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RIO GRANDE BASIN HYDROLOGY

RIO GRANDE

GEOGRAPHY AND CLIMATE

The Rio Grande headwaters lie along the Continental Divide at elevations ranging from 2,440 m (8,000 ft.) to 3,660 m (12,000 ft.) in the San Juan Mountains of southern Colorado. The entire area of the Rio Grande drainage basin is about 470,000 sq. km. (182,200 sq. mi.) of which about 230,000 sq. km. (89,000 sq. mi.) are in the United States and the remainder in Mexico (Hunt, 1974). The river flows south from Colorado through the length of New Mexico and then forms the international boundary between Texas and the Republic of Mexico. The drainage basin area above Elephant Butte Dam is about 76,275 sq. km. (29,445 sq. mi.), including 7,615 sq. km. (2,900 sq. mi.) in the Closed Basin of the San Luis Valley in Colorado. Above Velarde the drainage basin area is about 26,936 sq. km. (10,400 sq. mi.), including the Closed Basin. For the basin as a whole, the Rio Grande ranks last in a list of the world's principal rivers in the amount of water discharged per square mile of basin.

The San Luis Valley in south-central Colorado extends approximately ninety miles from north to south and fifty miles from east to west at elevations ranging between 2300 m (7,500 feet) and 2500 m (8,000 feet) above sea level. The major mountain boundaries are the San Juan Mountains to the west and the Sangre de Cristo Mountains to the east. The Rio Grande mainstem rises in the San Juan Mountains, flows south-easterly through the San Luis Valley, then into the State of New Mexico. The Conejos River rises in the Conejos Mountains and flows north-easterly along the southern edge of the San Luis Valley, joining the Rio Grande mainstem at Los Sauces. Despite its high altitude, short growing season, and average annual precipitation of only about 19mm (7.5 inches), the San Luis Valley sustains a productive agricultural economy dependent upon irrigation water.

A few miles north of the Colorado-New Mexico stateline, the Rio Grande enters a canyon which gradually increase in depth to more than 360 m (1200 feet) at Embudo, 112 km (70 miles) south of the state line. A short distance below Embudo the river enters the

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Espanola Valley, which is about 40 km (25 miles) long and 1.6 km to 4.8 km wide (1 to 3 miles). Here it is joined by the Rio Chama, an important stream draining some 8,288 sq. km. (3,200 sq. mi.). It is from this portion of the drainage basin, from the state line to the Espanola Valley, that the Rio Grande receives most of the part of the water supply which originates in New Mexico. At the lower end of the Espanola Valley, the river enters White Rock Canyon, a narrow gorge some 32 km. long (20 miles), leaving this at Cochiti, due west of Santa Fe.

The middle Rio Grande valley in New Mexico, where Rio Grande silvery minnow currently exist, extends from Cochiti Dam downstream 260 river km (160 mi.) to San Marcial. The middle Rio Grande valley constitutes 8% of the River's total length and 34% of its length in New Mexico. The valley's direct drainage accounts for 7% of the total Rio Grande drainage and about half of New Mexico's direct tributary drainage. The middle Rio Grande valley has an arid to semiarid climate typical of the southwestern United States. The climate is characterized by abundant sunshine, low relative humidity, light precipitation, and wide diurnal temperature fluctuations. The average annual precipitation varies from 178 mm (7 in.) to 380 mm (15.25 in.) over two-thirds of the basin and may exceed 635 mm (25 in.) only in the high mountain areas. Winters are generally dry, and snow rarely remains on the ground at low elevations for more than 24 hours. Snowfall in the high mountains composes 30-75% of the total annual precipitation; in the remainder of the basin snowfall composes less than 25% of the annual precipitation. Summer precipitation supplies almost half of the annual moisture. Most of the rain falls in brief, though sometimes intense, convective thunderstorms. These summer thunderstorms have a considerable moderating effect on daytime temperatures. The periods transitional to summer and winter (March through May and September through October) are associated with some of the largest flood-generating storms. Prevailing winds are from the southwest and typically are continuous during the spring months. Evaporation rate is high throughout the lower elevations of the basin and is highest in the southern part of the basin, where arid conditions exist.

The Rio Grande, known as the Rio Bravo del Norte in Mexico, marks the 2000 km. (1,248-mile) boundary between Texas and Mexico. This stretch flows in a generally

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southeasterly direction from El Paso to Brownsville. The Rio Conchos rises in the Sierra Madre Occidental in Mexico and flows in a northeasterly direction to join the Rio Grande near Presidio, Texas. The Pecos River rises in the Sangre de Cristo Mountains in New Mexico and flows in a southeasterly direction to join the Rio Grande near Langtry, Texas.

The Rio Grande and its tributaries drain a land area in three U. S. and five Mexican states (Colorado, New Mexico and Texas; and Chihuahua, Coahuila, Durango, Nuevo Leon and Tamaulipas). However, only about half of this total area actually drains into surface waters that eventually flow into the Gulf of Mexico. The other half is composed of closed sub-basins, which do not discharge directly into the Rio Grande.

The northern portion of the Rio Grande in Texas is mostly desert. The climate becomes less arid and more tropical as the river flows south. In general, the region is hot and windy. The basin averages more 38 degree C (100 degree F) days than any other part of Texas for the months of May through September. Temperatures are generally higher in the southern part of the basin than in the northern part.

The upper Rio Grande (in Colorado and New Mexico) the Pecos River and the Rio Conchos (in Chihuahua) receive flow from snow melt. Springs, seasonal rains, and occasional tropical storms provide most of the flow in the lower part of the basin. In Texas, the upper part of the basin has less precipitation than the lower part. Average rainfall ranges from 19.9 cm (7.82 inches) at El Paso, 31.0 cm (12.21 inches) at Fort Stockton, and 51.2 cm (20.14 inches) at Laredo, to 64.6 cm (25.44 inches) at Brownsville.

Prior to measurable human influence on the Rio Grande, pre-14th century (Biella and Chapman 1977), it was a perennially flowing, aggrading river with shifting sand substrate. Its channel pattern was, as a rule, braided and slightly sinuous. The river would freely migrate across the floodplain, the extent being limited only by the valley terraces and bedrock outcroppings. The Rio Grande's bed would aggrade over time; then, in response to a hydrologic event or series of events, it would leave its elevated channel and establish a new course at a lower elevation in the valley, in a process called river avulsion (Leopold et al. 1964). Although an aggrading, system the Rio Grande was in a state of dynamic equilibrium, providing periods of stability that allowed riparian

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vegetation to become established on river bends and islands alternating with periods of instability (e.g., extreme flooding) that provided, by erosion and deposition, new locations for riparian vegetation.

HISTORY OF DEVELOPMENT

Early Years

The Rio Grande above El Paso, Texas, is one of the oldest regions of continuously irrigated agriculture in the United States. Irrigation along the river and its tributaries extends back centuries to prehistoric inhabitants of the Rio Grande valley. When the Spaniards reached the valley they found the predecessors of the present day Pueblo Indians practicing irrigated agriculture. In the 16th century the Spanish began their settlements along, and irrigated from, the river. In the middle Rio Grande valley of New Mexico, this development peaked between 1850 and 1880 with an irrigated area of about 50,600 hectares or 125,000 acres (Clark 1987). Development in the El Paso area was contemporaneous with the Spanish colonization of the New Mexico portion of the Rio Grande basin; by 1896, about 16,200 hectares (40,000 acres) was irrigated near El Paso. Development in the Mesilla and Rincon valleys of southern New Mexico did not occur until the mid 19th century (Clark 1987). All of the irrigation during this time was by ditches cut from the river, aided by temporary check dams constructed during periods of low flow.

Initial irrigation diversions in the San Luis Valley of Colorado, above which the headwaters of the Rio Grande lie, began around 1850 (with Hispanic settlement and development), but were minimal until about 1880 following the arrival of the Anglo-Americans and inception of large canal projects (Follett Report 1896). The first appropriations in the San Luis Valley began in the 1850s on the Conejos River. The first appropriation on the Rio Grande mainstem was in 1866 and the most extensive development for irrigation purposes on both rivers was between 1880 and 1890. High spring runoff and low summer flows in valley streams, coupled with years of severe drought, resulted in undependable water supplies; thus, farmers turned to wells to supplement and regulate the water supply. Well construction in the San Luis Valley began during this time (1950s) and remains an integral part of the overall irrigation

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system in the Valley, using both artesian waters and shallow ground water derived from natural recharge as well as that caused by surface water irrigation.

Because the rapid development of the San Luis Valley was at its limits, local irrigators were developing plans for the construction of surface water storage reservoirs. The irrigation depletions in the San Luis Valley and the middle Rio Grande valley in New Mexico combined with drought resulted in the water supply shortages in the El Paso, Mesilla Valley and Juarez areas during the 1880s and 1890s. Protests from these areas, in particular on behalf of Juarez by the Mexican government, led to the era of river regulation by law and by dams.

The situation on the Rio Grande in the late nineteenth century was reported to the International Boundary Commission by Follett (1896). A summary of Follett's findings are quoted as follows:

- . The fact of a decrease in the flow of the river at El Paso exists, as claimed, and dates back to 1888 or 1889. Before those years the river went dry at intervals of about 10 years. Since 1888 it has been dry every year but two.
- . The use of water for irrigation has not materially increased in New Mexico since 1880, and hence is not the cause of this decreased flow.
- . The use of water in the San Luis Valley of Colorado has very largely increased since 1880, and at the present stage of development it takes from the river, in excess of what was taken in 1880, an amount of water equivalent to a flow of 1,000 second-feet, running for 100 days; at least this amount is taken and possibly more.
- . It is impossible to state specifically how much water was in the river prior to this increased use of water and since, as the records do not antedate this increased use, and as the flow since the records began varies within very wide limits.
- . This flow of 1,000 second-feet, if allowed to remain in the river, would do much toward preventing a dry river at El Paso.
- . The Mexican and American citizens of the El Paso Valley have suffered in common with their neighbors of the Mesilla Valley and those still farther up the

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river by this Colorado increased use of water. The suffering has been greater in the El Paso Valley than elsewhere.

All of the summer flow of the streams in the San Luis Valley, except their flood waters, are now appropriated, and therefore the use of water therein for direct irrigation is not likely to materially increase in the future.

The Embargo of 1896 and Construction of Elephant Butte Reservoir

A governmental-imposed embargo in 1896 on the use of public land for right of way in New Mexico and Colorado for further irrigation development effectively stopped the building of dams while the embargo was in place through 1925. Following the passage of the Reclamation Act in 1902, Elephant Butte Reservoir was authorized as a Reclamation project in 1905 to accommodate irrigation demands downstream in both New Mexico and El Paso County, Texas, and in anticipation of the Mexican Treaty of 1906 that committed the United States to delivering 74 million cubic meters (60,000 acre-feet) per year to Mexico. Elephant Butte was completed in 1916, with an initial capacity of 3.27 billion cubic meters (2.65 million acre-feet).

San Luis Valley Storage Development

Practically all storage development to date in the Upper Rio Grande Basin, by reservoirs of 1.2 million cubic meters (1,000 acre-feet) capacity or more, has been for irrigation purposes.

Although the need for storage to regulate the water supply of the Rio Grande and Conejos basins for irrigation in the San Luis Valley was indicated in the early eightennineties, construction on any large scale was prevented by the 1896 embargo. This was effective until 1925, and since 1929, storage development of magnitude has been limited by the terms of the Rio Grande Compact. The major storage development for San Luis Valley lands that could be accomplished notwithstanding the embargo took place in the period from about 1908 to 1914. Platoro Reservoir on the Conejos River is the only

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major post-Compact storage in the basin in Colorado and was constructed by the U.S. Bureau of Reclamation in 1951.

The embargo was opposed in Colorado, since even by 1896 the irrigated lands in the San Luis Valley used all the available natural flow of the Rio Grande and its tributaries in that valley. Storage appeared necessary not only for further development but even to maintain existing developments. But storage of any magnitude was impossible under the embargo. The effort of Colorado to secure permission to build reservoirs thus began early.

In the meantime, the Rio Grande system depletions in Colorado and drought, combined with the irrigation systems and practices in the middle Rio Grande valley of New Mexico, led to problems for its irrigators and those who lived there. Middle Rio Grande valley irrigation practices consisted of scores of discrete diversions and related acequias that carried water from the river to the fields. As irrigation development peaked in the middle valley, this practice gradually led to much of the land being seeped and fields being salt-laden. The naturally aggrading stream became more aggraded as it was depleted of water and had less energy to carry sediment downstream. This led to a river perched above the surrounding fields, villages and towns, that made them vulnerable to and were frequently devastated by flooding.

Development of the Middle Rio Grande Conservancy District

After the turn of the century, the middle Rio Grande valley in New Mexico was in crisis; with cultivated land being lost to seeping and alkalinity, the total cultivated land dropped to about 16,200 hectares (40,000 acres); downtown Albuquerque was in danger of becoming a swamp; the town of San Marcial, where the river had aggraded 4 meters (12 to 14 feet) in 50 years, was destroyed in the 1929 flood. The solution to this crisis was the formation of the Middle Rio Grande Conservancy District (MRGCD), covering the Cochiti to Bosque del Apache reach of the river. The mission of the MRGCD and its accomplishments were to (1) establish, straighten and narrow the river through jetty jacks and levees, (2) construct a system of riverside and valley interior drains to draw and flush the salt from the seeped lands, (3) develop a comprehensive system of diversion dams, canals and laterals, and (4) construct El Vado Reservoir on the Rio Chama for water

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storage and flood control. Four permanent diversion dams, crossing the Rio Grande at Cochiti, Angostura, Isleta and San Acacia replaced the eighty-some ditches and their temporary mud and brush dams that had been used. El Vado, with a capacity of 229 million cubic meters (186,000 acre-feet) was the second major reservoir on the Rio Grande system, being completed in 1935.

The Rio Grande Compact

Legal regulation of the river, beyond the Treaty of 1906 and the embargo of 1896, continued with the negotiation of the Rio Grande Compact (compact) among Colorado, New Mexico and Texas, to resolve the continuing interstate concerns on the sharing of Rio Grande waters. In 1923, the three states began steps toward negotiating an agreement on sharing the waters of the Rio Grande. With the lifting of the embargo in 1925 by the Secretary of the Interior, Colorado was in a position to increase its diversions of Rio Grande water through reservoir construction which gave it a more favorable bargaining position in compact negotiations and made it imperative to the downstream states that a Compact be put in place. A "status quo" compact was agreed to in 1929, pending investigations (the Rio Grande Joint Investigation completed in 1937) needed for the permanent compact. The permanent compact became effective May 31, 1939, and administration of the river under its terms began in 1940.

The compact has been the "Law of the River" since that time and allocates the water of the river between the states. The consumptive use or depletive effect to which Colorado and New Mexico are entitled is fixed by the delivery schedules, thereby determining the amount of water available at the lower terminus of their respective compact reach. The delivery schedules were determined by the inflow/outflow relationships in each portion of the basin during the study period (1928-37 for Colorado and 1909-30 for New Mexico) and sought to fix the level of depletion from the headwaters to the Colorado-New Mexico stateline and between Otowi and Elephant Butte Reservoir which existed during the study period. The flows that arrived at those points during the study period were determinate of the future delivery obligations of the two upstream states. The Rio Grande Compact therefore generally fixes the amount of water expected to flow from one compact reach to the next over the calendar year. The amount

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and timing of these flows is highly dependent on snowmelt runoff patterns, flood control activities, and rainstorm events throughout the year.

The Rio Grande Compact mandates water deliveries by Colorado on the Rio Grande at the New Mexico stateline amounting to a percentage of the gaged flows on the Rio Grande and Conejos River above the San Luis Valley. This percentage increases as the gaged flows above the San Luis Valley increases, ranging from about 20% in very dry years to over 60% in very wet years. The Compact also requires New Mexico to deliver into Elephant Butte Reservoir a quantity of water amounting to a percentage of the flow measured at the Rio Grande at Otowi gage located upstream of Cochiti Reservoir above the middle Rio Grande valley. This percentage also increases as the gaged native flow at Otowi increases, ranging from about 57% in dry years to about 86% in extremely wet years.

The Compact allows for under and over-delivery of water (debits and credits) from the scheduled deliveries; Colorado's and New Mexico's individual cumulative debits were not to exceed 123 million cubic meters (100,000 acre-feet) and 247 million cubic meters (200,000 acre-feet), respectively, except as either or both may be caused by holdover storage of water in post-compact reservoirs. The Compact also provides that accumulated debits or credits (to the extent that the spill exceeds accrued credit) would go to zero in any year in which actual spill occurs, and that neither state has delivery requirements in the year of a spill. The Compact also limits the use of post-1929 reservoirs, such as El Vado, when New Mexico is in a debit status and places similar limits on reservoirs constructed in Colorado after 1937. As a practical matter this has meant that El Vado was unavailable for use by the MRGCD during the many years of compact history that New Mexico has been in debit status, except for delivery to Pueblo land with prior and paramount water rights. The reader is directed to the Rio Grande Compact for details on specific provisions of the compact.

Caballo Dam and Rio Grande Canalization Project

Closure of Elephant Butte Dam had the result of cutting off annual flood flows that tended to scour the stream bed, hastening the aggrading, meandering and braided nature of the river below the dam. In 1933, the United States and Mexico entered into an

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agreement to straighten and stabilize the aggraded Rio Grande from El Paso to Fort Quitman, where the river is also the boundary between the two countries. In addition, the United States agreed to build Caballo Dam and Reservoir 35 km (22 miles) below Elephant Butte Dam. Caballo Reservoir, with a current capacity of 408 million cubic meters (331,000 acre-feet), was completed in 1938 for flood protection for the El Paso/Juarez area to which 123.3 million cubic meters (100,000 acre-feet) is dedicated as flood space and under the authority of the International Boundary and Water Commission, for reregulation space to allow hydroelectric generation at Elephant Butte Dam and for water conservation purposes. In 1935, Congress authorized the Rio Grande Channelization Project, Caballo Dam to El Paso, which was undertaken to provide more efficient water delivery and alleviate the threat of flooding.

Middle Rio Grande Project (Flood Control Act of 1948)

Following the wet years of 1941 and 1942 that caused numerous failures of the MRGCD-built levees in the middle Rio Grande valley in New Mexico and extensive flooding of both urban land (the railroad tracks through downtown Albuquerque defined the river course for some weeks in 1941) and farmland in both years, a drought ensued that persisted with only minor episodes of relief into the 1980's. The drought coincided with the deterioration of MRGCD facilities, from the diversion dams to the drains and spoil-fill levees devastated by the 1941-1942 flooding. Aggradation continued raising the river higher above the developed land in the valley. Lack of maintenance on the drains and the rise in the river bed above the drain outlets to the river drastically impaired their effectiveness, leading to renewed water-logging of the valley.

A dramatic decrease in the efficiency of the delivery of water to Elephant Butte Reservoir occurred during this time due to the creation of a huge delta deposited in the upper reservoir area as a result of sediment-laden water losing its velocity above the reservoir during times when it was full or almost full. With the combination of dry succeeding years, poorly functioning mid-valley drains and the barrier to efficient flow created by the sediment delta above and within the Elephant Butte Reservoir area as it was drawn down after 1942, New Mexico was regularly unable to make its Compact deliveries and there were frequent shortages of water to the MRGCD.

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Following reports by the Bureau of Reclamation and the Corps of Engineers, Congress passed the Flood Control Act of 1948 to address these problems. The essential features of this legislation were projects by the Bureau of Reclamation to rehabilitate the MRGCD's works and to construct what was to become the low flow conveyance channel to provide a route for more efficient water delivery through the sediment delta above and within Elephant Butte Reservoir. The act also authorized the Corps of Engineers to construct flood and sediment control dams on the Rio Grande, Rio Chama and Jemez River. As finally authorized and constructed, these were Abiquiu Dam on the Rio Chama and Jemez Canyon Dam on the Jemez. Finally, much of the levee system in the middle Rio Grande valley in New Mexico, particularly in the Albuquerque reach, was to be rebuilt.

With the extensive placement of jetty (Kellner) jacks along the sides of a 180 m (600 feet) cleared floodway, the previously meandering and braided river within the MRGCD levees became confined within the newly-defined and straighter water course with stabilized banks. As water was slowed by the jetty jacks, sediment would drop out providing a place for cottonwoods and other plants to colonize. This gave the river the well-defined character one can see today from the air compared to the levee to levee expanses of sand and sharp turns that formerly existed on much of the river.

Constructed between 1951 and 1959, the project that became the low flow conveyance channel (LFCC) was initially characterized as "the dredging of 20 miles of river channel above the head of Elephant Butte Reservoir." (H.D. 653, p. 10). By the time this project was initiated on the ground, Elephant Butte Reservoir had receded to below the "narrows". From at least the south boundary of the Bosque del Apache to the narrows, the river was discontinuous and largely consisted of a broad, diffuse salt cedar wetland. A contemporaneous Bureau of Reclamation estimate of the annual loss of water between San Antonio and the narrows was about 240.4 million cubic meters (195,000 acre-feet) (Initial Stage Channel Rectification, Middle Rio Grande Project, 1951).

The first phase of the project constructed a below grade channel from the narrows to the south end of San Marcial Lake. Then a channel was cut from the north end of the

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lake to a river heading near the south boundary of the Bosque del Apache Wildlife Refuge. Diversions at this heading began in November 1953. Sediment laden water was diverted through this heading into San Marcial Lake where sediment deposition occurred. Clearer water was decanted over the grade structure and conveyed to the reservoir. In 1958, the LFCC was connected through the silted up bed of San Marcial Lake. At the same time these channels were being built, a new "floodway" on the east side of the valley was excavated through the salt cedar delta by clearing and grubbing a 305 m (1,000 feet) wide strip essentially paralleling the conveyance channel. In 1956, the LFCC was extended from its Bosque del Apache terminus to a new heading at San Acacia, again with the creation of a parallel 180 m (600 feet) cleared floodway. The finished LFCC was, 110 km (68 miles) long including the portion within Elephant Butte Reservoir, was designed for a capacity of 57 cms (2,000 cfs) with a heading from the river at the San Acacia Diversion Dam.

The lower portion of the LFCC beginning near San Marcial began operations in 1954. The completed LFCC was put into service near the end of 1959 and functioned continuously for essentially its full length until late summer of 1974 when discontinuities began with shunting water that had been diverted into the LFCC at San Acacia back into the river at an outfall a mile or so above the railroad bridge at San Marcial. With this operation, the upper 80 km (50 miles) remained fully functional.

Over time, the lower portions of the channel sedimented in to a point that delivery of water was impaired. Much rehabilitation work was done in the late 1970s and early 1980s. However, diversion of water to the LFCC at San Acacia was suspended in March 1985 as Elephant Butte Reservoir was filling for the first time since 1942. Water has not been diverted into the LFCC at San Acacia since that time, except for small amounts of water diverted in 1996 and 1997 which were returned to the floodway at an outfall constructed about 15km (9 mi.) downstream from San Acacia.

The LFCC continues to operate as a drain to collect water discharged from the shallow ground water and from irrigation return flows and water seeped from the Rio Grande floodway. During the irrigation season, the flow in the LFCC will gain between 5.7 cms

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(200 cfs) and 8.5 cms (300 cfs) from ground water and return flows between San Acacia and San Marcial..

An integral part of the middle Rio Grande project as authorized by the Flood Control Act of 1948 was the construction of flood control and sediment control dams in the Rio Grande watershed above the middle Rio Grande valley in New Mexico. The authorized purpose was to reverse the continuing aggradation through trapping sediment in the new reservoirs and using the sediment-free reservoir releases as scouring flows to degrade the riverbed. This increased channel capacity lessened flood risks and helped restore functioning of the MRGCD drains where the river bed had become higher than drain outfalls. Large amounts of sediment were carried to the river from the Rio Chama and Jemez River as well as from smaller creeks and arroyo flows up and down the river. Large sediment loads also entered the river from Rio Puerco and Rio Salado flows, a few miles upstream of San Acacia, but sediment control facilities on these stream systems have not been developed.

Jemez Canyon Dam and Reservoir, the first authorized flood control structure, was constructed on the Jemez River, two miles upstream of its confluence with the Rio Grande, north of Bernalillo and south of Cochiti Dam. The dam was completed in 1953, and has a capacity of 130.7 million cubic meters (106,000 acre-feet). No conservation storage is allowed in the reservoir, but a sediment retention pool was created with San Juan-Chama Project water in 1979.

The next structure constructed was Abiquiu Dam and Reservoir, completed in 1963 on the Rio Chama about 50 km (32 miles) upstream of its confluence with the Rio Grande at Espanola. With a physical capacity of 1.48 billion cubic meters (1.2 million acre-feet), it had an initial authorized flood and sediment control capacity of 619 million cubic meters (502,000 acre-feet) and 94.9 million cubic meters (77,000 acre-feet), respectively. There has been San Juan-Chama Project water in Abiquiu Reservoir since the early 1970s, first in the sediment pool space, and then, following authorization by Congress (P.L. 97-140) in 1981, up to 246 million cubic meters (200,000 acre-feet) of San Juan-Chama Project water in the sediment/flood space. In 1989, Congress authorized

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storage of native water in this space when it is not needed for San Juan-Chama Project water storage (P.L. 100-522).

The 1960 Flood Control Act (P.L. 86-645) authorized Galisteo and Cochiti Dams. Galisteo Dam, completed in 1970, has an 109 million cubic meters (89,000 acre-foot) capacity designed for flood and sediment control from thunderstorm events and has an uncontrolled outlet that restricts releases to about 142 cms (5,000 cfs). Galisteo Creek enters the Rio Grande below Cochiti Dam. Cochiti Dam, below the Otowi gage, was completed in 1975 as a flood and sediment control structure with a capacity of 722.5 million cubic meters (586,000 acre-feet). In 1964, Congress authorized the creation of a permanent recreation pool of 486 hectares or 1200 acres (about 61.6 million cubic meters or 50,000 acre-feet) using San Juan-Chama Project water.

Except for the storage authorized by P.L. 100-522 and imported San Juan-Chama Project water, the Corps flood control reservoirs are only authorized to store water to prevent downstream flood damage from high flows with a requirement to release the stored flood water as fast as downstream conditions permit. Thus, the effect of a flood control operation is to spread flood peaks. P.L. 86-645 provides that,

“whenever during the months of July, August, September, and October, there is more than two hundred twelve thousand acre-feet of storage available for regulation of summer floods and the inflow to Cochiti Reservoir (exclusive of that portion of the inflow derived from upstream flood control storage) is less than one thousand five hundred cubic feet per second, no water will be withdrawn from storage in Cochiti Reservoir and the inflow derived from upstream flood-control storage will be retained in Cochiti Lake.”

In practice, this provides the possibility of carryover storage in both Cochiti and Abiquiu Reservoirs. In order to minimize carryover flood storage in Cochiti, the Corps manages the system, when carryover storage is indicated, to hold as much of it as possible in Abiquiu. This provision is in place (and can be waived with consent of the Rio Grande Compact Commission) to preclude the depletion through the middle valley of released flood storage that would have otherwise reached Elephant Butte Reservoir but for the storage. All flood control storage must be evacuated by March 31 of the following year.

A purpose of the dams was to change the middle valley reach of the river from an aggrading to a degrading stream. Combined with the channel work and jetty jack

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placement a streambed is being incised below the banks of the surrounding flood plain.

The levees acted to contain the historic meander of the river across a wide floodplain that over time deposited the sediment over its breadth. Trapping much of the sediment in the dams combined with the channelization work has changed the character of the river from a usually sediment-laden, shallow, braided stream to a more channelized, swifter flowing stream.

See Table 3 for a tabulation of major reservoirs in the Rio Grande Basin.

Elephant Butte and Cochiti Dams have effectively bracketed the middle Rio Grande valley in New Mexico. Within the middle Rio Grande valley, the three diversion dams at Angostura, Isleta and San Acacia can act as barriers to fish movement within the reach, particularly during periods of low flows. In periods of low flow and often when supplemental water from upstream storage is being utilized, MRGCD operations at Isleta and San Acacia diversion dams result in dewatered reaches between Isleta and Elephant Butte Reservoir. During periods of low flow, water for irrigators in the Socorro division can be diverted at Isleta and delivered all the way by the drain and canal system.

San Juan-Chama Project

In 1962, Congress authorized the San Juan-Chama Project which diverts San Juan/Colorado River Basin water by way of tunnels, the last through the Continental Divide, to Heron Reservoir on Willow Creek just upstream of the Rio Chama above El Vado Reservoir (P.L. 87-483). The firm yield of the San Juan-Chama Project is 118.6 million cubic meters (96,200 acre-feet) per year, of which about 93.7 million cubic meters (75,400 acre-feet) is dedicated for use in the middle Rio Grande valley in New Mexico, including 59.4 million cubic meters (48,200 acre-feet) to the City of Albuquerque, 25.8 million cubic meters (20,900 acre-feet) to the MRGCD and 6.2 million cubic meters (5,000 acre-feet) to the Cochiti Reservoir recreation pool and smaller amounts to Los Lunas, Belen and Bernalillo.

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Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA)

Following several large, damaging floods east of the Rio Grande in urban Albuquerque in 1955, 1961 and 1963, AMAFCA was created in 1963 to address and alleviate the problems of urban flooding from unregulated ephemeral tributaries. A series of concrete lined drainage channels were constructed from arroyos at the foot of the Sandia Mountains and feed into the Rio Grande. Discharges from these drainage channels are collected and flow into the Rio Grande near Alameda and at Tijeras Arroyo.

The Closed Basin Project

The Closed Basin Project in Colorado was authorized by P.L. 92-514 in 1972. The project consists of 170 salvage wells that remove groundwater from the unconfined aquifer in the Closed Basin and discharge the water into the Rio Grande southeast of Alamosa. The water would otherwise be lost by evapotranspiration. The Project became operational in 1989, and has delivered a total of 171.4 million cubic meters (139,030 acre-feet) through 1995 or an average annual delivery of 24.5 million cubic feet (19,900 acre-feet) since then.

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Table 3. Major reservoirs on the Rio Grande in Colorado and New Mexico. (Source: Shupe and Folk-Williams, 1988)

Reservoir	River/Location	Primary Owner	Authorization	Purpose	Year completed	Water supply Storage	Total storage capacity
Abiquiu	Rio Chama	Corps of Engineers	1948 Flood Control Act	Flood and sediment control, water supply	1963	200,000 af	1.2 million af
Caballo	Rio Grande main-stem downstream of Elephant Butte Reservoir	Bureau of Reclamation	Acts in 1935 & 1936	Water supply, flood control	1938	231,000 af conservation storage, 100,000 af flood control	331,000 af
Cochiti	Rio Grande main-stem upstream of Albuquerque	Corps of Engineers	1960 flood control act	Flood and sediment control, fish and wildlife enhancement	1975	0	586,000 af
Elephant Butte	Rio Grande main-stem downstream of San Marcial	Bureau of Reclamation	1905 Act	Water supply, hydroelectric power, recreation	1916	2.1 million af	2.1 million af
El Vado	Rio Chama mainstem	MRGCD	non-federally financed	water supply storage, hydro- electric power	1935	186,000 af	186,000 af
Galisteo	Galisteo Creek upstream of Rio Grande	Corps of Engineers	1960 flood control act	Flood and sediment control	1970	0	89,000 af
Heron	Willow Creek immediately upstream of Rio Chama	Bureau of Reclamation	1962 (PL 87-483)	Water supply storage for San Juan - Chama project	1971	400,000 af	400,000 af
Jemez	Jemez River two miles upstream of Rio Grande	Corps of Engineers	1948 Flood Control Act	Flood and sediment control	1954	0	106,000 af
Rio Grande	Rio Grande mainstem headwaters	San Luis Valley Irrigation District	non-federally financed	Irrigation	1912	51,000 af	51,000 af
Platoro	Conejos River upstream of Rio Grande confluence	Bureau of Reclamation	1941 Interior Appropriation Act	Water supply and flood control	1951	54,000 af	60,000 af

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Hydrology and Hydrologic Modifications of the Rio Grande below Caballo Dam

The major tributaries of the Rio Grande below Caballo Dam are the Devils and Pecos Rivers in Texas and the Rio Conchos, Rio Salado, Rio San Juan, Rio Alamo, and Rio San Rodrigo in Mexico. Many of the river's minor tributaries are intermittent streams that cease to flow during the dry period of the year. Below El Paso, the mainstem has little, if any, flow for much of the year.

The Rio Grande waters reaching Texas are primarily provided by releases from Elephant Butte and Caballo Reservoirs. Before the waters of the Rio Grande reach the cities of El Paso and Juarez, most of the flow is diverted for irrigation and municipal uses at the American Dam (Texas) and the International Dam (Acequia Madre, Mexico). Downstream of El Paso most of the flow consists of occasional storm run-off, treated municipal wastewater from El Paso and irrigation return flows. From El Paso to Presidio, the flow is intermittent. Inflow from the Rio Conchos near Presidio provides a perennial base flow and over three-quarters of the flow to the Big Bend reach of the Rio Grande.

In the middle reach of the Texas part of the basin, the construction of International Falcon Dam in 1953 and International Amistad Dam in 1968 resulted in the most significant hydrologic modifications to the flow of the lower Rio Grande. Both of these dams were constructed by the International Boundary and Water Commission (IBWC) under the terms of the 1944 Water Treaty between the U. S. and Mexico. Also, Red Bluff Dam and Reservoir was constructed on the Pecos River just downstream of the Texas-New Mexico state line in 1936. On the Pecos River in New Mexico, Lakes McMillan and Avalon were originally constructed in the early 1890s (Brantley Reservoir replaced Lake McMillan in 1989), Sumner Lake was constructed in 1937 as Alamogordo Reservoir, and Santa Rosa Reservoir was built in 1980. Water deliveries by New Mexico in the Pecos River at the Texas stateline are subject to administration in accordance with the Pecos River Compact of 1949 and the United States Supreme Court's 1988 Amended Decree in Texas v. New Mexico.

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In the Lower Rio Grande Valley (Starr, Hidalgo, Willacy and Cameron Counties) the floodplain of the Rio Grande narrows considerably and is less than a mile wide in northwestern Starr County where the river leaves the impoundment of Falcon Dam. The floodplain is about 9.7 kilometers (six miles) wide in Hidalgo County but then broadens into a wide delta fronting the Gulf of Mexico near the mouth of the river in Cameron County. The flow discharges directly into the Rio Grande, except during floods, when much of the water is diverted into flood channels and thence to the Laguna Madre.

Other hydrologic modifications include canal construction near El Paso, and river channel and levee projects on the mainstem of the Rio Grande, such as the American Canal extension project in El Paso. Anzalduas Diversion Dam and Retamal Diversion Dam in the Lower Rio Grande Valley were constructed after floods in 1958 and 1967. Anzalduas Diversion Dam diverts flood waters to the interior floodways in the Lower Rio Grande Valley. It is also used as a diversion point for irrigation by Mexico. Retamal Diversion Dam diverts floodwater into Mexico's interior floodway system.

Treaty on the Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande (Water Treaty of 1944)

The Water Treaty of 1944 provides for the distribution of waters of the Rio Grande between the United States and Mexico from Fort Quitman downstream to the Gulf of Mexico. Texas is the recipient of all waters allocated to the United States under the Treaty. All measured waters originating in the United States belong to the United States. Two-thirds of the flow of certain Mexican tributaries is allotted to Mexico and one-third to the United States, provided that the one-third allotted to the United States shall not be less than 431.5 million cubic meters (350,000 acre-feet) (computed as an average in cycles of five consecutive years). All unmeasured inflows are divided equally between Mexico and the United States.

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Operations of the Rio Grande - Texas/Mexico

Operations of the Rio Grande in Texas are generally divided into two regions (above Fort Quitman and below Fort Quitman) based on two treaties between the United States and Mexico. The Rio Grande in Texas is over appropriated, with demand exceeding supply.

Above Fort Quitman, the 1906 Treaty with Mexico provides for the delivery of 74 million cubic meters (60,000 acre-feet) of water to Mexico. Mexico takes its water at International Dam in El Paso. Any water which passes this point belongs to Texas until it reaches Fort Quitman where it is reapportioned in accordance with the 1944 Treaty with Mexico. Water stored in Elephant Butte and Caballo Reservoirs are used to supply water to the Elephant Butte Irrigation District and the El Paso County Water Improvement District (WID) #1. Each has the right to call for releases from Elephant Butte Reservoir. Also, the Hudspeth County Conservation and Reclamation District uses the return flows from the El Paso WID #1 as their primary source of water. This water is collected before it reaches the Rio Grande via canals and diverted from the Rio Grande. The City of El Paso continues to increase the amount of water they use from the Rio Grande. They acquire rights via contract from the El Paso County WID #1. The system is operated to minimize flows past Fort Quitman. Excess releases from Elephant Butte may reduce future years water supply and the likelihood of a "spill" pursuant to the Rio Grande Compact.

Below Fort Quitman, all water rights have been adjudicated and are administered under the Texas Natural Resource Conservation Commission's (TNRCC) Rio Grande Watermaster Program. For the reach from Fort Quitman to Amistad Reservoir, the diversions are from run of the river waters. For diversions below Amistad and Falcon Reservoirs, the watermaster tabulates the water requests and asks for water releases from Amistad and Falcon Reservoirs. The watermaster's requests for releases are made to the

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International Boundary and Water Commission (IBWC). In a similar manner, Mexico also requests releases from their allotment of water in Falcon and Amistad Reservoirs. Their requests are made through their section of the IBWC. The IBWC maintains an account of water for the United States and Mexico pursuant to the Treaty of 1944. The TNRCC Rio Grande Watermaster (RGWM) program is charged with allocating the water to all Texas water rights holders. Any water user who wishes to divert water must contact the watermaster for prior approval before diverting water. Each water user has an account from which water is withdrawn. The predecessor agency to the TNRCC assumed responsibility for this program in 1971, which began in the 1950s under jurisdiction of the courts. The Rio Grande Watermaster operates the system to minimize releases from Falcon and Amistad Reservoirs and strives to keep flows past the last diversion point into the Gulf of Mexico to a minimum. There is no requirement for releases from the reservoir to maintain minimum instream flows in the Rio Grande below Caballo Dam.

Table 4 is an inventory of hydraulic structures in the Rio Grande Basin in Texas and Mexico.

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Table 4. Structure inventory; Rio Grande Texas and Mexico

NAME	State (if trib of RG)	Water Body	Year Const.	Constructed Capacity (acre-feet)
*American Diversion Dam		Rio Grande	1938	small div. structure
*International Diversion Dam		Rio Grande	1940	small div. structure
*Riverside Diversion Dam		Rio Grande	1940	small div. structure
Red Bluff Dam and Reservoir	Texas	Pecos River	1936	289,700
Amistad Dam and Reservoir		Rio Grande	1968	3,151,362
Falcon Dam and Reservoir		Rio Grande	1953	2,673,418
Anzalduas Dam and Reservoir		Rio Grande	1958	13,911
Retamal Dam and Reservoir		Rio Grande	1967	pass thru (flood control)
Venustiano Carranza	Coahuila			1,114,726
Piedritas	Coahuila			20,268
Nochebuena	Coahuila			32,428
San Miguel	Coahuila			19,457
La Fragua	Coahuila	Rio San Rodrigo	1992	36,482
Centenario	Coahuila			16,214
La Boquilla	Chihuahua	Rio Conchos	1916	2,224,588
Luis Leon	Chihuahua	Rio Conchos	1968	616,140
Chihuahua	Chihuahua		1960	19,457
La Rosetilla	Chihuahua			16,214
Fco Madero	Chihuahua		1949	344,552
La Colina	Chihuahua			14,593
Pico Del Aguila	Chihuahua			40,536
San Gabriel	Durango		1979	194,570
La Boca	Nuevo Leon			33,239
El Cuchillo	Nuevo Leon	Rio San Juan	1993	829,356
Cerro Prieto	Nuevo Leon			318,609
Salinillas	Nuevo Leon			15,403
Marte Gomez	Tamaulipas	Rio San Juan		755,582

* The dates associated with these structures reflect the current facilities.

On or about 1916, rock type structures were constructed and operated at these locations.

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PECOS RIVER

GEOGRAPHY AND CLIMATE

The principle tributary of the Rio Grande in the United States, the Pecos River rises in high altitudes in the southern terminus of the Sangre de Cristo mountains in north-central New Mexico and flows southward some 1450 km. (900 miles) to join the Rio Grande in the international reach of the Rio Grande, draining some 64,750 sq. km. (25,000 square miles) in New Mexico and 49,200 sq. km. (19,000 square miles) in Texas. Watershed elevations in the basin vary from above 3900 meters (13,000 feet) at the river's head, to about 300 meters (1,000 feet) at its mouth. Most of the valley's 11.3 million hectares (28 million acres) are semiarid. About 98% of the watershed of the Pecos River is used for grazing, the remainder for cropland and municipal development. About 64% of the total area is privately owned, 18% is state owned, and 18% is federally owned or administered.

Climatic conditions vary considerably within the watershed, owing principally to variations in geographic location and topography. Generally speaking, the summers are warm in the upper part and hot in the lower part. Maximum and minimum temperatures of 116 degrees F and -35 degrees F have been recorded in Artesia, which has an elevation of 1020 meters (3,350 ft.) The average growing season at the lower elevations in Texas is about 220 days, extending from late March to mid-November. The period shortens with increasing elevation and latitude to about 100 days, from early June to mid-September, in the mountainous areas of New Mexico. The average annual precipitation varies from about 254 mm. (10 inches) in the vicinity of Pecos, Texas, to more than 762 mm. (30 inches) in the mountains at higher elevations. Snowfall follows the same general pattern, varying from 7.6 meters (300 inches) annually in the high mountains to 50 mm. (2 inches) near the river's mouth. The maximum annual precipitation record, 1.59 meters (62.45 inches), occurred in White Tail in the Sierra Blanca in New Mexico in 1941. The minimum annual precipitation of 55 mm (2.16 inches) was recorded at Lake Avalon, New Mexico, in 1917. About 75% of the mean annual precipitation occurs from July through September. This pattern of rainfall, often torrential and of brief duration,

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results in frequent floods. In May 1942, the National Resources Planning Board estimated that the average water production for runoff in the Pecos River drainage for the period 1905-1939 amounted to 1.35 billion cubic meters (1,095,000 acre-feet) per year, or about 4 per cent of total precipitation. Of this yield, 67 percent originated in New Mexico.

History of Development

Irrigation in the Pecos River basin was being practiced in the upper basin (above Sumner Dam) by the Indians at the time of the Spanish conquest. Beginning with the close of the eighteenth century, expansion of irrigation in the upper basin coincided with the Spanish colonization. With the exception of the development of the Storrie Project (about 1918), development in the upper basin has remained about the same as it was under early Spanish occupation.

Directly before the Civil War, the Fort Sumner Project was constructed in the middle basin (Sumner Dam to the State line). A small project was constructed in the lower basin in the late 1870's. Very little additional development took place in either basin until the late 1880's.

In the middle basin, the principal irrigation developments are in the Fort Sumner, Roswell and Carlsbad areas. The Fort Sumner Project, constructed in 1863, was rehabilitated in 1906. Development in the Roswell area by the use of surface waters commenced in the period 1889-1904. The major development, however, has been the use of artesian water, which was initiated in 1891. This was followed much later by the pumping of shallow ground water in the Roswell artesian area, which commenced about 1927, with most of the development taking place during the years 1935-37.

Development in the Carlsbad area was commenced simultaneously with the surface water development in the Roswell area. The facilities to serve the Carlsbad area, including McMillan and Avalon reservoirs and the "southern canal" were completed about 1893. Many difficulties were encountered in maintaining the system. It was

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severely damaged by the flood of 1904. The project was taken over in 1906 by the then United States Reclamation Service, at which time it was completely rehabilitated.

Development in the Texas portion of the basin commenced in 1876 with the construction of one small canal. No further development took place until 1888. During a period of 25 years after that date, canals were constructed to serve nine projects. Two small off-stream reservoirs were also constructed. Because most of the area was dependent upon the erratic natural flow of the stream, need arose for major reservoir development on the stream; Red Bluff Reservoir was constructed and placed in operation in September 1936.

In the meantime, the capacity of the reservoirs of the Carlsbad Project had become so depleted the need arose for replacement of such capacity. Alamogordo (Sumner) Reservoir was completed in 1937 for this purpose.

The progressive sedimentation of McMillan Reservoir was offset by two enlargements. The original capacity of 98.6 million cubic meters (80,000 acre-feet) was depleted by sediment to 46.9 million cubic meters (38,000 acre-feet) by 1947. The reservoir leaked from the time it was built. As a WPA project, dikes were constructed to shut off the flow to some of the larger sink holes. The high water of 1941 opened other holes in the reservoir. Loss of the reservoir capacity was materially retarded by the growth of salt cedars on the sediment deposit at the head of the reservoir. The salt cedars over a period of years effectively had retained the sediments, allowing the relatively clear water to pass on the reservoir. However, in performing this function, nature had taken a heavy toll in water. The salt cedars were estimated to be consuming on the average of 67.8 million cubic meters (55,000 acre-feet) per year in 1947. (Senate Document No. 109, 81st Congress, 1st Session. 1949)

By 1925, the artesian water development in the Roswell basin was threatened by overdraft. Prior to the commencement of the artesian development, it has been estimated that the contribution to the surface water of the river from the artesian area averaged 9.2 cms. (325 cubic feet per second). It is estimated that by 1925, this flow had been depleted to 2.55 cms (90 cubic feet per second)(Senate Document No. 109, 81st Congress, 1st Session. 1949). The state legislature of New Mexico enacted a ground water statute in

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1931 which enabled the State Engineer to control development in the artesian basin by preventing expansion and eliminating waste. The shallow ground water development has also had a significant effect on the base flow of the stream. The pumping of groundwater in the Carlsbad area commenced in the late 1930's for the purpose of supplementing the surface flow when it is inadequate to satisfy current requirements. The State Engineer recognized the possibility of adverse effects of uncontrolled development on the groundwater supply in the Carlsbad area, and the basin was "declared" and development brought under his jurisdiction.

In the Malaga Bend area near the state line, the geologic formation which retains under artesian pressure a virtual sea of brine has been fractured. This permits leakage of about 0.01 cms. (one-half cubic foot per second) of brine into the river. The brine is a salt solution having concentrations of some 150,000 parts per million. The brine contributes 120,000 tons of salt per year to the supply of water which Texas receives from the river.

The Pecos River Compact

The Pecos River Compact, signed December 3, 1948, apportioned the waters of the Pecos River between the states of Texas and New Mexico. Under the Compact, New Mexico agreed not to deplete by man's activities, the flow of the Pecos River at the New Mexico-Texas state line below an amount which would give to Texas a quantity of water equivalent to that available to Texas under the 1947 condition. The Compact also apportioned 57% to New Mexico and 43% to Texas the consumptive use of water salvaged by federal projects which reduce non-beneficial consumptive uses on the river. The Compact also evenly apportioned between the states the consumptive use of unappropriated floodwaters. Both states also agreed to support Federal projects that would reduce the loss of water to salt cedars and to support a Federal project that effectuates a means of alleviating the salinity problems on the river. The Compact also allowed each state to construct additional storage to replace capacity of reservoirs lost due

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to sedimentation or other causes and allowed for the construction of flood control projects.

In March 1988, the U. S. Supreme Court entered its Amended Decree in the lawsuit styled Texas v. New Mexico, which enjoined the state of New Mexico to comply with Article III(a) of the Compact by delivering water at the State line each year in accordance with a formula adopted by the Court. The Court also appointed a River Master to perform the calculations using the adopted formula to determine annual delivery requirements and any shortfall or overages in deliveries. The Amended Decree further requires that if the River Master determines that a net shortfall has occurred in any accounting year, he must approve a plan by which New Mexico will increase the amount of water at the state line by the amount of the net shortfall prior to March 31 of the following year. Since entry of the Amended Decree, New Mexico has maintained an accumulated overage.

Pecos River and Reservoir Operations

In 1954, Congress authorized the construction of Los Esteros (Santa Rosa) Reservoir on the Pecos River 11.2 km. (seven miles) north of Santa Rosa. The Reservoir, with a total capacity of about 555 million cubic meters (450,000 acre-feet) allocated for flood and sediment control, began storage in 1980. In 1971, the Carlsbad Irrigation District filed an application to transfer to Santa Rosa Reservoir both a portion its storage rights in Alamogordo Reservoir (Sumner Reservoir) and that capacity of Alamogordo Reservoir lost to sedimentation since construction of Alamogordo Dam. Following a public hearing, the State Engineer issued an order which was conditioned as follows:

1. The amount of water stored in Santa Rosa Reservoir at any time for use by the Carlsbad Irrigation District shall not exceed 176,500 acre-feet less the total reservoir capacity available for storage by the District in Avalon, Brantley and Alamogordo Reservoirs. The total capacity in all reservoirs may exceed 176,500 acre-feet only if permission is granted by the State Engineer and provided that there is "unappropriated flood water" available, as defined by the Pecos River Compact.

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2. The inflow to Santa Rosa Reservoir shall be released from the reservoir at the maximum rate consistent with existing downstream conditions when the Reservoir capacity available for the storage of water for the District is filled.
3. No water shall be released from Alamogordo Reservoir when the water content of that Reservoir is 2,500 acre-feet or less.
4. Water released from Santa Rosa Reservoir for use by the District shall not be passed through Alamogordo Reservoir until the water content of the latter is at least 5,000 acre-feet, the water content in Alamogordo Reservoir in excess of 2,500 acre-feet may be released upon the termination of the release from Santa Rosa Reservoir

In 1988, the Bureau of Reclamation completed construction of Brantley Dam and Reservoir on the Pecos River 19.3 km. (12 miles) north of Carlsbad. The Reservoir, with a total capacity of about 1.23 billion cubic meters (1,000,000 acre-feet), was constructed for flood and sediment control and for irrigation purposes. The Carlsbad irrigation District has the right to store about 49.3 million cubic meters (40,000 acre-feet) of water in Brantley Reservoir for irrigation purposes. McMillan Dam was breached subsequent to the completion of Brantley Dam.

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REACH-BY-REACH ANALYSIS
and
REESTABLISHMENT SITE SELECTION PROCESS

The Recovery Team undertook a reach-by-reach analysis of the Rio Grande and the Pecos River Basins to summarize the salient hydrological, chemical and biological features of each reach, to address the threats to the Rio Grande silvery minnow and to consider the suitability of each reach for the potential for reintroduction. The analysis of each reach is not based upon detailed investigations made by the Recovery Team, but is based upon the combined experience and observations of the team members and evaluation and consideration of the research that has been completed. Water quality references to use attainability in stream reaches in New Mexico are taken from *Water Quality and Water Pollution Control in New Mexico - 1994* by the New Mexico Water Quality Control Commission.

Based upon the following reach-by-reach analysis and the consideration of the presence of other species that produce semi-buoyant eggs, the following reaches were selected to be suitable for reestablishment and prioritized as follows:

1. Sumner Dam to Brantley Reservoir
2. Red Bluff Reservoir to Amistad
3. Conchos to Amistad
4. Amistad to Falcon
5. Falcon to Gulf
6. Brantley to Red Bluff Reservoir

The conservation measures identified in the reach-by-reach analysis are to be studied and not all the measures are required to be implemented to satisfy the objectives and criteria of the Recovery Plan. Conservation measures will be investigated and implemented if the results of the investigation show that they are needed and feasible.

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Reach-by-Reach Analysis:

1. Rio Grande - Rio Grande Above Cochiti Lake

Hydrology: This reach has perennial flow. The hydrograph has a relatively natural shape with a spring peak that follows snowmelt runoff. On the Rio Chama below Abiquiu Dam, the summer and fall flows are higher than natural due to increased reservoir releases, including releases from the San Juan -Chama Project. This reach is likely not subject to a large increased diversion demand from future growth. There will be average increases in population growth and increased use of ground water but this will require transfer of existing water rights to offset these uses.

The majority of this reach is canyon bound with the remainder in open flood plain. From Otowi bridge upstream to the Velarde-Embudo reach it is non-canyon bound. The canyon bound reach has a high gradient, with a lower gradient in the open reaches. The substrate is dominated by gravel, cobble, and boulder with little fine material. There is low sinuosity and little segmentation with the exception of several concrete instream diversion structures near Velarde. These structures are likely impediments to upstream migration.

Sections of the Rio Chama have levees and the Espanola valley has a history of channel maintenance activities. This area on the Rio Chama also contains instream diversions. This reach has a stable bed with little aggradation or degradation.

Water quality: This is a cold water reach with low conductivity and turbidity. Some tributary streams that enter this section can introduce high sediment loads during storm events. There are point discharges from wastewater effluent from the communities upstream but the water quality of the reach is most influenced by non-point sources. There are historic and current sources from mining and heavy metals in the Red River drainage that then enter the Rio Grande.

The Rio Grande in this reach does not always fully support the designated fishery use due to turbidity, siltation, reduction of riparian vegetation, streambank destabilization and metals.

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Fish community: This reach is dominated by cool or cold water species including longnose dace. There has been a replacement of most native species by introduced nonnatives. Predation in this reach is from trout and northern pike. The Rio Grande silvery minnow was historically present but has not been collected since 1949 in the Rio Chama and the 1970s in the Rio Grande. There is no niche competition from other fish in this reach.

Last collection of Rio Grande silvery minnow: 1962-1963

Further Study: Contaminants from Red River and Los Alamos, additional fish studies.

Reestablishment potential: Yes (50-60 miles, marginal), perennial flows.

Cause of extirpation: Loss of habitat, dam construction,, cold water temperatures, loss of suitable substrate, change in hydrology, chronic/acute contaminants exposure, competition with introduced nonnative fish species.

2. Rio Grande - Cochiti to Angostura

Hydrology: This reach has perennial flow. The hydrograph is modified to reduce the peak in some years with extended release in years of high inflow. Under flood control operations, Cochiti Dam passes flows ranging between about 5000 cfs and 8500 cfs, depending upon downstream channel conditions. There is a spring peak that coincides with snowmelt runoff. Storm runoff can enter from Galisteo and Tonque arroyos.

This reach has levees on the east side and is incised in the upper sections. The width to depth ratio is lower in the incised section than in the downstream section. This is due to sediment capture by Cochiti Dam and a lack of upstream sources of sediment. The substrate is armored cobble in the upper section. The arroyos introduce sediment to the lower sections of this reach and higher percentage of finer sediments are found on the surface of the armored cobble. This finer sediment moves downstream with higher flows. The streambed gradient is moderate and lower than the reach above Cochiti.

This reach has low sinuosity and routine channel maintenance activities are performed, mainly bank stabilization activities. The segmentation in this reach is limited

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to the Angostura diversion structure on the downstream end and Cochiti Dam on the upstream end. There is low habitat variability in this reach.

Water Quality: The water temperature is cold due to release from Cochiti reservoir. The water temperature warms during summer in the downstream reaches. This reach has low conductivity and turbidity except for when sediments are introduced during storm events. The water quality is most influenced by non-point sources throughout the reach.

This reach of the river does not always fully support its designated fishery uses due to metals, reduction of riparian vegetation and streambank destabilization.

Fish Community: The fish community in this reach is almost exclusively nonnative fish dominated by white suckers, and bass and perch escapement from Cochiti Lake. There is no niche competition and this reach has the lowest density of Rio Grande silvery minnow of the areas currently containing populations of Rio Grande silvery minnow.

Further Study: Habitat quality (temperature and substrate), return flows, flow management, institutional constraints (e.g., Cochiti re-regulation, Rio Grande Compact), channel management studies, monitoring fish populations.

Conservation Measures: Monitoring of return flows, channel rehabilitation, nonnative fish management, monitoring fish populations, spring peak flows.

Reasons for Decline: Physical alterations in the channel (width/depth ratios, temperatures, substrate), fragmentation, flow regime changes, Cochiti Dam provides a physical barrier with colder clean tailwater, loss of low water/high water refugia, channelization, contaminants (past acute exposures resulting from mine waste spills); establishment of a permanent recreation pool at Cochiti Lake generated colder temperatures and clearer water, Galisteo sediment and flood control structure, nonnative fish introductions.

3. Rio Grande - Albuquerque Reach (Angostura to Isleta diversions).

Hydrology: This reach has perennial flow. The city of Albuquerque has agreed to maintain a minimum flow of 250 cfs at Albuquerque to the year 2000. The hydrograph follows the seasonal peaks released from Cochiti Dam reduced by the water diverted for

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irrigation at Angostura diversion. Downstream demands for irrigation augment flows in this reach during the summer season. Flows in this reach are highly managed. There are significant storm events that add to the runoff in this reach.

A higher than average population growth is anticipated in this reach. This could result in added surface water diversion for use by the city of Albuquerque from the San Juan-Chama Project that is currently in the system but variable.

This reach has a low gradient and is highly braided within the channel margins. The river channel is leveed and jetty jacks occur at various locations. There is a high level of channel maintenance activities in a channel with sand substrate. This reach has high habitat variability due to the channel braiding and there is no habitat segmentation from instream barriers within the reach. There are a number of return flows from riverside drains and inflows from the Jemez River.

Water Quality: This is a warm water reach. Conductivity is low and turbidity is low to moderate. Turbidity and sediment load can be high during storm runoff events. There are major urban point-source inflows in this reach and non-point sources from both urban and agricultural areas.

This reach does not fully support the fishery, irrigation and recreation designated uses due to metals, un-ionized ammonia, chlorine, pathogens, siltation and habitat alteration. During the past few years there have been several sewage spills and the reach is highly vulnerable to acute toxicity due to treatment of these and other spill events.

Fish community: This reach is dominated by a warm-water fish community. There is a low predator population, mostly dominated by channel catfish. The Rio Grande silvery minnow is present and in greater numbers compared to the upstream reach. There is no niche competition in this reach for the Rio Grande silvery minnow.

Further Study: Water quality impacts and sources, diversion structure modification, river and canal transmission losses and conjunctive use of municipal supply.

Conservation Measures: Measure diversions, maintain habitat quality, fish passage/ladders, fish transplant/augmentation, hatchery rearing for transplant.

Threats: Full use of all water in the system leading to dry reaches of river. Contaminants (both acute and chronic).

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Reasons for Decline: Channel maintenance activities, Jemez flood and sediment control dam, contaminants (storm drains and municipal water treatment effluent discharge), dewatering.

4. Rio Grande - Belen Reach (Isleta diversion to San Acacia diversion)

Hydrology: This reach is not perennial. The river has a spring peak that reflects the Cochiti releases and also storm peaks. The flow in this reach is highly managed for human uses. There are several riverside drains that can maintain flows in some sections of the reach. These drains are near Bernardo and San Acacia. More urbanization is anticipated in this reach but may not result in a change in river flows.

The river is leveed on both banks, especially through Belen. There are channel maintenance activities and jetty jacks in the reach. This is a low gradient reach dominated by sand substrate, with significant sediment inflows from Rio Puerco and Rio Salado. The river bed within the reach aggrades due to sediment load. There is increased channel mobility downstream of the Rio Puerco. Habitat variability is high within the reach. There are no constructed barriers within the reach but the reach becomes fragmented due to ephemeral flows.

Water Quality: Water temperature, conductivity and turbidity are higher than the upstream reach. Water quality is dominated by the non-point source discharges. The Rio Puerco and Rio Salado can introduce high sediment loads.

Portions of this reach do not fully support the fishery designated use due to metals, siltation and habitat alteration.

Fish community: This reach is predominantly a warm water native fish community. There is predation by channel catfish. The Rio Grande silvery minnow is present in the reach with no niche competition. The silvery minnow populations are higher than in the upstream reach.

Further Study: Water quality and sediment quality impacts from the Rio Puerco, Rio Salado and return flows, channel loss studies, phreatophyte evapotranspiration water use

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budgets, channel conveyance efficiencies, efficient application of irrigation water and conjunctive use of municipal supply.

Conservation Measures: Acquire water for conservation program, instream flow legislation, incentives to encourage water conservation, forbearance agreements, well pumping for river augmentation, adjudication, efficient use of diverted water, basin-wide annual planning of demand versus water availability.

Threats: Full use of all water in the system leading to dry reaches of river; contaminants.

Reasons for Decline: Dewatering and water quality.

5. Rio Grande - Socorro Reach (San Acacia to Elephant Butte)

Hydrology: This reach is not perennial although the spring runoff peaks and summer storm peaks often maintain surface flow. There is a high degree of flow manipulation outside of storm events. There is a stable human population base and the demand should be relatively stable.

The river is leveed on the west bank and open on the east. The LFCC begins in this reach. There is a high level of channel maintenance to maintain stream gradient. A levee project is planned to rebuild the existing levee with a more stable material. The channel is dominated by sand/silt substrate and is aggrading in this reach. Excavation within the river channel is used to open pilot channels to maintain flows into the lake. The stream has a higher sinuosity than the upper river and is highly braided within the channel margins. Habitat variability is moderate due to channelization within the reach.

The river channel in the section near San Marcial has been reconstructed after inundation from the previous times when Elephant Butte reservoir was full.

Water Quality: This is a warm water reach with higher levels of conductivity and turbidity than upstream areas. The water quality is dominated by non-point source discharges .

Portions of this reach do not fully support its fishery designated use due to pesticides, siltation, reduction of riparian vegetation and streambank destabilization.

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Fish Community: The fish community is dominated by warmwater native species. There is a predatory channel catfish population in this reach. There is no niche competition in this reach. When Elephant Butte reservoir is low there is increased riverine habitat in the lower sections of the reach.

Further Study: Water quality and sediment quality impacts, channel loss studies, phreatophyte evapotranspiration water use budgets, channel conveyance efficiencies, efficient application of irrigation water and conjunctive use.

Conservation Measures: Acquire water for conservation program, instream flow legislation, incentives to encourage water conservation, forbearance agreements, well pumping for river augmentation, adjudication, efficient use of diverted water, basin-wide annual planning of demand versus water availability.

Threats: Full use of all water in the system leading to dry reaches of river; contaminants.

Reasons for Decline: Dewatering and water quality.

6. Rio Grande - Elephant Butte to Ft. Quitman:

Hydrology: The river is not perennial in this reach. There is no spring runoff peak and a highly regulated hydrograph. There is an anticipated above average change in demand with an increased possibility for perennial flow in this reach due to change in water use from agricultural to urban uses. Releases in this reach are constrained by the Rio Grande Compact and downstream water demands.

There are many barriers in this reach with the major structure being Caballo Dam. The river is completely channelized with sand substrate, straight channel, high channel maintenance activity and levees in most areas.

Water Quality: This is a warmwater reach with higher levels of conductivity than upstream areas. The water quality is dominated by significant point and non-point source discharges. Within this reach, the El Paso area is heavily industrialized compared to the upstream reaches. This reach also receives both point and non-point source discharges from the Mexican side of the river which are subject to different water quality regulations than the United States.

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Portions of this reach do not fully support its fishery and irrigation designated uses due to metals, siltation, un-ionized ammonia, chlorine, pH, reduction of riparian vegetation and streambank destabilization.

Fish Community: This reach has a mixed coldwater and warmwater fishery between Elephant Butte release and Caballo Reservoirs. The river from Caballo Dam to Fort Quitman is a warmwater nonnative fish community. The Rio Grande silvery minnow was historically present, but no longer is found in the reach. There are predators present, such as bass and catfish, but no niche competitors.

Last Collection: 1944-Caballo to State Line.

Further Study: None at this time.

Reestablishment potential: Poor, short distance from Elephant Butte Dam to Caballo Reservoir, low temperatures downstream of dams, and low dissolved oxygen levels are all problems. The reach below Caballo Dam is canalized.

Cause of extirpation: water quality degradation, canalization, change in hydrology, diversion (physical barriers and de-watering).

7. Rio Grande - Presidio to Amistad Reservoir

Hydrology: The river in this reach is perennial and is dominated by the Rio Conchos entering from the Mexican side of the river. There is a seasonal peak modified by upstream dams on the Conchos. The peak is short due to water diversions and upstream dams in the Conchos. There are large storm event peaks in October and November. There are increases in depletion anticipated due to increased irrigation on the Mexican side of the river. The Treaty of 1944 sets the upper limit for the amount of diversion.

This reach is not leveed and has small rock dam weirs, all but one of which (Foster's weir) are not a barrier. The substrate ranges from silt to cobble and boulder depending on local conditions. There are no channel maintenance activities in this reach. Almost half of this reach is in canyons, including the Big Bend National Park. The lower canyons reach is outside the park, but land use is managed by the National Park Service.

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The channel is not mobile in the canyon sections. Outside the canyon reaches, the river is braided in some sections with a moderate gradient on average but higher gradient relative to the immediate upstream reach. Base flow in this reach is approximately 400 cfs.

Water Quality: The river in this reach has high salinity and turbidity. This reach has both point and non-point source discharges with the water quality dominated by contributions from the Rio Conchos.

Fish Community: This reach has a warm water native fish community with some nonnatives. The reach has a high number of large river species such as gar and smallmouth buffalo. The main predators are gar and channel catfish. The Rio Grande silvery minnow was historically present in this reach, but is no longer present. There is no niche competition in this reach for the silvery minnow.

Last Collection: 1960.

Further Study: Existing fish community, water quality data from Rio Conchos gage.

Reestablishment potential: Good.

Cause of extirpation: Poor water quality-Rio Conchos, canalization, dam construction, loss of spring peak flow, diversion (de-watering).

8. Rio Grande - Amistad to Falcon Reservoir

Hydrology: This reach is perennial with a small seasonal peak due to delivery schedules. Flow in this reach is highly regulated due to water releases to satisfy demands for irrigation in both Texas and Mexico. This reach is administered by a watermaster. The base flow in the reach is approximately 1000 - 3000 cfs. The demand in this reach is relatively stable but there is a conversion from agricultural to municipal uses. This reach is also subject to daily fluctuations to meet the downstream demands and for hydroelectric generation. Fluctuations can be as much as four to six feet in river level.

This section of the river is not leveed and there is no channel maintenance. The river is nearly straight with no braiding. The channel's gradient is lower than compared to the immediate upstream reach and its substrate is variable from coarse material

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downstream of Amistad to predominately sand substrate in the lower section of the reach.

There are several barriers in this reach at Maverick, Eagle Pass and Indio.

Water Quality: This section of the river has warm water with relatively high salinity and low turbidity. There are both point and non-point source discharges in this reach.

Fish Community: The fish in the reach are dominated by warm water nonnatives with high predator populations, including several basses, catfishes and gar. There are several native minnow species but Rio Grande silvery minnow is absent. The Rio Grande silvery minnow was historically present up to the Pecos, but not found in the Rio Conchos.

Last Collection: Inferred prior to 1960.

Further Study: Water quality, fish collection data, reestablishment potential.

Reestablishment Potential: Unknown

Cause of extirpation: Poor water quality (agriculture discharge, saline intrusion), Change in hydrology (regulated flows).

9. Rio Grande - Falcon Dam to Gulf of Mexico

Hydrology: This reach is perennial and highly regulated by releases from Falcon dam. Base flow is approximately 500 to 1000 cfs. There is a high level of urbanization. The peak flows are caused by spills from the reservoir due to storm peaks or reservoir releases for irrigation. The river has a low gradient in the reach and levees along some sections. There are barriers in the form of flood control structures. The substrate is dominated by sand with other particle size-classes present. There is little channel mobility and some channel maintenance activities.

Water Quality: Water quality in this reach is brackish due to influences from the Gulf of Mexico. Turbidity is low near Falcon Dam and increases in the downstream direction. There are both point and non-point source discharges from the increased urbanization and agriculture.

Fish Community: The fish community is dominated by warm water nonnatives including estuarian species in the lower river near Brownsville. There is a high predator population and no niche competitors.

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Last Collection: 1961

Further Study: Evaluate reestablishment potential.

Reestablishment potential: Some

Cause of extirpation: Estuarine conditions, predation, water quality, change in hydrology, diversion (physical barriers).

10. Pecos River - Santa Rosa to Carlsbad

Hydrology: This reach is not perennial. The flows are regulated by dams near Santa Rosa and Ft. Sumner. The section of reach from Santa Rosa Dam to Sumner Dam is short relative to the reach needed by the native species.

There are storm peaks during rain events, but significant spring peaks do not occur every year. There is no change in demand anticipated. The reach of river from Santa Rosa to Roswell loses flow but that from Roswell downstream to Carlsbad gains flow. The channel from Sumner Dam to Roswell has a moderate gradient with braiding within the stream margins as well as small sections of multiple channels. Substrate in this reach is variable with gradations from small to large substrate sizes. The upper section of this reach is similar in characteristics to the upper Rio Grande near Velarde.

The section from Roswell to Carlsbad is perennial. The gradient is moderate to low from Roswell to Carlsbad. The channel from Santa Rosa Dam to Sumner Dam is single with in-channel braiding. There is a single channel with channel braiding from Sumner Dam to Roswell. The lowest section of the reach has no braiding. Substrate in the river is cobble from Santa Rosa Dam to Sumner Dam, sand from Sumner Dam to Roswell and sand/silt from Roswell to Brantley Reservoir. There is low channel mobility in the entire reach.

Water Quality: The upper portion of this reach has cool water downstream of Santa Rosa Dam and warm water downstream of Sumner Dam. The conductivity and turbidity are low in the upper sections. The reach from Sumner Dam to Roswell has high turbidity and is highly variable in the downstream section. Salinity is high in the lower section of the reach.

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Portions of this reach do not fully support the fishery designated uses due to metals, siltation, pathogens, reduction of riparian vegetation, streambank destabilization, dissolved oxygen, un-ionized ammonia and total dissolved solids.

Fish Community: The fish community is dominated by warm water native species. The Rio Grande silvery minnow was historically present, but is not currently found in the river in this reach. There is a low predator population in the upper sections with a low to moderate predator population in the section from Roswell to Brantley Reservoir. There are no niche competitors in the reach from Santa Rosa Dam to Sumner Dam, but there is potential niche competition by nonnative plains minnow from Sumner Dam downstream.

Last Collection: 1968 (Roswell).

Further Study: Pecos hydrology (Sumner Dam to Acme), additional fish recovery areas.

Reestablishment potential: None above Sumner Dam (short reach), good potential below Sumner Dam.

Cause of extirpation: Santa Rosa Dam to Sumner Dam: Short reach (reproductive strategy requires more river channel). Below Sumner Dam: salinity, Plains minnow, dams, loss of suitable substrate, intermittent flow in river channel, change in hydrograph, loss of spring peak flows, diversion (de-watering).

11. Pecos River - Red Bluff to Confluence

Hydrology: This reach is not perennial. The reach does have storm events evident in the hydrograph in the lower sections of the river. The flows in the upper portion of this reach are dominated by releases from Red Bluff Dam. The lower section has significant spring sources and groundwater inflows that contribute to the discharge. There are no anticipated changes to flow regimes from increased demands for human uses.

This reach is a single channel, braided within the channel margins but without levees. The river gradient is high in the lower half of this reach with variable substrate types. There are some barriers in the upper section of this reach.

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Water Quality: This reach is a warm water stream with high conductivity, low turbidity, and is dominated by non-point source contaminants. This reach is subject to algal blooms from unknown causes, which have caused massive fish die-offs.

Portions of this reach do not fully support the fishery, irrigation, and livestock and wildlife watering designated uses due to metals, un-ionized ammonia, siltation, salinity, reduction of riparian vegetation, and streambank destabilization.

Fish Community: The fish community in this reach is dominated by warm water nonnatives with moderate predation from catfish and basses. The Rio Grande silvery minnow was historically present but no longer inhabits the reach. There is no niche competitors present in this reach.

Last Collection: 1954 (low numbers in collection).

Further Study: Study hydrology below Ft. Stockton, evaluate reestablishment potential.

Reestablishment potential: Unknown.

Cause of extirpation: Salinity, limited habitat, change in hydrology due to wells, diversions (physical obstructions & dewatering).

See Table 5 for a tabulation of Assessed Stream Reaches in New Mexico with Threatened, Partial or Non-Supporting Designated Uses. This table is excerpted from data tabulated by the New Mexico Water Quality Control Commission in partial satisfaction of the requirements of Section 305 (b) of the Clean Water Act.

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Table 5. Tabulation of assessed stream reaches in New Mexico in historic range of Rio Grande silvery minnow with threatened, partial, or non-supporting designated uses.

WATER BODY NAME (Basis of assessment) EVALUATED OR MONITORED (E/M), SUPPORT STATUS	TOTAL SIZE AFFECTED (MILES WITHIN STATE OF NM JURISDICTION)	PROBABLE SOURCE(S) OF POLLUTANT/THREAT	# OF NPDES PERMITS ON THE REACH ^a	USES NOT FULLY SUPPORTED/ THREATENED ^b	PROBABLE CAUSES OF NON-SUPPORT OR THREAT STATUS	TOXINS AT CHRONIC LEVELS ^c	AQUATIC SPECIES ON THE REACH	ACUTE PUBLIC HEALTH CONCERN (YES/NO)
Rio Grande from Northern Border of Isleta Pueblo to Jemez River ^d (Rio Grande, 2105, 2105.1, M Partially Supporting	38.3 (34.7)	Municipal point sources (0200), Urban nonpoint sources (4000), Spills (8400)	11	LWWF, SC, IRR	Metals, un-ionized ammonia, chlorine, pathogens, siltation, habitat alteration	AI	YES Rio Grande Silvery Minnow Endangered	NO
Rio Grande from Rio Puerco to Southern Border of Isleta Pueblo ^e (Rio Grande, 2105), M Partially Supporting	42.7 (37)	Agriculture (1300, 1500)	7	LWWF	Siltation, habitat alteration		YES Rio Grande Silvery Minnow Endangered	NO
Rio Grande from USGS gauge at San Marcial to Rio Puerco ^f (Rio Grande, 2105), M Partially Supporting	58.3	Agriculture (1301, 1500), Hydromodification (7100), Other (8010)	1	LWWF	Pesticides, siltation, un-ionized ammonia, reduction of riparian vegetation, streambank destabilization	Chlordane	YES Rio Grande Silvery Minnow Endangered	NO
Rio Grande from Leadburg Dam to Cabrillo Dam (Rio Grande, 2101, 2102), E Partially Supporting	45.6	Agriculture (1300, 1500), Hydromodification (7100, 7400)	1	LWWF, WWF	pH, reduction of riparian vegetation, streambank destabilization		NO	NO
Rio Grande from New Mexico-Texas border to Leadburg Dam (Rio Grande, 2101), E Partially Supporting	43.4	Municipal point sources (0200), Agriculture (1300, 1500)	7	LWWF, IRR	pH, siltation, un-ionized ammonia, chlorine		NO	YES Colonias
Rio Chama from mouth on Rio Grande to Abiquiu Dam ^g (Rio Grande, 2113), E Partially Supporting	31.6 (28.2)	Agriculture (1301, 1500), Hydromodification (7300)	0	MCWF, WWF	Turbidity, siltation, pH, dissolved oxygen, nutrients, un-ionized ammonia, reduction of riparian vegetation, streambank destabilization		NO	NO
Jemez River from mouth on Rio Grande to Rio Grande Dam ^h (Rio Grande, 2106), M Partially Supporting	26.9	Agriculture (1300), Natural (6600), Unknown (9000)	0	LWWF, LW	Metals, reduction of riparian vegetation, pathogens	As	NO	NO
Pecos River from the inflow to Summit Reservoir to Crown Point Dam ⁱ (Pecos River, 2211), M Partially Supporting	102.1	Agriculture (1300), Hydromodification (7400)	0	LWWF	Metals, siltation, pathogens, reduction of riparian vegetation, streambank destabilization	AI	NO	NO

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WATER BODY NAME (Basis for Permit) EVALUATED OR MONITORED (E/M) SUPPORT STATUS	TOTAL SIZE AFFECTED (MILES WITHIN STATE OF NM JURISDICTION)	PROBABLE SOURCE(S) OF POLLUTANT/THREAT	# OF NPDES PERMITS ON THE REACH ^a	USES NOT FULLY SUPPORTED/ THREATENED ^b	PROBABLE CAUSES OF NON-SUPPORT OR THREAT STATUS	TOXINS AT CHRONIC LEVELS ^c	AQUATIC T or E SPECIES ON THE REACH	ACUTE PUBLIC HEALTH CONCERN (YES/NO)
Pecos River from Salt Creek to Summit Dam (Pecos River, 2100), E Partially Supported	112.6	Agriculture (1500), Hydromodification (7400)	0	LWWF	Siltation, reduction of riparian vegetation, streambank destabilization		YES Bluntnose Shiner Threatened	NO
Pecos River from Rio Puelasco to Salt Creek (Pecos River, 2100), E Partially Supported	88.7	Municipal point sources (0100), Agriculture (1201, 1500), Unknowns (9000)	1	WWF	Metals, un-ionized ammonia, siltation, reduction of riparian vegetation, streambank destabilization	Hg	YES Bluntnose Shiner Threatened	NO
Pecos River from Black River to Lower Tandil Dam (Pecos River, 2102), M Not Supported	22.8	Municipal point sources (0300), Agriculture (1201, 1500)	1	WWF ^d	Metals, siltation, un-ionized ammonia, siltation, reduction of riparian vegetation, streambank destabilization	Al	NO	NO

^a = Conclusions concerning attainment of fishery uses are largely based on water quality analysis, where available, biological data was used to verify these results.

^b = All toxics for which EPA has prepared a federal Clean Water Act § 304(a) guidance document were reviewed as required by EPA.

^c = Pollutants present in concentrations or combinations such that designated or attainable uses are not supported.

^d = This reach includes areas wholly or in-part on Tribal Lands which are removed and separate from State of New Mexico jurisdictional authority.

LWWF = Limited warmwater fishery

SC = Secondary contact recreation

IRR = Irrigation

WWF = Warmwater fishery

MCWF = Marginal coldwater fishery

LW = Livestock and wildlife watering

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WATER MANAGEMENT STRATEGY FOR THE MIDDLE RIO GRANDE VALLEY

prepared by

Jeff Whitney (U.S. Fish and Wildlife Service)
Rob Leutheuser, Rich Barrios (U.S. Bureau of Reclamation)
Dick Kreiner (U.S. Army Corps of Engineers)
John Whipple (N.M. Interstate Stream Commission)
Subhas Shah (Middle Rio Grande Conservancy District)
Gary Daves (City of Albuquerque)

November 14, 1996

INTRODUCTION

The listing in 1994 of the Rio Grande silvery minnow as endangered under the Endangered Species Act and the drought conditions experienced in the middle Rio Grande valley during the first half of 1996 combined to underscore the need to address long-term water management options to meet water needs in the valley. The purpose of this paper is to outline alternative courses of action to satisfy these water needs that merit further investigation by agencies and entities which have a stake in water management for the valley.

The middle Rio Grande valley is hydrologically very complex and is home to substantial agricultural activity, urban development and the silvery minnow. Uncertainties exist in our understanding of the hydrologic connections between surface-water and ground-water systems in the valley principally due to a lack of data. There are also uncertainties regarding water needs over time for various purposes. Additionally, there are numerous incompatibilities between existing institutions as well as federal and state laws which affect water management in the valley and upstream reservoir operations for the valley.

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Still, during the 1996 irrigation season, agencies and entities directly involved in water operations for the middle valley largely succeeded in satisfying the water needs of the silvery minnow and water users, including Middle Rio Grande Conservancy District (District) irrigators. This success was due to the District operating its system to allow native Rio Grande water to remain in the river undiverted for the minnow and the city of Albuquerque (City) and other entities making some of their San Juan-Chama Project water available to the District for use by irrigators at no cost to the water users in the valley. It is expected, however, that San Juan-Chama Project water owned by the City and these other entities may not be available in future years to augment surface-water supplies in the valley.

Without proactive water planning and related commitments to action, water management decisions may be made through litigation. Environmental organizations have sent Notices of Intent to Sue, and others have contemplated legal action, regarding operation of the river system through the middle valley and related impacts to the silvery minnow. Government agencies with a stake in water management in the middle valley are now in the process of developing a plan for 1997 river operations for the silvery minnow and the District. Agencies and entities directly involved in water operations for the middle valley also share responsibilities in equitably meeting future water needs with the goal to satisfy water uses and the needs of the silvery minnow beyond 1997.

ACTIONS

To meet the needs of the silvery minnow, it is most desirable to take actions which will secure long-term, dependable amounts of water for the middle Rio Grande. In doing so, water users need to be accommodated. No single action will by itself accomplish these goals.

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However, the preparers of this paper believe that some combination of the following actions will be instrumental in meeting these goals. These alternative actions require further investigation and refinement to ensure that actions ultimately taken are responsive to these goals and to changing needs. Actions to be taken must be legal, economically feasible, politically acceptable, and implementable in a timely manner. Successful implementation of any of these actions will require improved water measurement, monitoring and accountability. The following alternative actions are non-exclusive and no order of priority has been assigned to them.

1. **Acquisition of Water:** Acquisition of water from willing sellers to facilitate water supply management in the middle Rio Grande is an action that could be taken within existing laws. Modifications to existing laws and contracts might further facilitate various ways of implementing a water acquisition program which may involve elements of water-use forbearance agreements or water banking. While water could be acquired from water users, the District may need to be a party to agreements to allow such a program to be effective in satisfying needs of the water users and the silvery minnow. A water acquisition program may require sustained funding from federal and other sources, and it would require development of institutional and physical criteria for obtaining water in a timely manner.
2. **Conjunctive Ground-Water and Surface-Water Use:** The use of ground-water and surface-water supplies could be co-managed to contribute to meeting the needs of water users and the silvery minnow. During wet years, ground-water users such as the City might use a higher proportion of surface water for direct use or artificial ground-water recharge. During dry years, more ground water might be pumped in lieu of using surface

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water so that additional surface water may augment the total surface-water supply available for the silvery minnow and surface-water users such as the District.

Another option is to strategically place shallow ground-water wells in the middle Rio Grande valley for use in times of severe surface-water shortages, thereby providing a supplemental source to the total water supply in years of low streamflow. This option could be expensive, but would provide a means to respond to emergency low-flow situations. These options would provide for a more comprehensive water use; however, institutional and water rights constraints need to be addressed to implement them.

3. **Upstream Water Management:** Changes to Rio Grande system water operations could increase the capability of storing native Rio Grande water upstream from the middle valley. Some reservoir and river operation options could require new authorizations, while other options could be accomplished under current authorities through changes to federal water control manuals. Possible options for consideration, in no order of priority, are: (1) storing Rio Grande water in vacant storage space in Heron Reservoir when space is available, as well as utilizing San Juan-Chama Project water; (2) transferring water from El Vado Reservoir to Abiquiu Reservoir; (3) increasing the storage capability in Abiquiu and Jemez Canyon Reservoirs; and (4) using Cochiti Lake for a re-regulation reservoir during the irrigation season. Aspects related to these options which would need to be addressed include: water supply, Native American water rights, effects on water management outside the middle valley, recreation, compliance with laws related to the environment, the Rio Grande Compact, and specific agency and project authorizations. There is also a need to annually prepare an operating plan for reservoirs and diversions of

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the Middle Rio Grande Project in consultation with stakeholders to specifically evaluate water management needs and opportunities for the middle valley.

4. **Water-Use Efficiency Increases:** Increased water-use efficiencies in the middle Rio Grande valley should contribute to an increase in the flexibility to manage the water supply. Options for action by which water-use efficiencies could be increased include improving off-stream water-delivery systems by such means as lining canals, improving on-farm irrigation practices, or improving water delivery scheduling. Prior to taking action to increase efficiencies, the impacts of various options on the hydrology and the environment of the middle valley need to be assessed. Further, the disposition of water “saved” by these measures would need to be resolved in accordance with state and Federal water law and possibly by agreement with the District to allow water saving measures to effectively aid water managers in meeting the needs of the water users and the silvery minnow.
5. **Water Rights Administration:** Water rights in the middle Rio Grande valley are not adjudicated and much of the water uses in the valley are not metered. Metering surface-water and ground-water irrigation deliveries and drain flows would help clarify existing water uses and needs, quantify the available water supply, and identify water management options. Adjudicating water rights in the middle valley would, in conjunction with a metering program, allow for improved administration of water rights and improved water management. However, an adjudication may not be completed for the middle valley in the foreseeable future unless alternative dispute resolution procedures can be adopted by the state, water users and the court to carry the adjudication

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forward. Still, sustained funding from federal and other sources to meter and monitor flows throughout the valley is needed.

RECOMMENDATIONS

Agencies and entities directly involved in water operations for the middle Rio Grande valley should diligently and cooperatively investigate with the broader community of interests, the feasibility of implementing the actions described herein and develop a plan of action to serve as the basis for future river and reservoir operations to meet the needs of water users and the silvery minnow in the middle valley. Such a plan of action might include any combination of the alternative actions described herein which would lead to maximum improvements in water management for water users and the silvery minnow as a whole.

Attention should first be directed towards more immediately attainable actions such as upstream water management options which can be accomplished within existing authorities and the acquisition of water. Concurrently, existing institutional constraints to implementing potential actions should be examined and efforts should be initiated to make institutional changes as may be deemed appropriate to help accommodate both water users and the silvery minnow in the long term. Where additional studies are deemed required to fully evaluate a potential action, the agencies and entities represented in the preparation of this paper should cooperate in securing the necessary resources to complete such studies promptly. These agencies and entities should also continue to dedicate staff to working on issues related to development and implementation of a plan of action to address future needs of both water users and the silvery minnow in the middle valley. To this end, the preparers of this paper seek confirmation from the leadership of their respective agencies or entities that the actions described herein should be pursued.

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DEC 24 1996

ALB-400
RES-3.10

LTC Lloyd S. Wagner
District Engineer
U.S. Army Corps of Engineers
4101 Jefferson Plaza NE
Albuquerque NM 87109

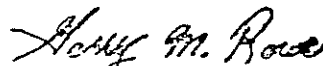
Subject: *White Paper* Addressing Water Management Strategy for the Middle
Rio Grande

Dear Mr. Wagner:

The purpose of this letter is to inform you of the Bureau of Reclamation's position regarding the subject paper, which was prepared by members of our staffs. The paper addresses water management strategies for the middle Rio Grande valley that should be explored to assure that the future water needs of water users and the Rio Grande silvery minnow can be satisfied.

Our Commissioner, Regional Director, and myself discussed the document at length. We understand that the *white paper* is only a single step in the continuum of activities that all of us need to pursue, but an important step. The Bureau of Reclamation endorses the paper, and is committed to work with your agency and others to develop workable solutions to the water management challenges.

Sincerely,


Garry M. Rowe
Area Manager

cc: Mr. Eluid Martinez
Commissioner
Bureau of Reclamation
1849 C Street, NW
Main Interior, Room 7060-MIB
Washington DC 20240-0001

Mr. Charles Calhoun
Regional Director
Bureau of Reclamation
Upper Colorado Regional Office
125 South State Street, Room 6103
Salt Lake City UT 84138-1102

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Identical letter sent to the following:

Mr. Thomas Turney
Secretary
New Mexico Interstate Stream
Commission
P. O. Box 25102
Santa Fe NM 87504

Mr. Subhas Shah
Chief Engineer
Middle Rio Grande Conservancy
District
P. O. Box 581
Albuquerque NM 87103

Mr. Robert E. Gurule
Director, Public Works Department
City of Albuquerque
P. O. Box 1293
Albuquerque NM 87103

Ms. Jennifer Fowler-Propst
U. S. Fish and Wildlife Service
2105 Osuna Road NE
Albuquerque NM 87113

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Martin J. Chávez, Mayor

January 3, 1997

~~Robert E. Durulé~~, Director

Mr. Garry Rowe
Area Officer Manager
Bureau of Reclamation
505 Marquette Ave. NW, Suite 1313
Albuquerque, NM 87102

Dear Mr. Rowe:

I have reviewed the White Paper prepared by representatives from the Corps of Engineers, Interstate Stream Commission, Middle Rio Grande Conservancy District, Fish and Wildlife Service and our respective staffs. It was prepared in the context of the fresh memory of the crisis-driven and difficult but successful management of Rio Grande flows during this drought year for the protection of the endangered Rio Grande Silvery Minnow while ensuring adequate deliveries for mid-Valley farmers. This crisis year served to drive home the need for developing a long term strategy for water management to meet the full range of water uses in the Middle Valley. The White Paper is a helpful initial step to accomplish this. The City stands ready to continue cooperative efforts with your agency and others to pursue the recommendations to determine the feasibility of implementing the actions proposed for consideration in the Paper while assuring that the needs of the City's water ratepayers continue to be met.

One of the proposed actions proposed for consideration in the White Paper is the conjunctive use of ground and surface water supplies. As you know, pursuant to Mayor Chavez's directive, my Department is actively formulating a strategy to transition as quickly as possible to full use of its renewable water supplies and away from reliance upon non-replenished ground-water. Contemplated in this planning effort is an ultimate ability for the City to conjunctively use surface and ground water in a manner reflecting their hydrologic interconnection and with flexibility to accommodate periods of limited surface water availability while at the same time ensuring the continued viability of the ground water resource. While consideration of this course of action is being driven by imperatives facing the City, we understand it can only be accomplished in the context of all water uses and needs in the Middle Valley being met as is the premise of the White Paper. Accordingly, this City effort amounts to a significant undertaking towards realization of the water management goals of the White Paper.

Good for You, Albuquerque!

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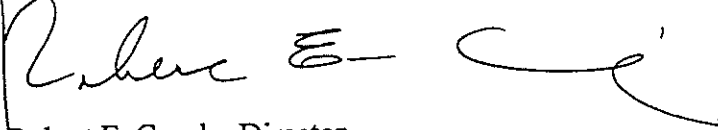
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Mr. Garry Rowe
Page 2
January 3, 1997

The City will not be as directly involved in the consideration and implementation of some of the other proposed alternative actions, but understands their vital importance to success of the goal of meeting overall Middle Valley water needs for the future and the City's needs in particular. In that light, we would hope that all the proposed alternatives and any others that emerge are actively pursued by the appropriate parties.

Finally, the City views the White Paper as a useful guide to continued efforts to meet the middle Rio Grande Valley communities' individual and shared water management goals and needs.

Sincerely,



Robert E. Gurule, Director
Public Works Department

c: Mayor Martin Chavez
Lawrence Rael, CAO

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ORIGINAL



DEPARTMENT OF THE ARMY
ALBUQUERQUE DISTRICT, CORPS OF ENGINEERS
4101 JEFFERSON PLAZA, NE
ALBUQUERQUE, NEW MEXICO 87109-3435
FAX (505) 342-3199

Engineering and Planning Division
Planning Branch

Mr. Garry M. Rowe
Area Manager
Albuquerque Area Office
U.S. Bureau of Reclamation
505 Marquette, Northwest
Suite 1313
Albuquerque, New Mexico 87102-2162

Dear Mr. Rowe:

The purpose of this letter is to provide you my position on the "white paper" titled *Water Management Strategy for the Middle Rio Grande* and dated November 14, 1996. This paper, which was prepared by members of our staffs, is primarily focused on the long-term needs of the Rio Grande Silvery Minnow. I certainly support the concepts embodied in the paper. However, I recommend that we re-title it *Water Management Strategy for the Silvery Minnow in the Middle Rio Grande*.

While it is imperative to address the needs of the silvery minnow, we need to place yet greater emphasis on the development of a broader comprehensive water management strategy that all interests in the Middle Rio Grande can support. The U.S. Army Corps of Engineers, Albuquerque District, is committed to working with your agency, and all interests, toward these objectives.

Sincerely,

Lloyd S. Wagner
Lieutenant Colonel, EN
District Engineer

DRAFT

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Same Letter Sent To:

Mr. Thomas Turney
New Mexico State Engineer
P.O. Box 25102
Santa Fe, New Mexico 87504-5102

Mr. Subhas Shah
Chief Engineer
Middle Rio Grande Conservancy
District
P.O. Box 581
Albuquerque, New Mexico 87103-0581

Mr. Robert E. Gurule
Director
Public Works Department
City of Albuquerque
P.O. Box 1293
Albuquerque, New Mexico 87103-1293

Ms. Jennifer Fowler-Propst
U.S. Fish and Wildlife Service
2105 Osuna Road, Northeast
Albuquerque, New Mexico 87113

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ORIGINAL

United States Department of the Interior

FISH AND WILDLIFE SERVICE

New Mexico Ecological Services Field Office
2105 Osuna NE
Albuquerque, New Mexico 87113
Phone: (505) 761-4525 Fax: (505) 761-4542

January 24, 1997

Memorandum

To: Area Manager, Bureau of Reclamation, Albuquerque Area Office,
Albuquerque, New Mexico (Attn: Garry M. Rowe)

From: Field Supervisor, New Mexico Ecological Services Field Office, U.S. Fish and
Wildlife Service, Albuquerque, New Mexico

Subject: White Paper entitled Water Management Strategy for the Middle Rio Grande

I wanted to acknowledge receipt of your letter dated December 24, 1996, voicing endorsement of the subject paper which members of our respective staffs have developed.

The Regional Director, Regional Office staff, and I all endorse and support the concepts identified by the entities represented. The Service agrees that this document is a first step toward broader suite of activities to assure that the future water needs of all water users and uses are considered and can be satisfied to the fullest extent possible. I look forward to continued cooperation with your Agency and the other participants in furthering the development of solutions related to the issues identified in the white paper.

Jennifer Fowler-Propst

cc:
District Engineer, U.S. Army Corps of Engineers, Albuquerque, New Mexico
Secretary, New Mexico Interstate Stream Commission, Santa Fe, New Mexico
(Attn: Thomas Turney)
Chief Engineer, Middle Rio Grande Conservancy District, Albuquerque, New Mexico
(Attn: Subhas Shah)
Director, Public Works Department, City of Albuquerque, Albuquerque, New Mexico
(Attn: Robert E. Gurule)
Regional Director, U.S. Fish and Wildlife Service, Albuquerque, New Mexico

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January 29, 1997

To: John Whipple, NM Interstate Stream Commission
Jeff Whitney, US Fish & Wildlife Service
Dick Kreiner, NM State Engineer's Office
Rob Leutheuser, US Bureau of Reclamation
Richard Barrios, US Bureau of Reclamation
Gary Daves, City of Albuquerque

Re: WATER MANAGEMENT STRATEGY FOR THE
MIDDLE RIO GRANDE VALLEY (WHITE PAPER)

Gentlemen:

On January 13, 1997, the MRGCD staff presented the "Water Management Strategy for the Middle Rio Grande Valley" (White Paper) created by staff of the NMISC, USCOE, COA, USBOR, USFWS and the District to meet the water needs of the Rio Grande Silvery Minnow and the water users.

The MRGCD Board of Directors unanimously supported the "white paper" in concept with the consideration of comments submitted by District staff to the committee. This is a first step in water management in order to protect the diverse interests of water users along the Middle Rio Grande.

We look forward to more detailed discussion on this issue in the near future.

Sincerely,

Lawrence C. Troncosa
Chairman

P.O. Box 581

87103-0581

1931 Second St. SW

Albuquerque, NM

87102-4515

505-247-0234

Fax # 505-243-7308

xc: Subhas K. Shah, CEO
Board Members

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ORIGINAL NEW MEXICO INTERSTATE STREAM COMMISSION

COMMISSION MEMBERS

J. PHELPS WHITE, III, Chairman, Roswell
TRACY SEIDMAN HEPHNER, Vice-Chairman, Wagon Mound
THOMAS C. TURNEY, PE, Secretary, Santa Fe
PALEMON A. MARTINEZ, Valdez
PAULINA SALOPEK, Las Cruces
RICHARD P. CHENEY, Farmington
HAL E. ENGLE, Edgewood
ROY T. PATTISON, Clovis



BATAAN MEMORIAL BUILDING, ROOM 101
STATE CAPITOL
POST OFFICE BOX 25102
SANTA FE, NEW MEXICO 87504-5102
(505) 827-6160
FAX (505) 827-6188

February 3, 1997

Garry M. Rowe, Area Manager
Bureau of Reclamation
Albuquerque Area Office
505 Marquette, N.W., Suite 1313
Albuquerque, New Mexico 87102-2162

Dear Mr. Rowe:

This letter is in response to your request for comments on a white paper entitled: "Water Management Strategy for the Middle Rio Grande Valley (MRGV)." The document is dated November 14, 1996, and was prepared by an ad hoc work group representing several organizations.

I support the study of alternative water management actions for the MRGV outlined in the paper. However, the paper presents a study strategy which may not be fully comprehensive in dealing with all water issues in the MRGV. I suggest that other issues be addressed during the course of further studies by the ad hoc work group.

Please continue to coordinate activities related to water management for the MRGV and development of a recovery plan for the Rio Grande Silvery Minnow with Mr. John Whipple of my staff, (505) 827-6160.

Sincerely,

Thomas C. Turney
Thomas C. Turney
Secretary

TCT:rav

cc: Nancy Kaufman
Colonel Wagner
Robert Gurule
Subhas Shah

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United States Department of the Interior

BUREAU OF RECLAMATION

Albuquerque Area Office
505 Marquette NW, Suite 1313
Albuquerque, New Mexico 87102-2162

IN REPLY REFER TO:

ALB-400

RES-3.10

FEB 18 1997

LTC Lloyd S. Wagner
District Engineer
U. S. Army Corps of Engineers
4101 Jefferson Plaza NE
Albuquerque NM 871089

Subject: *White Paper* Addressing Water Management Strategies for the Middle Rio Grande

Dear Mr. Wagner:

Enclosed is the subject *white paper* with the letters of endorsement written by you, me, and our counterparts in the other agencies who collaborated on the document. For future distributions of the *white paper*, we believe that the letters should be attached to it so every agency's viewpoints are fully represented.

The value of the *white paper* cannot be underestimated. It is the first such document, endorsed by this group representing diverse institutional interests, that begins to address the wide spectrum of middle Rio Grande water management challenges that we collectively must resolve. As we are all aware, this is but another step in a long process. Among the tasks that lie ahead are: the initiation of tasks; assuring that other members of the water management community and concerned public continue to have meaningful input to resultant activities; and, to coordinate these activities with the other programs in the Rio Grande Basin. I understand that members of our staffs are meeting in the near future to address these issues.

If you wish to discuss the *white paper* and associated activities, please do not hesitate to contact me, or Rob Leutheuser of my staff. We can be reached at 248-5357.

Sincerely,

Garry M. Rowe
Area Manager

Enclosure

cc: Mr. Eluid Martinez
Commissioner
Bureau of Reclamation
1849 C Street NW
Main Interior Building, Room 7060-MIB
Washington DC 20240-0001

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Appendix C

Identical letters sent to:

Mr. Thomas Turney
Secretary
New Mexico Interstate Stream Commission
P. O. Box 25102
Santa Fe NM 87504-5102

Mr. Subhas Shah
Chief Engineer
Middle Rio Grande Conservancy District
P. O. Box 581
Albuquerque NM 87103

Mr. Robert Gurule
Director
Public Works Department
City of Albuquerque
P. O. Box 1293
Albuquerque NM 87103

Ms. Jennifer Fowler-Propst
Field Supervisor
U. S. Fish and Wildlife Service
2105 Osuna Road NE
Albuquerque NM 87113

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cc: Mr. Charles Calhoun
Regional Director
Bureau of Reclamation
Upper Colorado Regional Office
125 South State Street, Room 6103
Salt Lake City UT 84138-1102