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Restoration of an International River Basin

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ABSTRACT

The Rio Grande River flows from its headwaters in southern Colorado, south through New Mexico, turning southeast at El Paso, Texas, where it becomes the international boundary between the United States and Mexico until it drains into the Gulf of Mexico. The Rio Grande is a "National Historic River." The Rio Grande is managed according to interstate and international agreements that apportion its water through the operation of reservoirs and diversion systems. Downstream of Elephant Butte Reservoir, New Mexico the waters of the Rio Grande are used primarily by irrigators on both sides of the border. The City of El Paso, however, under contractual agreements with the local irrigation districts treats Rio Grande water to supplement the city's drinking water supply. This paper provides an overview of the hydrologic challenges of making the Rio Grande "wet" once again through the El Paso-Ciudad Juarez region on the U.S.-Mexico border.

Currently water is released downstream only during the irrigation season, which during normal-flow years extends from late February to early October. Every aspect of water delivery in the stretch of the Rio Grande from Elephant Butte Reservoir and El Paso, Texas is managed through the use of engineering structures that divert water for irrigation or municipal uses. In the past 100 years, the response to declining flow within the actual river has turned a once meandering stream to an efficient conveyance channel. The historical water flow and water quality data recorded at various gauging locations downstream of the Elephant Reservoir to Fort Quitman, Texas are reviewed and analyzed to determine the impacts and structure of the existing delivery system. Key issues discussed include the implications to the efficiency of water delivery, flood control, sedimentation buildup in the river channel, and water quality. An extensive literature review of hydrological data, field visits, and interviews with local stakeholders is being conducted to evaluate the current structure. The main objective of this work is the development and assessment of scenarios that would allow the river to remain "wet" through the year in the El Paso, Texas and Ciudad Juarez, Mexico portion of the Rio Grande while minimizing the impact to the existing water delivery structure. A review and analysis of hydrological data will help to demonstrate potential long-term consequences of water development in other rivers.

Introduction

The Rio Grande extends from its headwaters in the San Juan Mountains in southern Colorado, flowing south through New Mexico, turning southeast when it reaches El Paso, Texas, where the river becomes the international border between the United States and Mexico, until it drains into the Gulf of Mexico. Although the Rio Grande is known in Mexico as the 'Río Bravo', which translates to wild river, the Rio Grande is one of the most heavily regulated, controlled, and managed rivers in America. International and interstate agreements dictate water use along the river. Every aspect of water delivery is managed through the use of engineering structures that divert water for predominantly irrigation uses. It is not uncommon for segments of the Rio Grande go dry during the non-irrigation season. In the past 100 years, the response to declining flow within the actual river has turned a once meandering stream to an efficient conveyance channel.

This paper provides an overview of the hydrologic challenges of making the Rio Grande "wet" once again through the El Paso, Texas and Ciudad Juarez, Chihuahua region on the U.S.-Mexico border. Currently, local irrigation districts use the bulk of the water from the Rio Grande that is stored upstream in Elephant Butte Reservoir and released only during irrigation season which lasts from late February, early March to September or early October. Communities in the region have to rely on ground water resources that are rapidly being depleted. Only El Paso, which has entered into contract agreements with a local irrigation district, uses water from the Rio Grande. The surface water in the region is regulated by international, interstate, and local agreements that dictate water use along the river.

The current hydrological structure of the Rio Grande provides flood control, reduction in losses due to bed seepage and surface evaporation, maintains the channel as the international boundary, and provides a more equitable distribution of water between the U.S. and Mexico as described in ratified legal treaties. However, sufficient water for non-irrigation or municipal usage is not available under the current system. In a river system where the water has already been assigned a pre-designated owner and usage, restoration effort in the El Paso-Ciudad Juarez region must look either to work within the existing hydrological and legal structure or evaluate the potential changes needed to the existing structure to allow the Rio Grande to flow once again.

Description of Area

The Rio Grande Basin is located in the southwestern United States. It drainage basin covers two nations, three states (Colorado, New Mexico, and Texas) on the United States side and four Mexican states (Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas). Two regions with their own distinct flow regimes and water quality define the Rio Grande Basin. The Upper Rio Grande Basin is composed of the relatively cool and wet mountainous regions of Colorado and northern New Mexico that feed the narrow irrigation valleys in the central New Mexico and semi-arid valleys of southern New Mexico and far West Texas as far downstream as Fort Quitman, Texas which is approximately 145 kilometers downstream of El Paso, Texas. The Lower Rio Grande Basin is the remaining portion of the drainage basin that is feed primarily by the Rio Conchos from Mexico and the Pecos River flowing south from eastern New Mexico. The focus of this study is the region of the river basin in southern New Mexico and west Texas just as the Rio Grande becomes the international boundary. The Rio Grande Basin is shown in Figure 1.

Southern New Mexico and west Texas is a semi-arid region with low annual precipitation, low humidity, high temperatures, and persistent winds during spring. Because of the scarcity and seasonal variability in precipitation, agriculture throughout the region relies on irrigation primarily from the Rio. The region consists of river valleys with adjoining desert terrain boxed in by mountains formations that occasionally create bottlenecks that reduce the floodplain width and confines the river's flow. All irrigable land in this area falls under the management of the Rio Grande Project.

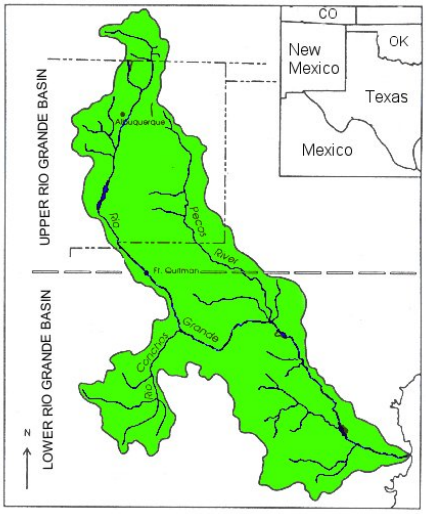

Figure 1. Rio Grande Basin (Adapted from Stone, 1991)

The Rio Grande Project furnishes irrigation water to southern New Mexico and west Texas. The Rio Grande Project is composed of Elephant Butte and Caballo Dams, 6 diversion dams, canals, laterals, drains, and a hydroelectric power plant. The Rio Grande Project is shown in Figure 2. Elephant Butte Reservoir and Dam is the primary water storage facility for the Rio Grande Project with a capacity of just over 2 million acre-feet (2,467 million cubic meters). Elephant Butte Reservoirs also stores water that is diverted by the U.S. Section of the International Boundary and Water Commission (IBWC) to fulfill the 1906 Water Treaty with Mexico. Elephant Butte Dam is located 201 kilometers north of El Paso, Texas. Elephant Butte Dam releases water during the irrigation season that begins in late February-early March to late September-early October. Water released from Elephant Butte Reservoir flows into Caballo Reservoir. Caballo Dam is located 32 kilometers downstream of Elephant Butte Dam and provides flood control for the Rio Grande Project. Downstream of Caballo Dam, the waters of the Rio Grande are diverted by a six diversion dams. Percha, Leasburg, and Mesilla dams divert water in southern New Mexico for use by the to the Elephant Butte Irrigation District (EBID). A portion of the water diverted through the Mesilla Dam, located 64 kilometers north of El Paso, Texas feeds land under management of the El Paso County Water Improvement District No. 1 (EPCWID No. 1). Irrigation water is returned back into the river upstream of the El Paso gauging station at Courchesne Bridge, located 8.9 kilometers north of downtown El Paso. American Dam located 2.7 kilometers downstream of the El Paso gauging station diverts practically all the water that is not allocated to Mexico under the 1906 Water Treaty into the American Canal. The water diverted into at American Dam travels parallel to the Rio Grande to the Riverside Canal heading, 24 kilometers south of downtown El Paso, where Riverside Dam used to divert water from the Rio Grande into Riverside Canal. Riverside Dam is no longer in operation; it was removed in 2003. Water passing through the American Dam flows toward International Dam where Mexico's allotment, under the 1906 Water Treaty, is withdrawn into the Acequia Madre that feeds the Juarez Valley. Beyond the International Dam, the Rio Grande is only feed through irrigation returns south of El Paso, wastewater discharges, and to lesser extent runoff.

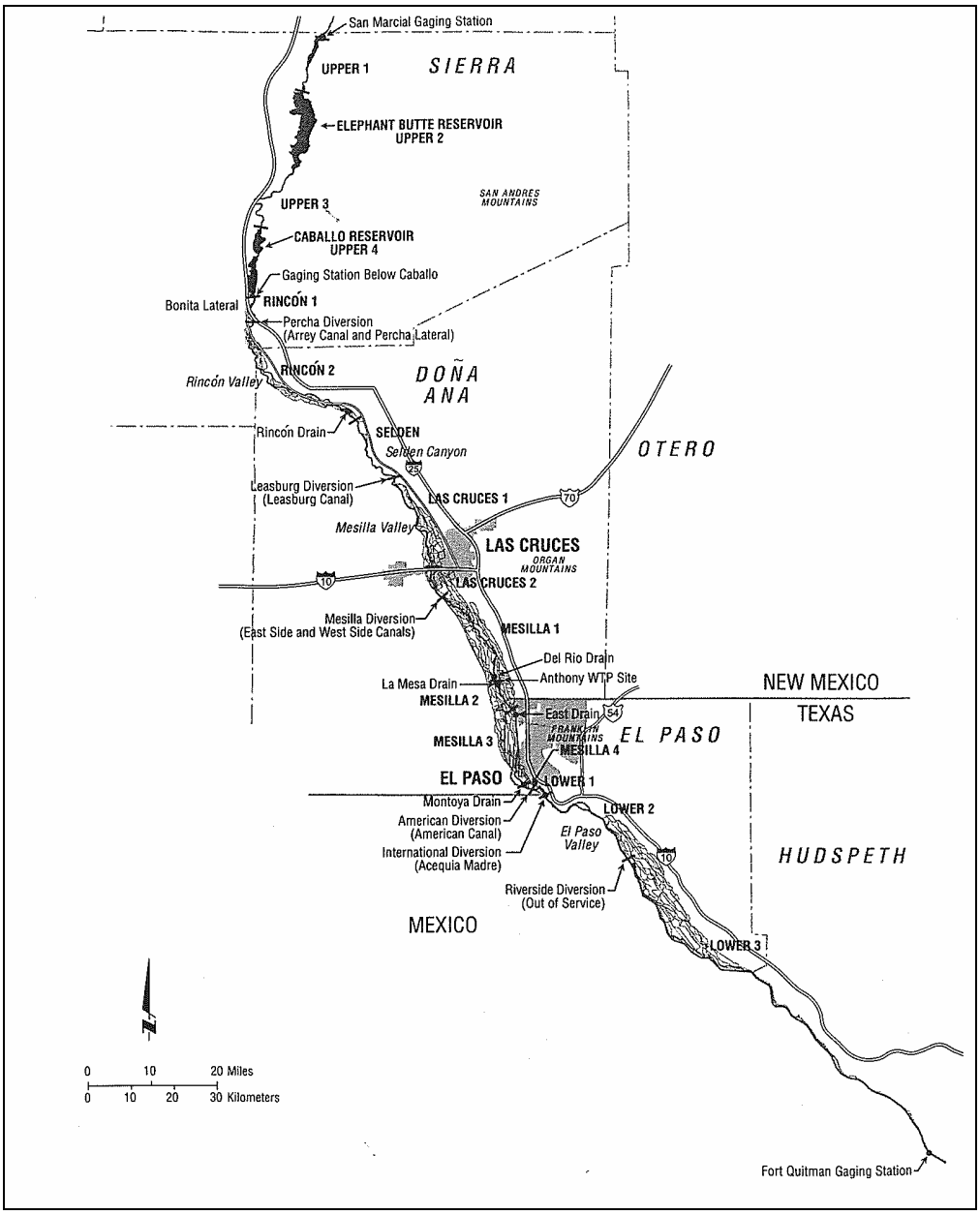

Figure 2. The Rio Grande Project (Image courtesy of Jahagirdar)

Historical Background

The increased development and construction of diversion structures during the late 1880's and 1890's as far upstream as Colorado contributed to the reduced-flows in the Upper Rio Grande Basin. Two major treaties eased the water dispute in the basin and changing the hydrology of the Rio Grande: the Rio Grande Compact and the 1906 Water Treaty. The Rio Grande Compact, which was approved by the U.S. Congress in 1938, is an interstate agreement between the states of Colorado, New Mexico and Texas. The Compact apportions the waters of the Rio Grande from its headwaters in Colorado to Fort Quitman, Texas to assure equal distribution of the water to each state. Each upstream state must deliver the appropriate amount of water to its downstream state. In the case of Texas, the state receives a percentage of the

amount of water passing at Otowi, New Mexico. The percentage of water is the amount of water that must flow downstream of San Marcial, New Mexico located at the head of Elephant Butte Reservoir. Under the Compact, Texas is considered to be the area below Elephant Butte Reservoir, and thus includes both southern New Mexico and west Texas (Rio Grande Compact Commission 2001

The El Paso - Ciudad Juarez Valley suffered from water shortages and floods at the end of the nineteenth century and start of the twentieth century. Mexico filed a formal complain to the State Department concerning the water shortages (Clark 1975). The Convention of 1906 (the 1906 Water Treaty) allocated 60,000 acre-feet (74 million cubic meters) of water to be delivered to the head of the Acequia Madre in Juarez. In part to fulfill its obligations under the 1906 Water Treaty that, the U.S. federal government took over construction of the Elephant Butte Dam being construct near present day Truth and Consequences, New Mexico in 1908 but construction was delayed and the dam was not completed until 1916 (Mueller 1975). Elephant Butte was part of the Rio Grande project that had been authorized by Congress in 1905, under provisions of the Reclamation Act, to provide irrigation water to southern New Mexico and west Texas (U.S Bureau of Reclamation 2005). The constructions of a network of diversion dams and canals soon followed.

Water stored in Elephant Butte is allocated to the irrigation districts of EBID in southern New Mexico, EPCWID No. 1 in west Texas, and Mexico in order to comply with the 1906 Water Treaty. Both irrigation districts in the United States are political entities responsible for operation and maintenance of their corresponding irrigation districts. The water delivered annually to Mexico is for irrigation purposes by the Distrito de Riego 009 located in the Juarez Valley. In order to meet their irrigation needs, farmers in the Juarez Valley supplement water obtained from the Rio Grande with untreated and treated wastewater (black water) from Ciudad Juarez and with pumped ground water (Vazquez-Montiel et al. 1999). Starting in the 1940s, the city of El Paso has supplemented its municipal and industrial water needs through a combination of ground water from two aquifers and waters from the Rio Grande obtained under contractual agreement with the EPCWID No. 1 (El Paso County Water Improvement District No. 1 2000). All remaining communities in the region rely on ground water.

The international boundary had been established as the Rio Grande. But continued flooding caused the Rio Grande to shift or abandon its channel causing parcels of land to become detached from one nation and attached to the other. Several treaties and projects followed to deal with the meandering river. Under the Rio Grande Rectification Treaty of 1933 the river channel was straightened. As part of flood control measures and efforts to reduce sediment, Caballo Dam was constructed in 1936-38 to regulate water releases from Elephant Butte Dam. The signing of the Chamizal Treaty in 1963 settled the dispute regarding Cordova Island, which had been a source of tension between both Mexico and the United States. The resolution established the international boundary, as it exists today, and cleared the way to upgrading the water delivery to irrigators on the American side, which had previously had to divert water at the Riverside Dam (Mueller 1975). In an attempt to improve water delivery efficiency and provide the correct amount of water to both the United States and Mexico, the American Dam diverts all United States water from the bed of the Rio Grande; providing sufficient water downstream to comply with the 1906 Water Treaty. As part of improvements to water delivery Congress passed the Rio Grande American Canal Extension Act of 1990 (Public Law 1101-438). The act recognized that building a permanent structure in an international reach to replace a rockfill dam that was constructed when Riverside Dam failed in June 9, 1987 would allow Mexico to divert

water for its own uses. The construction and operation of an extension of the American Canal that would deliver water from American Dam south to Riverside Canal, which had previously received its water by diverting at Riverside Dam, would lie entirely on the American side running parallel to the mostly dry bed that used to be the Rio Grande until the river is feed through irrigation returns, wastewaters flows from Mexico, and to lesser extent storm runoff south of El Paso.

Methodology

Data analysis was performed using mean-daily flow data downloaded from the IBWC web site (http://www.ibwc.state.gov/). The mean-daily flows were summed up to calculate the total annual flow and total flow for a water year. The total annual flow was calculated by summing up the mean-daily flow from January 1st to December 31st of each given in year for a period of record from 1889 to 2003 at the El Paso gauging station (note: data was not available for the years 1894 to 1896). The total annual flow was calculated to expand the period of record at the El Paso gauging station, plot the hydrograph showing mean-daily flow, and to evaluate the changes each structure contributed to the stream flow observed in the river. Some information is presented according to a pre-defined hydrological period. The hydrological periods are separated according to the construction of major engineering structures (Elephant Butte Dam and Caballo Dam) on the Rio Grande upstream of El Paso.

The total water year flow for each year from 1938 to 2003 for the El Paso gauging station and releases from Caballo Dam was calculated by summing the mean-daily flows in cubic meter/day for a period starting on March 1st and ending on the last day of February of the following year. A water year is used to account for all the releases upstream during irrigation and during non-irrigation season combined with any return flows that are passing the El Paso gauging station during each water year. Water year data was used to observe the impact due to rectification and canalization, irrigation, and the legal treaties and engineering projects after 1938. Informational plots of the Rio Grande were generated for both the total annual flows and the total water year flow.

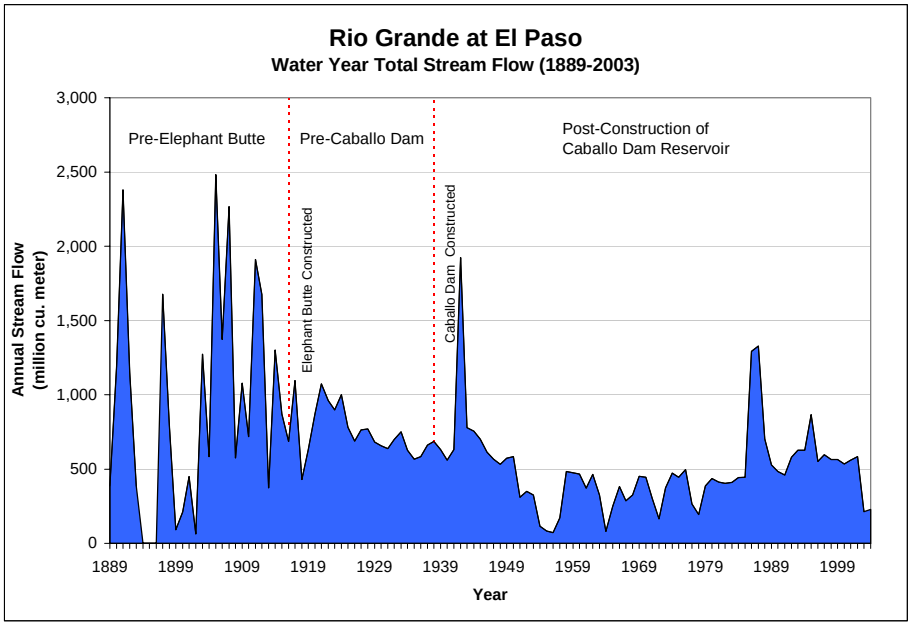

Figure 3. Total Annual Flow at El Paso (Data source: IBWC)

Discussions

A hydrograph showing the total annual flow passing the El Paso gauging station for the period of record is shown in Figure 3. The stream flow of the Rio Grande as gauged at the El Paso station is defined by three hydrological periods. The periods are divided according to the construction date of the two major engineering structures on the river, Elephant Butte and Caballo dams. Construction of Elephant Butte Dam was completed in 1916. Prior to Elephant Butte Dam, the Rio Grande was plagued by a series of floods and droughts. Flooding during this period cause scouring on one riverbank while deposition occurred on the other riverbank causing a shift to the international boundary line between the United States and Mexico. Droughts would cause water shortages. Elephant Butte Dam was constructed to regulate flow and store water.

During period defined as "Pre-Caballo Dam" (1916-1938), the period after Elephant Dam was constructed and before Caballo Dam was built, the water being released had a more uniform pattern that decrease slightly year to year. Elephant Butte Dam helped control stream flow variability and unpredictability. Prior to completion of Elephant Butte Dam (for the period of record from 1889 to 1915) total annual flows exceeded 1000 million cubic meters seventeen times while occurring only five times after Elephant Butte Dam was built (1916 to 2003). The reduced flow caused the channel to change its morphology. The Rio Grande's channel was unable to cope during period of flooding as the water overflowed the riverbanks. The discharge from Elephant Butte Dam would scour the channel's bed causing problems further downstream where the stream flows were not sufficient to carry the sediment load.

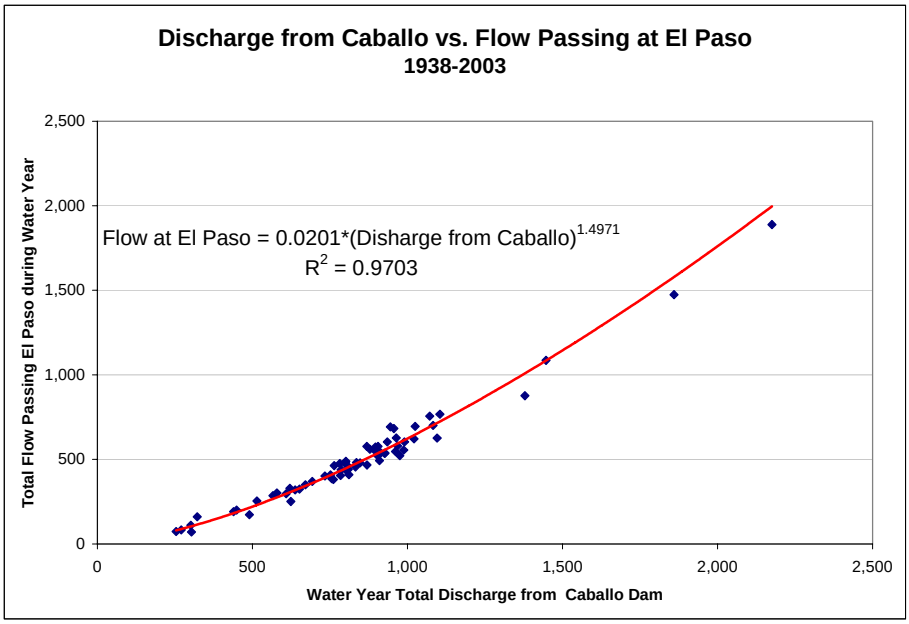

Figure 4. Release from Caballo versus the Flow Passing El Paso (Data Source: IBWC)

Caballo Dam was constructed in 1938 as part of rectification and canalization project undertaken after the Rectification Treaty of 1933, which straighten out the channel. The period "Post-Construction of Caballo Dam Reservoir" is the period from 1938 to 2003. The flow pattern during this period is deceiving because the Rio Grande stream flow has fluctuated between high flow years and low-flow years. The impact of the stream flow is due to climatic conditions further upstream in the Upper Rio Grande Basin. However, comparing the discharge from Caballo Dam versus the flow passing the El Paso gauging station during a water year for

the period of record, presented in Figure 4, shows that rectification and canalization has produced an efficient and near predictable water delivery system. Additional stream inflows such a storm runoff, groundwater pumpage, or discharges were considered minimal for a period of a water year. Losses from Caballo Dam to El Paso, predominantly due to irrigation, show that an increase in flow resulted in a decrease in the theoretical percentage losses. During low-flow years the losses were as high as 70 %while during high-flow years the theoretical losses were as low as 10 % to 20 %. This is primarily due to the physically capacity of the irrigable land. Under legal agreement, the irrigation districts are only allocated a specified amount of irrigation water. Figure 5 shows a comparison between the total annual releases from Caballo Dam versus the total annual withdrawals from the major diversion structures upstream of El Paso, Texas. The irrigation districts tend to divert the full allocation of irrigation water from the Rio Grande each year, except during years of extremely low flow when farmers supplement using ground water. The decrease trend in percentage losses from Caballo to El Paso is due to the capacity of water withdrawals: during high-flow years more water is allowed to remain in the river.

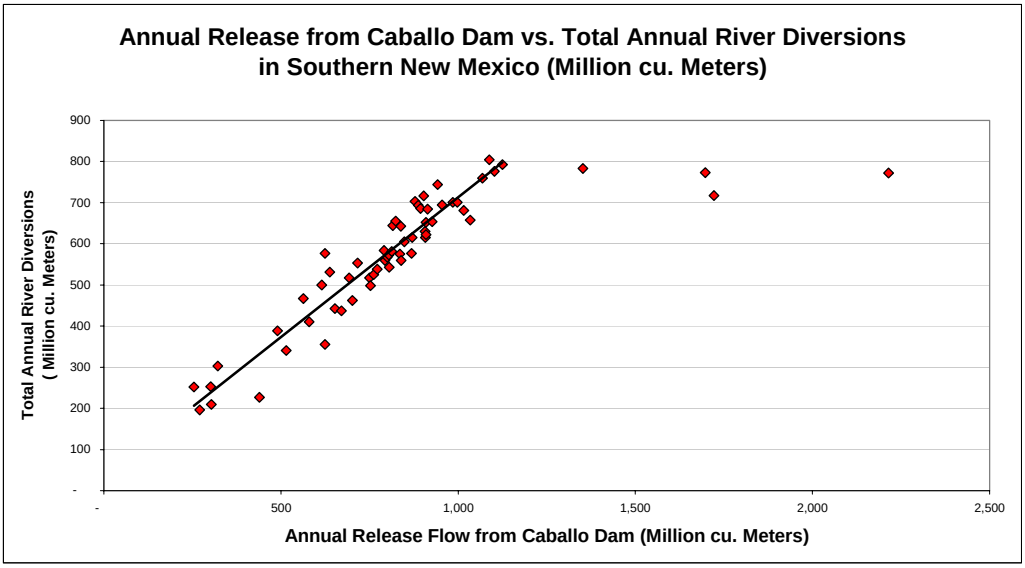

Figure 5. Release from Caballo Dam versus Withdrawals (Data soure: author)

The Rio Grande Project has transformed the meandering river into an efficient delivery network. It is an important aspect to consider when evaluating potential restoration projects in the El Paso-Juarez Valley. The first step during a restoration project is to establish the goals of restoration and the desired outcome. The Rio Grande has not had an unregulated stream flow for over 90 years. It would be impossible to return the river back to this unregulated period because of changes to the channel's morphology, international boundary issues, flood-control considerations, and economic impact to the region. The restoration project must either work within the existing hydrological and legal structure or evaluate the potential changes needed to the existing structure to allow the Rio Grande to remain "wet" through the year in the El Paso, Texas and Ciudad Juarez, Mexico. Both are discussed briefly here.

Restoration efforts working within the hydrological and legal structure is best suited when dealing with restoring a segment of the river upstream or downstream of El Paso, Texas. Restoring a segment upstream of El Paso would be dependent on the availability of water.

Sufficient stream flow would be required for both restoration and to meet the water delivery obligations of the 1906 Water Treaty. A study focusing on restoring a segment of the Rio Grande far downstream of El Paso after the river is replenished with irrigation returns and wastewater is warranted. However, the water quality in the Rio Grande would be questionable and possibly not suited for wildlife and vegetation. Restoring a segment of the Rio Grande would probably not be an international effort because the available water would flow on the American side. Segment restoration would probably not be suited in the portion of the Rio Grande that forms the international boundary, because under the American Canal Extension Act, the water flow would be on the American side and restoration efforts would not be on the Rio Grande but run parallel to a dry riverbed.

The existing hydrologic network, on the other hand, is an efficient water delivery system. Past upgrades have improved water delivery. The practice of lining canals and drains to reduce seepage losses would allow more water to flow downstream. A storage basin or wetland could be used to capture winter runoff or irrigation returns that would allow the Rio Grande to stay "wet" throughout the year by retarding the flow downstream. However, this poses a problem. The water saved through engineering measures would improve and to a certain degree assure water delivery to the segment of the river being restored but at a cost to an upstream stretch of the river.

Another more radical approach is to change the existing hydrological and institutional structure of the Rio Grande. There are two primary reasons why this alternative might not be viable. First, modification of the main structures on the Rio Grande may prove counter productive. Removal of Elephant Butte Dam would restore the Rio Grande to the unpredictable and variable stream flow pattern that caused problems at the turn of the twentieth century. Caballo Dam was built for flood control and to reduce sediment problems in the river. Rectification and canalization helped improve the water delivery efficiency of the Rio Grande. This water delivery efficiency would not be maintained if the Rio Grande was allowed to meander and its banks covered by vegetation. A solution upstream might create environmental and economic impacts downstream.

Second, it is likely that water being diverted currently for irrigation purposes would shift to municipal uses rather than to direct restoration applications. The increasing drinking water demand in the El Paso-Ciudad Juarez region would play a major role in addition to the require approval from the United States and Mexican governments, the allocation of resources between the two countries, and flood-control issues. One possible solution is water markets. By purchasing water rights and then entering into agreements with local water institutions to allow usage of that water in return for an equivalent amount that would be delivered elsewhere. The problem is that water quality of the equivalent amount of water may not be of the same quality as the original water. Additional issues include costs associated with purchasing the water rights, determining the legal owner, and the proper usage for the purchased water. The characteristic of the Rio Grande has been transformed over the past one hundred years and modifying the existing hydrological and legal structure requires detailed understanding of the Rio Grande's past and present stream flow conditions.

Conclusions

Rectification and canalization of the Rio Grande has produced a managed and efficient river that does not reflect the pre-developed river basin. While the large reservoirs have turned the El Paso-Ciudad Juarez region into prosperous agricultural lands by straightening a once

meandering river into an efficient conveyance channel. The Rio Grande Project provides flood control, reduce the losses through bed seepage and surface evaporation, establish the rectified river channel as the international boundary, and provide a more equitable distribution of water between the U.S. and Mexico as described in ratified legal treaties. Legal agreement such as the Rio Grande Compact, the 1906 Water Treaty, and the subsequent treaties and engineering projects failed to provide sufficient water for non-irrigation or municipal usage. In a river system where the water has already been assigned a pre-designated owner and usage, restoration effort in the El Paso-Ciudad Juarez region must look either to work within the existing hydrological and legal structure or evaluate the potential changes needed to the existing structure to allow the Rio Grande to flow once again.

References

Clark, Ira G. 1975 The Elephant Butte Controversy: A Chapter in the Emergence of Federal Water Law. *The Journal of American History* 61(4), 1006-1033

El Paso County Water Improvement District No. 1, Water Guide 2000. El Paso, Texas

International Boundary and Water Commission. U.S. Section. http://www.ibwc.state.gov/ (accessed January 15, 2005)

Jahagirdar, Abhijeet B. 2003. "Water Markets Features for Rio Grande Water in El Paso County Texas." Master's project. University of Texas at El Paso.

Rio Grande Compact Commission. 2001. Report to the Rio Grande Compact Commission 2000 to the Governors of Colorado, New Mexico, and Texas. El Paso, Texas

Rio Grande American Canal Extension Act of 1990. Public Law 101-438. 101st Congress.

Stone, William. 1991. The Rio Grande Basin. Paper presented at proceedings of workshops and conference, June 1-2, 1990, The Rio Grande Basin, global climate change scenarios.

Mueller, Jerry E. 1975. *Restless River: International Law and the Behavior of the Rio Grande*. El Paso, Texas: Texas Western Press

U.S Bureau of Reclamation. The Rio Grande Project. U.S Department of the Interior http://www.usbr.gov/dataweb/html/riogrande.html (accessed April 1, 2005)

Vazquez-Montiel, et al. 1999. Dilution effects on the quality of untreated wastewater used for irrigation along the USA-Mexico border, *International Journal of Environmental Health Research* 9(2), 125-129