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Water Issues along the Rio Grande Elephant Butte Reservoir: A Water Quality and Quantity Assessment

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ABSTRACT

Water issues are invariably contentious because of the value of water and its scarcity in the Rio Grande Basin. The management of water resources is mainly concerned with two important aspects quantity and quality, both of which vary over time. This article provides an historical overview, dating back 50 years, of releases from Caballo Reservoir and storage in Elephant Butte Reservoir. Historical diversions by water users and historical water quality issues, such as salinity, are presented graphically. A perspective of the past, current trends, and implications for the future are presented.

INTRODUCTION

The 100 years between 1900 and 2000 have brought tremendous change to the upper half of the Rio Grande Basin. In 1900, the Mexican government was contesting reduced flows in the Rio Grande (Rio Bravo) at Ciudad Juárez, Chihuahua, to the U.S. government. Mexican and U.S. farmers were unable to irrigate land that had been receiving water for decades. At the same time, 500 miles to the north, settlers in the San Luis Valley of southern Colorado near the headwaters of the Rio Grande were developing privately funded irrigation districts as fast as possible. In New Mexico, between Albuquerque and Las Cruces, spring flooding along the Rio Grande was an annual irritation for farmers. (The spring floods, however, were part of the process that provided a rich and diverse riparian habitat for

wildlife.) As a result, Elephant Butte Dam was proposed just prior to 1900. The proposed dam would store spring runoff near Truth or Consequences, New Mexico, thereby providing water for reliable summer irrigation releases and preventing downstream flooding. Private funds were not available to construct the dam, and the U.S. Bureau of Reclamation (USBR) did not yet exist. However, the U.S. Congress supported water development for agriculture because it viewed farming as the preeminent tool in settling the west.

The USBR, which was created in 1902, completed construction of Elephant Butte Dam in 1916 and continues to operate the facility for power generation and for water deliveries to the Elephant Butte Irrigation District (EBID) and the El Paso County Water Improvement District (EPCWID). The dam has a storage capacity of 2.065 million acre-feet¹ and a generation capacity of 28 MW of hydroelectric power. The USBR completed Caballo Dam 40 kilometers downstream of Elephant Butte in 1938 to capture and store winter power generation releases from the dam. Below Caballo Dam, all the way to El Paso, the Rio Grande is largely channelized, i.e., straightened and bounded by flood control levees. Most of the riparian habitat has been replaced with irrigated fields, including the habitat of the silvery minnow, an endangered species that reflects the troubled ecological status of the river. Elephant Butte Reservoir provides irrigation water for 178,000 acres in New Mexico and Texas, with return flows irrigating an additional 18,000 acres in Hudspeth County, Texas. Agriculture still controls the vast majority of the water along the Rio Grande, despite the fact that the economy is dominated by urban industries. Agriculture employed only 14,000 (1.7%) of the 820,000 person workforce and generated \$268 million (1.06%) of the \$25 billion income in the Upper Rio Grande basin in 1993 (Niemi and McGuckin 1997). Elephant Butte Dam produced approximately 102 million kilowatt hours of electricity in 1999, which at seven cents per kilowatt hour would be valued at \$7.1 million.² The economic power of municipalities is shown by the transfer of water into municipal and industrial uses. The El Paso water utility is switching from groundwater to sustainable Rio Grande surface water by purchasing rights from agricultural irrigation districts. At the turn of the century, most people lived in rural areas, whereas today most live in cities. Changes are being driven by the tremendous increase in the population of the region and the movement from rural to urban communities.

One other important variable has entered the water equation: salinity. For the lower part of the Upper Rio Grande basin, salinity has become nearly as important as water quantity. Salinity is measured by total dissolved solids (TDS). The headwaters of the Rio Grande

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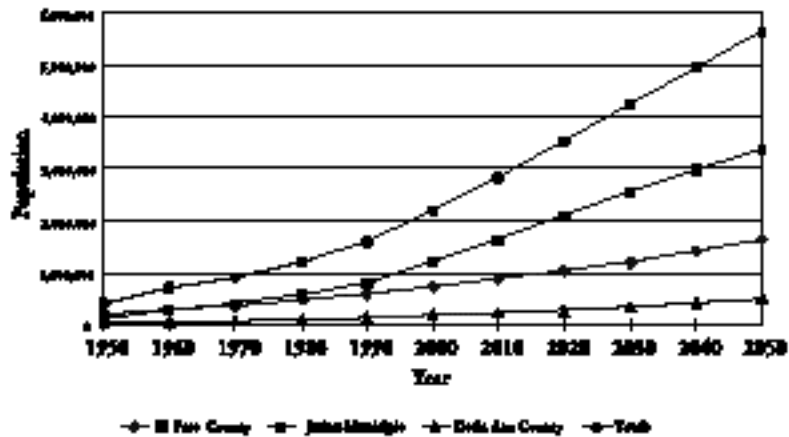
contain less than 50 mg/L of TDS, releases from Elephant Butte Reservoir contain approximately 300 mg/L, and flows in the Rio Grande at El Paso during the winter months contain 1,600 mg/L. The TDS drinking water limit in Texas is 1,000 mg/L and the recommended U.S. EPA secondary limit is 500 mg/L. TDS concentrations in the Rio Grande at El Paso are directly impacted by upstream irrigation return flows. As El Paso switches from groundwater to Rio Grande surface water, conflicts are certain to arise between irrigators and downstream users.

POPULATION

The El Paso Ciudad Juárez region population has grown from less than 60,000 in 1900 to over 2 million today. The population is projected to climb to approximately 6 million by 2050 as shown in Figure 1. El Paso alone, currently at 650,000, is projected to grow to approximately 1.8 million by 2050. The population of Doña Ana County, New Mexico, which includes Las Cruces, was 155,000 in 1994 (CERM 1998). This growth is occurring in a desert region that receives 20 cm of rainfall annually, yet all of these communities tout growth and promote it at every opportunity.

Sustainable development is a buzzword that attempts to distinguish quality growth, especially concerning sufficient water supplies. The cities of El Paso and Ciudad Juárez are intimately connected com-

Figure 1: Population Trends for the El Paso Ciudad Juárez Region



Source: CERM (1998).

mercially, culturally, and geographically. Maquiladoras tie both cities together economically. Culturally, both cities share a 400-year history, with many families in El Paso having strong family ties to Mexico. Geographically, the two cities are connected because they share the Rio Grande, as well as the region's two main aquifers, the Hueco and the Mesilla bolsones. As a result, Ciudad Juárez's projected population of 3.5 million for the year 2050 will have a direct impact on El Paso. Water usage rates between the two communities vary greatly, with Ciudad Juárez using approximately 340 liters per capita per day (lpcd) and El Paso using 643 lpcd in 1999. The El Paso Water Utilities Department hopes to reduce water use to 605 lpcd in the year 2000.³

RIO GRANDE COMPACT

The Rio Grande Compact affects the states of Colorado, New Mexico, Texas, and Chihuahua (Mexico). The compact deals with the portion of the Rio Grande drainage basin above Ft. Quitman, and forms the basis for water allocation by law. The Rio Grande Compact Commission was created to equitably allocate water to the three U.S. states and Chihuahua, Mexico.

In the 1890s, water shortages began to occur along the Rio Grande in the Mesilla and El Paso valleys. People near Ciudad Juárez began to complain to the Mexican government. In response, the Mexican government filed a claim against the United States, asserting that the water shortage was due to increased diversions from the Rio Grande in Colorado, New Mexico, and Texas. In 1906, a treaty with Mexico was reached that entitled Mexico to 60,000 acre-feet annually, to be delivered from Texas. To ensure delivery, Elephant Butte Dam, with a capacity of approximately 2 million acre-feet, was constructed in 1916. With water demands increasing in Colorado, New Mexico, and Texas, a commission was formed of appointees from each state and one federal representative to study the water supply in the area and to allocate water to the states involved. They concluded a compact in January 1929 (Clark 1987; Hill 1968).

Later, on 28 October 1935, Texas sued New Mexico, citing that New Mexico had violated the terms of the 1929 compact by impairing the water supply in Elephant Butte Reservoir through increased diversions and increased salt content in the river, and that these actions violated the rights of Texas water users as set out by the Supreme Court. As a result, then-president Franklin D. Roosevelt requested an investigation of the situation, and upon completion, the Rio Grande commissioners met to negotiate a new compact on 27 September 1937. These negotiations resulted in the formulation of the Rio

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Grande Compact Commission of 1938, which included a set of delivery schedules and requirements for the three states (Clark 1987). The delivery schedule stipulates that 790,000 acre-feet are to be released annually from Elephant Butte for use by New Mexico, Texas, and Chihuahua. In order to guarantee this release, during a year of typical runoff, Colorado is required to deliver one-third of the total Rio Grande flow to Elephant Butte. This amount increases to 50% in wet years and reduces to 20% in dry years.

New Mexico's delivery requirements are as follows: the state must contribute 60% of the Rio Grande flow passing the Otowi bridge above Albuquerque. Flow at this bridge serves as the index station for determining deliveries south of Elephant Butte, and is measured at the San Marcial gauging station above Elephant Butte Reservoir. The requirement is 80% in wet years with no requirement for water deliveries at the lower end of the scale (Clark 1987).

Texas is required to deliver 60,000 acre-feet to Mexico in accordance with the 1906 treaty. The quantity of water available for use in the El Paso County Water Improvement District (EPCWID) and the Hudspeth County Conservation and Reclamation District (HCCRD) of Texas are less precisely defined.

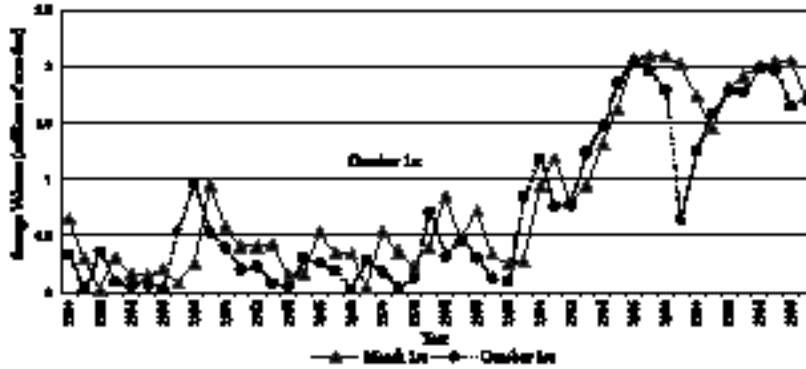
The states of Colorado and New Mexico do not need to strictly adhere to their delivery requirements each and every year. However, the compact does set limits for debits and credits. New Mexico may not be charged with more than 150,000 acre-feet in any one year, or a total of 200,000 accrued acre-feet. Similarly, Colorado has a debit limit of 100,000 acre-feet in any one year and an accrued debit of the same amount. In the case of over-deliveries, or credits, the maximum amount that either state may claim in any year is 150,000 acre-feet. Also, the amount of credit will be reduced by the amount of the spill

Table 1: Water Allocations from Elephant Butte Reservoir

Item	EPCWID	HCCRD	Mexico	Total
Water right acres	69,510	90,640	19,840	179,990
Percent of total	38.5%	50.5%	11%	100%
Delivered at head gates when 492,000 acre-feet are available for release	217,000 af	285,000 af	33,400 af	555,400 af
Delivered at head gates in years of full supply	360,00 af	475,000 af	60,000 af	895,000 af

Source: U.S. Department of Interior (1980).

Figure 2: Elephant Butte Storage

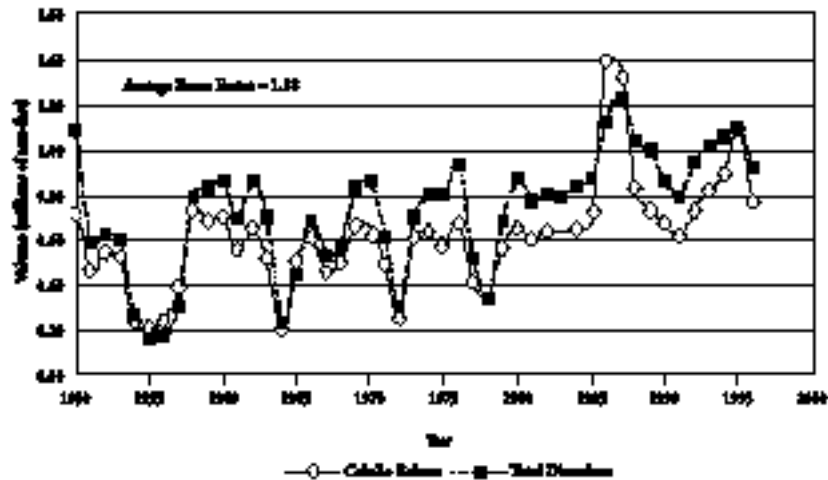


Source: USBR data.

from the reservoir, and no credits can be claimed in the year of any such spill.

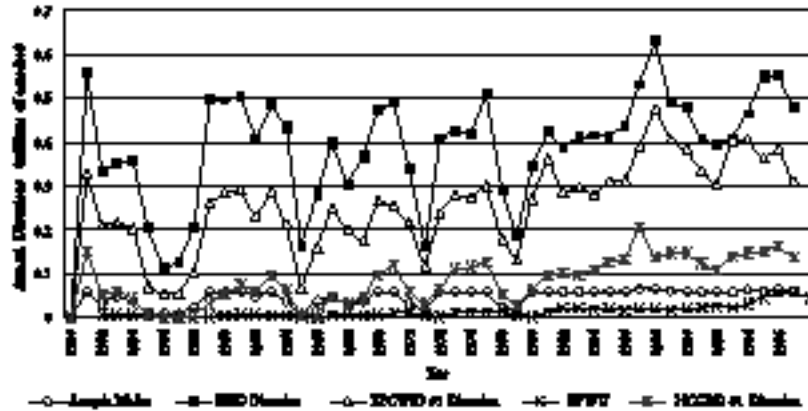
The agreements of the compact are much more specific than stated above and include many more provisions for the debit and credit of water. Despite continued controversy over water use, the Rio Grande Compact has accomplished what it was designed to do, namely, to equitably allocate water for use by each state (CERM 1998; Hill 1968).

Figure 3: Caballo Releases Versus Total Diversions



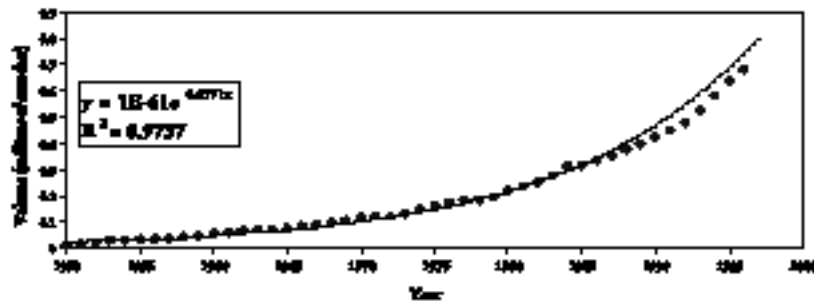
Source: USBR data.

Figure 4: Annual Diversions from the Rio Grande below Elephant Butte Reservoir



Source: USBR data

Figure 5: Cumulative Rio Grande Water Usage for EPWU



Source: USBR data

WATER STORAGE, USE, AND SALINITY

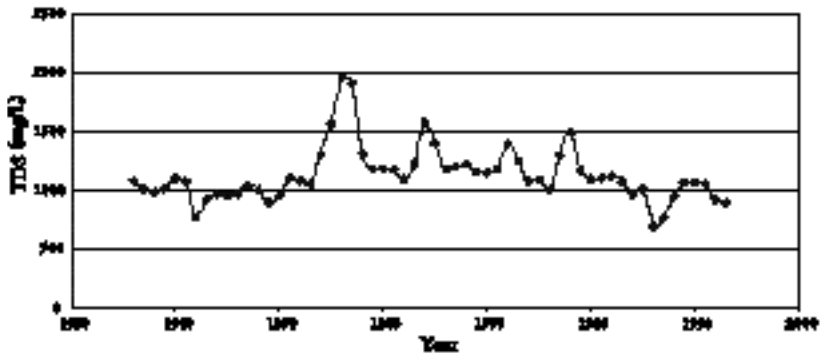
A summary of the water allocations from Elephant Butte Reservoir is shown in Table 1. The EBID is responsible for water deliveries in New Mexico from Elephant Butte Dam, and the EPCWID has similar duties in El Paso County in Texas (Moseley 1970). Water deliveries to Mexico are made at the Acequia Madre headgate in Ciudad Juárez. The difference in total deliveries between years of limited supply and full supply is approximately 360,000 acre-feet of water. (A year is considered limited in supply when only 492,000 acre-feet of water are available for release.) This is very significant, espe-

cially as municipal water supplies become more dependent on the water formerly used for irrigation.

Water storage levels in Elephant Butte Reservoir have varied dramatically since the 1950s, as shown in Figure 2. Beginning in 1979, the volume of water in storage on March 1 increased dramatically over the previous 30 years. This increase in storage translates to a high degree of certainty for full-supply deliveries to head gates during the irrigation season. When 200,000 acre-feet are in storage on March 1, head gate deliveries are usually close to the full-supply scenario shown in Table 1 and confirmed in Figure 3. Figure 3 includes the average reuse factor, which was determined by dividing Caballo Reservoir releases by total diversions. The average reuse factor between 1950 and 1996 was 1.18. The reuse factor since 1980 has been higher than the long-term average.

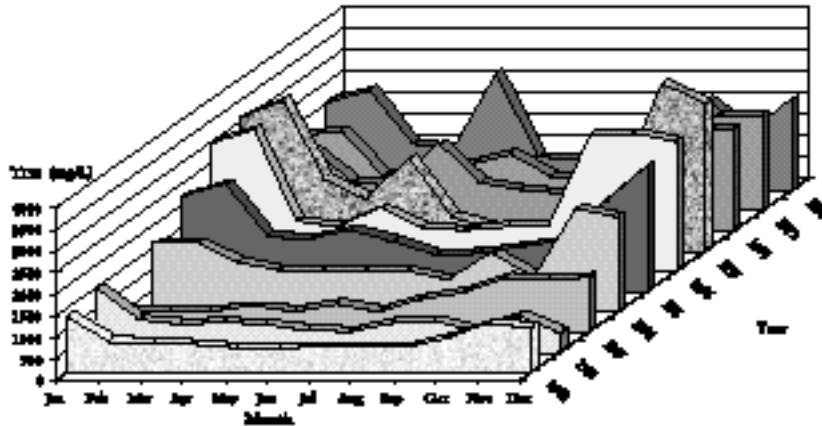
Diversions from the Rio Grande between Caballo Reservoir and HCCRD are shown in Figure 4. Diversions by EBID are followed by EPCWID, HCCRD, and Mexico at the Acequia Madre. Bringing up the rear is the El Paso Water Utility (EPWU). Although the amount of the diversion for EPWU seems insignificant by comparison, there has been a marked increase since the early 1990s. This increase reflects the EPWU's plan to increase utilization of Rio Grande water as a renewable resource. Figure 5 shows the exponential growth of El Paso's cumulative water use since 1950. The R² value for the exponential fit to the data in Figure 5 is 0.97. The exponential growth of Rio Grande water use clearly illustrates El Paso's increasing dependence on the Rio Grande for water. El Paso's total water demand increases every year despite decreasing per capita use, because the rate of population growth is higher than the rate of declining per

Figure 6: Yearly Average TDS in the Rio Grande at El Paso Station



Source: IBWC (1931).

Figure 7: Rio Grande TDS in Wet Years (1942, 1966, 1987) and Dry Years (1954-57, 1964, 1972, 1978)



Source: IBWC (1931).

capita use. In addition, El Paso is being forced to decrease its use of aquifer water due to declining water tables and salinization.

El Paso currently has 300,000 m³/d of surface water treatment capacity split evenly between two surface water treatment plants. These plants treat surface water during the irrigation season, which begins in late February and ends in early October. The EPWU wants to bring these plants on-line earlier in the year and shut them down later, eventually operating them throughout the year. In addition, the EPWU is currently working on the design of a new 300,000 m³/d surface water treatment facility that would be located near the New Mexico Texas border at Anthony, Texas. The city of Las Cruces, New Mexico, is also considering the use of Rio Grande water to supplement its groundwater resources. The trend is obvious. Municipalities are switching to the Rio Grande as a long-term sustainable resource as aquifers decline and become more saline.

Salinity is a contentious issue. Salinity reduces the economic usefulness of water in every instance, whether for agriculture or municipal use. Unfortunately, nearly every use of water increases salinity. Municipal use increases salinity 200 to 300 mg/L as it makes the transition from the water supply in the distribution system to treated wastewater. This has little impact since less than 10% of water usage is for municipal and industrial use in arid regions. Figure 4 shows that the EPWU has diverted approximately 50,000 acre-feet per year in recent years. In 1999, 58,000 acre-feet were taken from the Rio Grande. Total agricultural diversions are 10 to 20 times this amount.

Figure 8: Fields near Hatch, New Mexico



Irrigation has a dramatic impact on salinity because 85-90% of consumptive water use is for agriculture as shown in Figure 4. With each application, salts are concentrated, as approximately half of the water is lost through evapotranspiration, while additional salts are leached out of the soil profile.

The annual average TDS concentration in releases from Elephant Butte Dam is approximately 300 mg/L, while the annual average TDS concentration at the El Paso Station is approximately 1000 mg/L, as shown in Figure 6. The legal maximum TDS concentration in drinking water in Texas is 1000 mg/L. TDS concentrations for January through December for selected wet years (1942, 1986, and 1987) and dry years (1954, 1957, 1964, 1972, and 1978) are shown in sequence in Figure 7. The impact of successive dry years is shown when looking at the years 1954, 1955, 1956, and 1957, which are stacked one behind the other. The TDS concentrations during the winter months are extremely high during each of these years, and the TDS during summer months gradually increases for each succeeding year of drought. The TDS concentrations in winter months increase to nearly 4000 mg/L in 1956 and 1957 as a result of the drought that started in 1954. Fields such as those shown in Figure 8 near Hatch, New Mex-

ico, suffer decreased productivity when TDS increases and urban areas have to consider the use of membrane desalination.

CONCLUSIONS

- 1 Population growth and the predominance of urban economics indicate that water transfers from agricultural use to urban use will continue.
- 1 Water is available to support urban growth as long as it can be transferred from agricultural use to municipal and industrial uses.
- 1 Yearly average TDS concentrations in the Rio Grande shown in Figure 7 are directly impacted by drought, but appear to remain constant overall. High winter season TDS concentrations limit water use during this period. Increased use and reuse of water in upstream metropolitan areas like Albuquerque, New Mexico, are likely to slowly increase the salt load delivered downstream.
- 1 Periods of drought pose the largest challenge, not only because of reduced water quantities, but also because of the increased salinity in the available water supply.
- 1 The need for urban areas to have surface water deliveries 12 months of the year will gradually change the long-term dynamics of the riparian system.
- 1 The riparian ecosystem will continue to degrade because of the pressures of urban growth and more intensive water-use practices. Only major efforts and significant investment will change this.

El Paso has supported its growth by utilizing a large part of the available fresh groundwater in the Hueco Bolson. This aquifer is gradually being exhausted. Plans to inject treated Rio Grande water into this aquifer will make it into a storage reservoir for seasonal or drought use, depending on management decisions. As the Upper Rio Grande basin system becomes more and more intensively managed and developed, perturbations such as drought or climate change will have significant impacts. The extent and magnitude of these impacts should be studied in order to better understand the effects of our growth and management decisions on the environment in which we live.

NOTES

1. Land units and water volumes in the United States are commonly measured in terms of acres. One acre is equal to 43,560 square feet, which is equivalent to a square parcel of land approximately 209 feet on each side. The amount of water used to irrigate one acre of land to a depth of one foot is called an acre-foot. An acre-foot contains 325,851 gallons of water, or 1233.5 cubic meters. One cubic meter of water contains 264.2 U.S. gallons. An acre of cotton requires three to five acre-feet during a growing season. A family of four using 200 gpd of water during a year will use 0.9 acre-feet of water.
2. For more information regarding the Elephant Butte Dam see <<http://www.usbr.gov/power/data/sites/elephant>>.
3. For more information regarding El Paso usage rates see <<http://www.epwu.org/>>.

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