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.

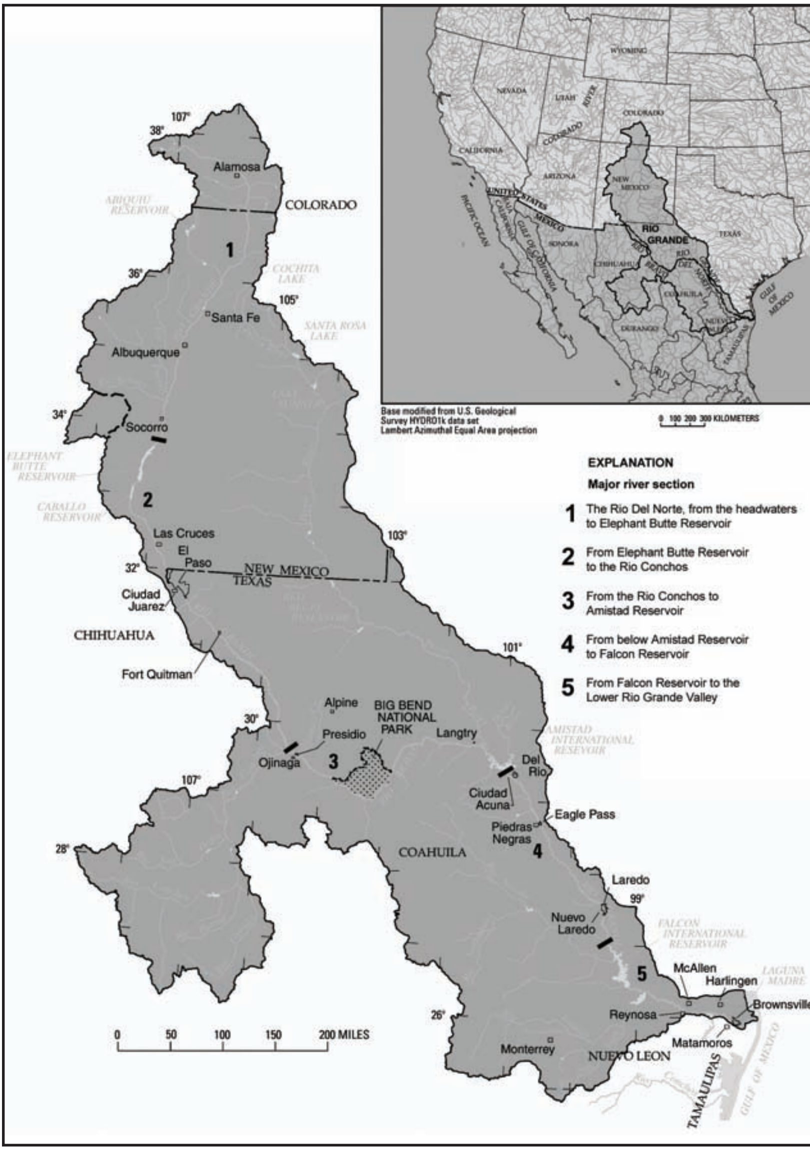

Figure 1. The five major river sections of the Rio Grande-Rio Bravo watershed.

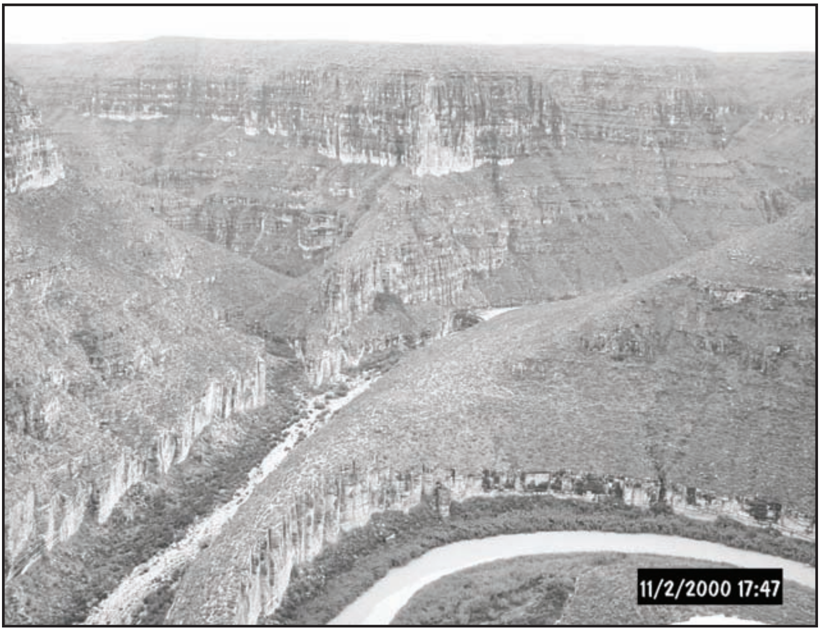

Figure 2. Aerial photograph of the Rio Grande Wild and Scenic River near Big Bend National Park.

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

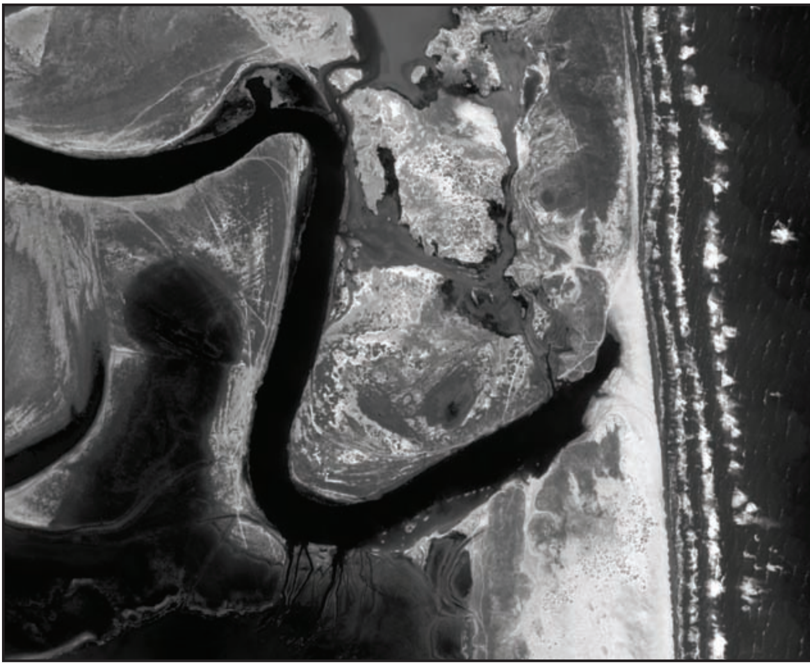

Figure 4. A high resolution SPOT satellite image taken May 2, 2002, showing the sandbar sedimentation blocking the flow of the Rio Grande-Rio Bravo into the Gulf of Mexico (courtesy of University of Texas, Center for Space Research).

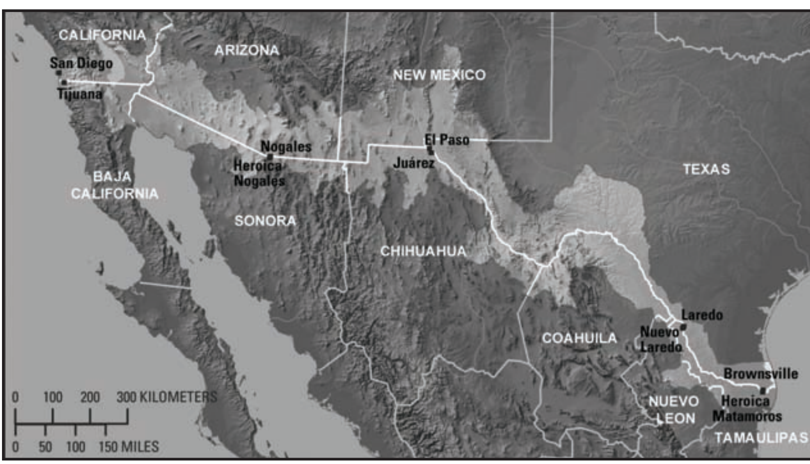

Figure 5. The major watersheds along the U.S.-Mexico border compose the current project area for the U.S.-Mexico Border Geographic Information System.