacy where it remains at 31 percent. Cross-border trade is the single most important industry representing 20 percent or more of total earnings. Services and public sector spending are strong, while manufacturing is less important. Unemployment in the border region has been high but the region has enjoyed solid economic growth throughout the 1990s. This upward trend was slowed, however, by the 1994 devaluation of the peso and the ensuing recession in Mexico. Industrial water use in the LRGV accounts for about 10 percent of municipal and industrial (M&I) use.

Irrigated agriculture: The border region in Texas as well as the Mexican state of Tamaulipas is an important supplier of fruits and vegetables, as well as corn and sorghum. In 1996/97, notwithstanding the ongoing drought in the Lower Rio Grande Basin, irrigated agriculture in Tamaulipas was responsible for 17 percent of Mexico's agricultural production. Irrigation district 025, Lower Río Bravo, is the principal producer with a total area of 236,735 ha. Four of the district's six units (210,362 ha) receive Río Bravo water through the Anzaldúas diversion channel, and the remaining two units pump water directly from the Río Bravo. The amount of irrigated land varies greatly from year to year depending on water availability and several other factors. In 1981, for example, only 140,000 ha were irrigated. Between 1980 and 1993, the size of irrigated land declined by 1400 ha each year. Annual water deliveries reached an all time high of 1900 Mm^3 in 1989 but plunged to 382 Mm^3 in 1996 due to drought. Average annual use is 1100 Mm^3. Irrigation district 026, Lower San Juan, is second in importance: 86,097 ha were irrigated during the best years (1970s), 76,602 ha received water from the San Juan. The remainder is irrigated by water from the Río Bravo. Due to drought the irrigated area during most of the 1990s was $<$40,000 ha, and only 1/3 of the total available acreage in 1998 (Aguilar Barajas, 1999).

In Texas, farmers are organized in 28 irrigation districts. All districts pump water directly from the Rio Grande. Because ground water is brackish only a small amount is used for irrigation. According to IBWC statistics, irrigated land on the US side of the Lower Rio Grande Basin declined from 300,000 ha in 1980 to 288,000 ha in 1993. The US Census of Agriculture reports a much steeper 44 percent decline in irrigated land between 1982 (657,750 acres) and 1992 (366,656 acres). During the same time the market value per acre of land in the LRGV declined by 23 percent. Our analysis shows that the agricultural sector is highly adaptive and can compensate for reductions in water by crop selection, better technology and reduction in water losses. One irrigation district convinced their members to pay for installation of underground water pipes, thereby reduced water use by 40 percent, but still harvested the same value of crops. The same district did better than its neighbors when water supply was curtailed during the current drought. Modeling a 20 or 40 percent reduction of agricultural water for all districts in the LRGV showed minimal impact on the LRGV economy.

The decline in irrigated land is partly the result of periodic droughts. However, more permanent factors contribute to this trend. Land is withdrawn from agricultural production as the region becomes more urbanized. As part of this change in land use agricultural water rights are transferred to cities. Difficult market conditions have made it advantageous for farmers to sell water rights. High-value citrus plantations were destroyed by frost twice in a row, and many farmers never replanted.

Water supply and demand: Releases from Amistad–Falcón account for 95 percent of the water supply to the LRGV. The river channel serves as the conduit for delivery. Water diverted to users in Mexico and Texas reduces flow in the channel. As a result, the river looses part of its ability to dilute wastewater discharged in the river, to extrude salinity intruding up the channel from the Gulf of Mexico, and to maintain ecosystems in and along the river. During the first 18 years of joint operation of Amistad–Falcon reservoirs (1972–90) average monthly delivery was 202 Mm^3. The firm yield of the system, defined as constant delivery to the point of zero storage under drought of record conditions (1950–54), amounts to about 232 Mm^3.

Mexico diverts its water mainly at a single point, the Anzaldúas canal. Water in Texas is diverted at numerous pump stations. From 1980–93 average monthly Mexican diversion was 115 Mm^3. This is practically equal to the United States diversion of 113 Mm^3/m. The total flow in the channel diminishes from an average below Falcón of 258 Mm^3/m to a flow at Brownsville of 51 Mm^3/m. The estimated firm yield for the Amistad–Falcón reservoir system varies dramatically under the following assumed conditions: (a) simulated reservoir yield using historical climate data; (b) full Mexican development of the Conchos basin, (c) super drought, and (d) worst case (full Mexican development combined with super drought). The results of these scenarios are summarized in Table 1.

Sensitivity of the system to Conchos development is highest. It should be noted that this scenario assumes that Mexico will continue to deliver 350,000 acre-ft/yr, as required under the Treaty. Historically, Mexico provided more water in most years, reaching 700,000 acre-ft on occasion. Continued development in the Conchos basin is likely to limit releases to the amount specified in the 1944 treaty. During drought years, even less may be available, as has been the case in recent years. Reduction in firm yield, compared to historical hydrology, represents 13 percent in the case of Super drought, 23 percent in the case of Full Mexican Development and 31 percent in the case of Worst Case (Acosta Ramirez, 1997).

Municipal and industrial (M&I) demand will reach 45 Mm^3/month by 2030, representing about 20 percent of firm yield under the historical hydrology scenario, and 28 percent under the worst-case scenario (Table 2). At present, M&I uses 12 percent. Using different assumptions about future per capita water use in Mexico considerably higher M&I demand for Mexican communities

Table 1
Scenarios of firm yield from the Amistad–Falcón reservoir system (Mm^3/month)

1945–60 Hydrology[a]	Full Mexican development	Super drought	Worst case
230	176	200	158

[a] Includes drought-of-record years.

Table 2
Projected municipal and industrial (M&I) water demand (Mm^3/month) in the LRGV

	1990	2000	2010	2020	2030
Texas	14.29	19.96	22.89	25.15	29.73
Mexico	6.57	8.85	11.07	13.11	15.18
Total	20.88	28.80	33.96	38.26	44.91

is possible (all in Mm^3/month): 1997–16, 2010–17, 2020–20, and 2030–23. If so, the M&I share for the same scenarios will rise to 23 and 34 percent, respectively.

At present, agriculture uses 80–88 percent of river water. Irrigation use varies greatly from year to year. During 1980–94 (just before major reductions due to the current drought occurred), the combined average of Mexican and United States irrigation use was 3000 Mm^3/yr or 250 Mm^3/m. Assuming that municipal and industrial water demand takes priority over irrigation and that the remaining volume of water is allocated to irrigation, significant annual irrigation shortfalls occur under each study scenario. By 2030, these shortfalls could reach 55 percent under the worst-case scenario. Part of the shortfall will be met by declining water use by agriculture due to land use and market changes. The Texas Water Development Board estimates that irrigation demand will decline by 10 percent between 2000 and 2030. However, larger reductions in agricultural use are likely both in Mexico and in Texas. Such reductions would be consistent with the decline in irrigated land on both sides of the border.

Water quality: Using EPA water quality parameters and models, the Lower Rio Grande exhibits surprisingly good water quality. Exceptions are locations downstream from several major cities. Agricultural runoff, which often causes water quality problems, does not reach the river because the land slopes away from the Rio Grande. High levels of total dissolved solids exist at times. They seem to be more due to natural brines originating in the Pecos River than to point or non-point source loads within the Lower Rio Grande Basin. During periods of low flow the rise of dissolved solids increases dramatically. The frequency of low-flow periods, and therefore of poor water quality, will increase in the future. This will limit the use of water for agricultural irrigation and other uses at times. Review of available data for conventional pollutants, nutrient concentrations and toxic substances allow for a general characterization of water quality with regard to conventional and non-conventional pollutants, but data on toxic substances is incomplete. Available data show lower concentrations of toxic substances than might have been expected based on suspected loadings.

Ecosystem: Nearly 700 species of wildlife have been documented in the study area (Jahrsdoerfer & Leslie, 1988). More than 86 vertebrate species are listed as endangered or threatened or are considered candidates for immediate protection. Using fish communities as an indicator of ecological health the study found that major alterations have occurred. The river from Falcón to Brownsville–Matamoros has lost many of its freshwater components. Instead, exotic or estuarine forms are found. The river close to its mouth has many fewer freshwater taxa. They have been replaced by estuarine and marine species (Contreras-Balderas, 1999). These faunal changes appear to be correlated with decreasing stream flows, the proliferation of exotic species, and increases in chemical pollution. An index of biological integrity was developed for the riverine ecosystem. The resulting quality ratings are poor for most locations, except Falcón Reservoir. Decreased stream flow and pollution are the main culprits. It is noteworthy that chemical and biological water quality ratings yield different results.

Water management: At the international level, reservoir management by the IBWC is conducted professionally and harmoniously. The 1906 and 1944 treaties limit the authority of the agency to surface water. In recent years, the agency has received limited authority to conduct water quality and groundwater studies. Texas has created the office of (Lower) Rio Grande Water Master as an intermediary between IBWC and large water users (irrigation districts and cities). The water master keeps track of water rights and deliveries and controls compliance. This office has been instrumental in bringing water peace to the Texas side of the border (Schmandt, Stolp & Ward, 1998). Texas has also begun basin-based water planning under a new water law passed in 1996 (Texas Water Development Board, 1997). Along with other basin-planning groups, the Lower Rio Grande and the Far West Texas planning regions completed their first water plan late in 2000. The Texas Water Development Board will consolidate the regional plans into a State water plan for consideration by the Legislature in 2002. Different water laws and management systems in Mexico and the United States make cooperation difficult for issues that do not fall under the authority of the International Boundary and Water Commission. This gap is particularly serious in the areas of water planning and ecological protection.

The future: There will be enough water, of acceptable quality, to support the growing population of the Lower Rio Grande Border Region by 2030. However, this outcome can only be achieved with a significant reduction of agricultural water use. Market forces and partnerships between cities and irrigation districts can make this transition less controversial than might be the case otherwise. Stream flow requirements for a healthy river are not met today. They will decline further unless additional reductions in agricultural water use are agreed upon. In the wake of the NAFTA agreement, cooperation between Mexico and the United States on improving river quality has increased (TNRCC, 1994). Major results of improving water treatment infrastructure are already visible, and more treatment plants will come on line in the next few years.

4. Policy and management

The Rio Grande Border Region—both in the Paso del Norte and the Lower Rio Grande Valley—is already under water stress. No significant sources for increasing the volume of surface water exist. A plan to build a third dam in the Lower Rio Grande near the mouth of the river in Brownsville, Texas is controversial. The weir would provide 20,640 acre-ft of water for the City of Brownsville. At the same time, it would further reduce river flow to the estuary and possibly damage the habitat of shrimp and the livelihood of shrimp fishers. In Mexico, new reservoirs on the Río Conchos may be built, but would serve Mexican needs in that sub-basin. As growth in the region continues, water stress will get more severe, in particular during the periods of drought.

There is considerable concern among policy makers and community leaders about water quality, in particular concerning health. In contrast, except during droughts, there is little awareness that lack of water could constrain future growth. Water managers in Texas agree on the need for transferring agricultural water to municipal use. This is not the case in New Mexico, and controversial in Mexico. Whether this transfer will use market mechanisms, such as water markets, or regulation, and whether it will happen peacefully or because of political and social conflict, is uncertain.

The situation regarding the environmental degradation of the river is similar—a small number of informed observers are concerned, the public at large is not, nor are most public officials. There is also surprisingly little concern about the lack of institutional capacity to deal with water as a shared resource between Mexico and the United States.

Concern over reliable water supply has surfaced during an ongoing drought in Northern Mexico. As I pointed out earlier, the Lower Rio Grande depends on Conchos water, and, to a lesser extent, water from the Pecos River. Information on development plans in the Conchos sub-basin is sketchy. A useful preliminary overview was published by the Texas Center for Policy Studies (Kelly, 2001). An integrated assessment of water and development in the Río Conchos and the Pecos River is needed to establish more complete understanding of these sub-basins and their impacts downstream. For many years, the LRGV received more than the 350,000 acre-ft stipulated under the 1944 treaty. Starting in 1992, however, Mexico has run a deficit in meeting Treaty obligations. According to a story in the *Austin American Statesman* (April 2, 2000, p. A15) the highest deficit of 290,000 acre-ft occurred in 1995, and the total deficit amounts to 1.4 million acre-ft. The drought, as well as development in the Conchos basin, is cited as reasons for the short fall. Texas farmers have expressed their deep concern, at times accusing Mexico of hoarding water in the reservoirs on the Conchos. Mexican officials acknowledge the deficit but insist that their farmers are suffering as much as Texas farmers. They also seem to encounter internal conflicts between federal and state authorities in regulating Conchos reservoirs. Mexico and the United States worked out a timetable for repaying the Conchos water debt (IBWC/CILA Minute #307), but the most recent deadline for partial repayment (September 30, 2001) was not met.

Integrated assessments of the Conchos and Pecos sub-basins would analyze historical water flow and water diversions, plans for new water infrastructure, population growth, projected land use changes and development plans. While the Pecos does not attract large numbers of people, its waters are saline and may endanger agricultural irrigation. New development in the Conchos is intensive. Plans include logging, road construction and tourism. It is unknown what consequences these measures will have for runoff and erosion. The Conchos and Pecos studies should be conducted in parallel, using similar research methodologies and a joint bi-national steering group.

Agriculture uses 80–85 percent of available surface water. Urbanization, market forces and technological improvements will reduce the water needs of agriculture, thus making additional water available to cities and, perhaps, increased in-stream flow. Transfer of water from agriculture to cities is already under way because of market forces (Cummings & Nercessiantz, 1995; Gorriz, Subramanian & Simas, 1995; Hearne, 1988). Dramatic changes in land use are beginning to reduce agricultural demand. This trend will continue both in Texas and Mexico. Increases in irrigation efficiency will also free up water. Nonetheless, several concerns need to be addressed through study, outreach and policy:

- farmers and irrigation districts need to have access to *low-cost investment funds* to modernize their irrigation systems;
- cities need to *upgrade their distribution systems* to reduce waste and leakage;

- cities need to become more aggressive in developing *incentives for water conservation among municipal users*;
- irrigation districts and cities need to partner so that cities can help with up-grading irrigation systems and receive in exchange the water that is saved. Two irrigation districts in the LRGV have developed such city partnerships. More might be learned from evaluating the experience of Los Angeles and San Diego in collaborating with irrigation districts in California.
- Irrigation districts in Mexico are being decentralized. The experience to date needs to be evaluated. Limited information currently available paints a mixed picture: (1) success or failure seem to be directly related to conditions existing prior to decentralization, (2) reform did not automatically overcome old problems, and (3) decentralization of management has not resulted in concomitant reallocation of financial resources to the newly decentralized rural water management entities.

The LRGV has unlimited access to seawater and the Paso del Norte has untapped groundwater reserves. Seawater desalinization is expensive. Groundwater in the region is brackish and would need to be treated before it can be used. Again, cost has prevented this option from being used up to now. As a stand-by, however, both sea and groundwater will be of value for meeting future water needs. Water agencies should evaluate the cost of treating brackish ground water to the level required for irrigation. Better information, including comparative data from out-of-region water entities treating brackish water, is needed.

Water stress in the region can be alleviated by improving water institutions and strategies. Management improvements, rather than costly new water structures, hold the key for doing more with less. At present, surface water supply is managed jointly by Mexico and the United States through the IBWC. There are no institutions to plan basin-wide water demand, groundwater development and ecosystem restoration. A number of specific management improvements are needed. Some should be developed for the entire border region, others for the two sub-basins.

The IBWC should examine the operating rules for the combined Amistad–Falcón reservoirs and evaluate the option of using part of the flood pool for seasonal storage.

A drought management plan does not exist on either side of the border (Brown et al., 1993; Mumme, 1999). Dealing with drought, in Mexico as well as in Texas, is reactive rather than proactive. The Amistad–Falcón reservoir system is currently experiencing its most severe drought since completion of the system three decades ago. In 1996 the lowest reservoir levels recorded to date were measured. In Mexico, supplies to irrigation districts were stopped during several growing periods. The Rio Grande Water Master (Texas) urged rationing of water. This was not done, due to opposition of powerful irrigation districts. Consequently, several irrigation districts on the US side of the border ran out of water. Economic losses on both sides of the border have been high. A comprehensive analysis of impacts and remedial measures taken in Texas and Mexico would be a first step in developing a drought management plan. The experience of the National Drought Mitigation Center at the University of Nebraska would be helpful in developing the drought management plan. The US Drought Policy Report should provide significant guidance.

The water protection agencies in Texas, New Mexico and Mexico should develop guidelines for minimum required in-stream flow for the Paso del Norte and the Lower Rio Grande. The guidelines would consider the role of the river in diluting and dispersing waste loads, as well as arresting the intrusion of salt water from the Gulf of Mexico. A related concern is the need for minimum inflows to maintain riparian and floodplain ecological communities. Ecologists consider stream flows below 30 percent as undesirable. Stream flow in the Lower Rio Grande is below this standard. In the Upper Rio Grande it is below this standard during the winter.

The regional water planning entity for the LRGV has identified, as one of its management options, construction of a pipeline to move drinking water directly from Falcón reservoir to cities in the Lower Rio Grande Valley. The pipeline would bypass the river and further reduce in-stream flow in the river. As a first step, the Council suggests study of the issue. Such a study should carefully evaluate the ecological cost of further reductions of in-stream flow. And the costs of such engineering solutions be compared against the costs of less intrusive management solutions.

The report of the World Water Commission for the 21st Century, *A Water Secure* World: Vision for Water, Life, and the Environment (World Water Council, 2000) recommends two linked strategies for using water more efficiently: full cost pricing of water services combined with a new system of "water stamps" for the poor. Such measures require national debate and action before they can be fully implemented. However, partial steps can be taken within the region. Irrigation districts already charge for their services. An effort should be made to develop a more comprehensive system of water fees charged by irrigation districts.

An assessment of the likely impact of climate change and variability on water supply in the Lower Rio Grande Border Region should be undertaken (Schmandt & Ward, 1993; Ward & Valdés, 1995). At present, water managers on the border do not consider global warming as a potential risk factor. They argue that available information is not region specific and controversial. However, the upper basin is entirely dependent on snowmelt. Enough information has been accumulated over the last decade to conduct a study of the likely impacts of both global warming and the El Nino/La Nina oscillation on the region. Better information on the frequency of droughts as well as changes in volume and seasonality of snowmelt in the Rocky Mountains is particularly needed.

The single most important concern for the water future of the Rio Grande Border region is directly related to its political diversity. Water planning is now done, where it is done at all, at the city or multi-county level. It must be organized at the level of each sub-basin, will full Mexican and US participation. Without improved joint fact-finding and planning across national and state borders, the border region will face a water emergency and see its growth seriously constrained.

In Texas, new legislation has created regional water planning entities with membership of all interested parties. The Far West Texas Water Planning Group in the Paso del Norte and the Regional Water Planning Group in the LRGV are making progress in developing water plans for their sub-basins. All stakeholders participate, and the Texas Water Development Board provides guidance and support. Yet planning does not include the non-Texas entities (New Mexico and Mexico) that depend on the same sources of water. While officials from Mexico and New Mexico are invited to attend meetings of the regional planning groups as observers, they do not participate in decisions nor are their data considered in detail. In Mexico, a Consejo de Cuenca for the entire Rio Bravo basin (including the upstream area around Cd. Juárez) has been created. At this point, the Council is short of resources, and has not been able to engage in water planning.

5. A radical proposal

What has been discussed so far are partial reforms: more is needed. The time is ripe to upgrade the existing structure for bi-national water management. The 1944 Treaty between Mexico and the United States provides a foundation on which the two countries can build. The proposed reforms will complement the existing river management approach, designed and implemented by professional engineers, with integrated science-based basin management, designed and implemented by teams of experts and stakeholders. Several policy innovations can guide the reforms.

The United States–Canada International Joint Commission was created using an organizational structure similar to the IBWC. A treaty concluded in 1912 gave the Commission the task of improving navigation in the Great Lakes. Over the course of the last 30 years, additions to the treaty allowed the Commission to address new problems as they arose—cleaning up pollution in the Great Lakes, improving air quality in the border region, and managing 13 border waterways with the help of science advisory boards. The new programs changed the Commission fundamentally. Today it works intimately with groups of experts and residents of border communities in planning and implementing its programs.

France has pioneered participatory basin management. In the 1960s, the country was divided into five large basins, each with its own basin parliament and financing instruments. In the 1990s, participatory sub-basin councils were created, each responsible for developing water development plans for its region. The European Union used this approach to adopt a decree on integrated basin management that is now being implemented throughout Europe. Using these models, the governments of Mexico and the United States should consider the following reforms in the Rio Grande basin:

The International Boundary and Water Commission/Comisión Internacional de Limites y Agua (IBWC/CILA) will be expanded to become a model organization for international basin management. In addition to its current functions—river water allocation, reservoir management and flood control—the Commission will develop a new basin management program that is based on the principles of sustainability, equity and participation. All aspects of the initiative will be developed jointly by Mexico and the United States. Specifically, the following steps would be taken:

- IBWC/CILA will convene a bi-national *Rio Grande/Río Bravo Basin Council.* The Council will address two tasks: (1) developing and updating a basin-wide water plan, and (2) designing water improvement projects. Membership of the Council will include representatives of bi-national agencies, federal and state water agencies, communities and NGOs, representatives of regional water committees and experts.
- The Council will establish a *Scientific Advisory Committee* for conducting or overseeing research studies and policy analyses required for sound basin management.
- In each of four distinct hydrological sub-basins—Paso del Norte, the Conchos-Pecos Reach, the International Reservoirs Reach, and the Lower Rio Grande Valley— *Bi-National Regional Water Task Forces* will be established. This serves two purposes: (1) it recognizes the diversity of hydrological and economic conditions in each sub-basin, and (2) it provides the opportunity for meaningful participation of local water managers, water users, and communities. The Task

Forces will be organized as independent non-governmental organizations that work closely with the Basin Council. The Task Forces will be responsible for: (1) preparing and updating a regional water plan, and (2) designing regional water improvement projects. Committee members will include urban and agricultural water managers, communities and NGOs, and experts. The experience of the Paso del Norte Water Task Force provides a useful model.

- CILA and IBWC will each appoint a *second commissioner* who will be responsible for integrated basin management. The new commissioners will co-chair the Rio Grande/Río Bravo Basin Council. CILA and IBWC will set up a joint staff unit to implement integrated basin management. The unit will have the capacity to conduct or contract for studies.
- Two ad hoc Committees will be set up to address urgent issues: drought management and groundwater management. The committees will submit recommendations within 12 months. The recommendations on groundwater management must take into account the different legal regimes for groundwater in parts of the Rio Grande basin.
- Action and project recommendations resulting from the above initiatives will be submitted to the other bi-national organizations in the basin. The Border Environment Cooperation Commission (BECC) will provide review and comment, particularly with regard to the sustainability of proposed improvements. The North American Development Bank (NADBank) will decide on funding.

Bi-national discussions considering these and similar recommendations are currently underway. The clock is ticking. Only time will tell if meaningful reforms will be adopted and achieve the goal of ensuring water security for the threatened border region.

References

Acosta Ramirez, E. (1997). *Impacto de la Sequía en la Producción Agropecuaria y Forestal en el Estado de Tamaulipas*, Ciudad Victoria, Tamps, Delegación Estatal de la Comisión Nacional de Zonas Aridas, Internal document.

Aguilar, B. I. (1993). Economía Regional Transfronteriza: Consideraciones en torno a la integración Méxicoestados unidos. *Estrategia*, *1*(2), 2–8.

Aguilar Barajas, I. (1995). Monterrey: Formas de integración a la economía del sur de los Estados unidos. *Comercio Exterior*, *45*(5), 409–415.

Aguilar Barajas, I. (1999). Interregional transfer of water in Northeastern Mexico: The dispute over El Cuchillo. *Natural Resources Journal*, *39*(1), 65–98.

Center for Environmental Resource Management, (1998). *An economic development strategy for the sustainable use of water in the Paso del Norte Region*. University of Texas at El Paso.

Army Corps of Engineers (1992). Design and cost estimate report addressing international boundary and water commission sanitation issues: The United States and Mexico, prepared for US Section, IBWC, Fort Worth, TX, September.

Brown, R., et al. (1993). *Climate change adaptation: Drought contingency planning in Texas*. Austin, TX: Texas Water Development Board.

Contreras-Balderas (1999). Annotated checklist of introduced invasive fishes in Mexico, with examples of some recent introductions. In R. Claudi, & J. H. Leach (Eds.), *Nonindigenous freshwater organisms: Vectors, biology, and impacts* (pp. 31–52). Boca Raton, London, New York, Washington: Lewis (Chap. 2).

Cummings, R., & Nercessiantz, V. (1995). The use of water pricing to enhance water use efficiency in irrigation: Case studies from Mexico and the United States. In Guy Le Moigne, et al. (Eds.), *Water policy and water markets*. World Bank Technical Paper Number 249. The World Bank, Washington, D.C.

Department of the Interior (1995). Lower Rio Grande Basin study, Texas: Summary of water resources, ecological resources, and socioeconomic conditions. US Department of the Interior, Bureau of Reclamation, Austin, TX, December 1995.

Eaten, D. J., & Hurlbut, D. (1992). Challenges in the binational management of water resources in the Rio Grande/Río Bravo. Austin, US–Mexican Policy Studies Program, Policy Report No. 2.

Gorriz, C. M., Subramanian, A., Simas, J. (1995). Irrigation management transfer in Mexico: Process and progress. World Bank Technical Paper Number 292.

Hearne, R. R. (1998). Opportunities and constraints to improved water markets in Mexico. In Easter, A. W. (Ed.), *Markets for water: Potential and performance*. Boston: Kluwer.

Herzog, L. A. (1990). *Where north meets south: Cities, space, and politics on the US–Mexico border*. Austin: Center for Mexican American Studies, University of Texas.

Hibbs, B. J., et al., (1997). Transboundary Aquifers of the El Paso/Ciudad Juárez/Las Cruces Region: *Joint report of the Texas Water Development Board and New Mexico Water Resources Research Institute*. Austin, TX: Texas Water Development Board.

International Boundary and Water Commission (1993). Flow of the Rio Grande and related data. Water Bulletin No. 63, IBWC, El Paso (published annually under same title).

Jahrsdoerfer, S. E., & Leslie Jr., D. M. (1988). Tamaulipan brushland of the Lower Rio Grande Valley of South Texas: Description, human impacts, and management option. iological Report 88(36), US Fish and Wildlife Service.

Kelly, M. E. (2001). *The Río Conchos: A preliminary overview*. Austin, TX.

Managing North American Transboundary Water Resources (1993). *Natural Resources Journal* parts 1 and 2, *33*.

Mathis, M. (1999). Using new approaches to environmental decision-making: An application of integrated assessment methods to water resource issues in the Binational Lower Rio Grande Basin. *Policy Studies Review*, *16*(3/4), 138–167.

Mumme, S. (1999). Managing acute water scarcity on the US–Mexico border institutional issues raised by the 1990s drought. *Natural Resources Journal*, *39*(1), 149–166.

Paso del Norte Water Task Force (2001). Water planning in the Paso del Norte: Toward regional coordination. Available in English and Spanish at www.sharedwater.org.

Schmandt, J., Aguilera-Barajas, I., Mathis, M., Armstrong, N., Chapa-Almena, L., Contreras-Balderas, S., Edwards, R., Hazleton, J., Navar-Chaidez, J., Vogel, E., & Ward, G. (2000). Water and sustainable development in the binational Lower Rio Grande/Río Bravo Basin. Final Report to EPA/NSF Water and Watersheds grant program (Grant No. R 824799-01-0), Houston Advanced Research Center, The Woodlands, TX.

Schmandt, J., Stolp, C., & Ward, G. (1998). *Scarce water: Doing more with less in the Lower Rio Grande*. US-Mexican Policy Report No. 8. Austin, TX: Lyndon B. Johnson School of Public Affairs.

Schmandt, J., Stolp, C., & Rhodes, L. (1999). *Navigating the waters of the Paso del Norte: A people's guide*. US-Mexican Special Publication. Austin, TX: Lyndon B. Johnson School of Public Affairs.

Schmandt, J., & Ward, G. (1993). Climate change and water resources in Texas. In T. M. Valentine, E. Z. Stacie, & J. B. Smith (Eds.), *Proceedings of the First National Conference on Climate Change and Water Resources Management*. Institute for Water Resources, US Army Corps of Engineers.

Sepulveda, C., & Utton, A. E. (Eds.) (1984). *The US–Mexico border region: Anticipating resource needs and issues to the year 2000*. El Paso, TX: Texas Western Press.

Szekely, A. (1991). Establishing a region for ecological cooperation in North America. Albuquerque, NM: University of New Mexico Press.

Texas Water Development Board (1997, 2001). *Water for Texas*. Austin, TX (this state water plan is updated every four years).

Texas Water Development Board and New Mexico Water Resources Research Institute (1997). *Transboundary aquifers of the El Paso/Ciudad Juarez/Las Cruces Region*.

TNRCC (1994). Regional assessment of water quality in the Rio Grande Basin: Including the Pecos River, the Devils River, the Arroyo Colorado and the Lower Laguna Madre. Watershed Management Division, Austin, TX.

US Department of State (1946). *Utilization of waters of the Colorado and Tijuana Rivers and of the Rio Grande.* Treaty Series 994, Treaty between the United States of America and Mexico. Washington, DC: Government Printing Office.

Utton, A. (1999). Coping with drought on an international river under stress: The case of the Río Grande/Río Bravo. *Natural Resources Journal, 39*(1), 27–34.

Ward, G. H., & Valdés, J. B. (1995). Water resources. In G. R. North, J. Schmandt, & J. Clarkson (Eds.), *The impact of global warming on Texas: Report of the task force on climate change in Texas.* Austin: University of Texas Press.