LEGAL AND PHYSICAL CONSTRAINTS ON THE CONJUNCTIVE USE WATER SUPPLY OF THE MIDDLE RIO GRANDE REGION

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ABSTRACT: Conjunctive use of surface water and groundwater is being pursued in many regions to maximize water availability throughout dry and wet periods. Successful regional water management will recognize the physical and legal constraints on these integrated supplies. Entities developing regional water plans in the Middle Rio Grande basin face a challenging set of constraints.

Legal constraints on water use in the Middle Rio Grande include the Rio Grande Compact; existing water rights and associated state water law; desired flows for endangered species; and, pueblo issues. Probabilistic modeling of the conjunctive-use water supply highlights limits associated with the Rio Grande Compact. Vast quantities of groundwater are present in aquifers, but, on average, can be extracted only to the extent stream depletion from pumping is offset. Whereas the Compact constraint is "reach-blind" (i.e., adequacy of delivery is only judged at the downstream delivery point), constraints evolving from the Endangered Species Act may be "reach-specific" (i.e., a given quantity of water may be physically required in specific reaches). A reach-specific constraint impacts efficiency of use, whereas a reach-blind constraint like the Compact is only sensitive to consumptive use. Pueblo claims may result in further constraints of either or both types.

Physical constraints relate to water quality, aquifer yield and the variability of surface water supply. Probabilistic modeling of the conjunctive-use water supply illustrates the impact of natural variability in river and tributary inflows and establishes the need for conjunctive management. Yet, water quality and aquifer yield both limit the ability to tap into portions of the aquifer (deep or distant from the river) that would provide significant lag time benefits for conjunctive management.

Risk analysis modeling of the basin-wide water budget, reflecting several of these constraints, indicates that, absent careful water planning, there is about a 50 percent probability that the water supply will be inadequate to meet demand without incurring Compact debit in any given year.

Key Terms: Conjunctive use; uncertainty analysis; water planning; Rio Grande

INTRODUCTION

Conjunctive water use, or a water supply derived from the complementary use of both surface water and groundwater resources, is being pursued in many regions of the West. In its simplest form, conjunctive use may be conceptualized as the recognition that groundwater development from a stream-connected aquifer will result in a reduction of stream flow, at such quantities and according to a time-lagged schedule that is a function of the pumping schedule, pumping location and aquifer hydraulic properties. An understanding of stream-aquifer interactions and some measure of limitations on groundwater pumping to protect surface water supplies has been recognized in New Mexico water law and administration for decades (New Mexico Underground Water Act, 1931; Templeton v. Pecos Valley Artesian Conservancy District 65 NM 59 (1958), Albuquerque v. Reynolds, 71 N.M. 428 (1962); Spiegel, 1962). One might characterize New Mexico has having put conjunctive management principles into practice long before this concept gained popularity.

More recently, conjunctive use concepts have included active and integrated management of surface and groundwater resources to improve efficiency and maximize water availability. The recent passage of the Ground Water Storage and Recovery Act (1999) underscores New Mexico's recognition of the long-term limitations of groundwater mining. Municipalities and regional planning groups within New Mexico increasingly recognize the desirability of incorporating surface water sources as key components of

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regional sustainable supply. However, because surface water is subject to a high degree of variability, the surface water supply alone is subject to surplus and shortage. Conjunctive management plans incorporating groundwater recovery and/or storage; or, exchange/transfer arrangements between surface and groundwater users provide mechanisms for augmenting surface supplies in years of shortage and reserving excess water in times of surplus. Conjunctive use management typically is structured to increase the reliability of highly variable surface water supplies. Sustainable conjunctive management plans require full cognizance of legal and physical constraints on the water supply to avoid projecting shortages into the future or into a neighboring region. Regional water planning groups in the Middle Rio Grande region face a challenging set of constraints as they work to optimize the conjunctive use water supply.

LEGAL CONSTRAINTS ON SUPPLY

Legal constraints on water use in the Middle Rio Grande include the Rio Grande Compact; existing water rights and associated state water law; desired flows for endangered species; and, pueblo issues. The 1938 Rio Grande Compact was ratified by the states of Colorado, New Mexico and Texas and passed by the 76th Congress as Public Act No. 96 in 1939. This interstate compact placed a limit on the amount of allowable depletions in the Middle Rio Grande. The Rio Grande Compact and a subsequent 1948 resolution identifies New Mexico's delivery obligation (scheduled delivery) to Elephant Butte Reservoir based on the adjusted flow of the Rio Grande at Otowi bridge (Otowi Index Supply), as shown graphically on Figure 1. Despite that the average Otowi Index supply is on the order of a million acre-feet

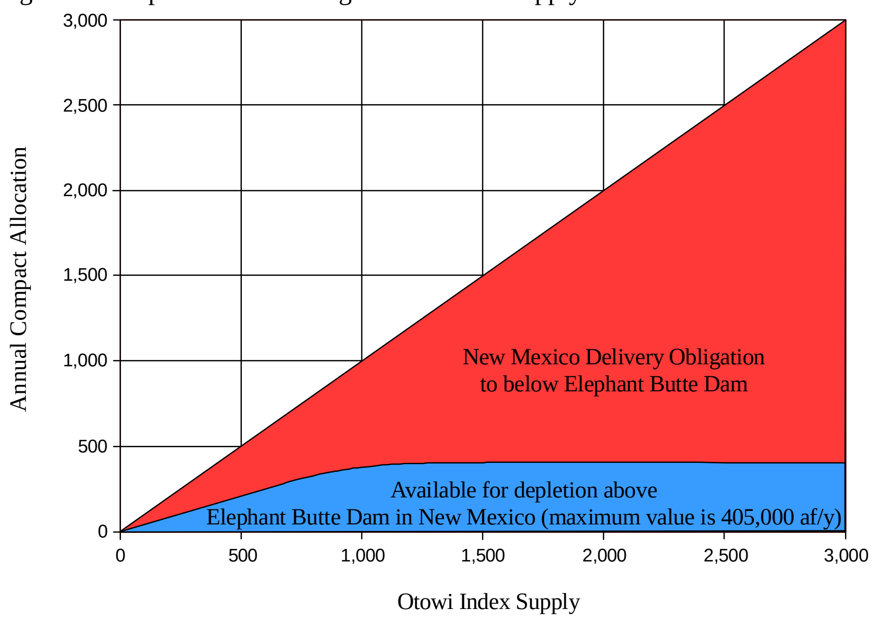

Figure 1: Allocation of Water in New Mexico under the Rio Grande Compact

per year, the Middle Rio Grande region is only entitled to a maximum of 405,000 acre-feet per year of this basin inflow (and less in years of below-average supply). To avoid Compact violations, New Mexico cannot allow over-use of surface or groundwater to diminish the downstream obligation beyond what is allowed under a system of debit/credit accumulation. The Rio Grande Compact constitutes a key constraint on the available water supply in that, unlike conditions in coastal regions or downstream Compact states, truly surplus flows rarely exist. For example, in a year of abundant Otowi Index Supply, the New Mexico allocation is capped at a uniform value; surplus flows passing Otowi must be delivered to Elephant Butte. Furthermore, the Compact allows for a system of credits and debits, in effect, a "paper" water bank with respect to Compact obligations. However, under occasional wet conditions, useable water is spilled from project storage at Elephant Butte Reservoir. In such years of "spill", no annual credit or debit is computed, accrued debits are set to zero and the accrued credits of Colorado and New Mexico are reduced in proportion to their respective credits by the amount of the spill. Under these circumstances (which occurred in 1942, 1985-1988 and 1995), surplus water could be claimed and put to use or stored in the Middle Rio Grande region. The constraint upon allowable depletions in the Middle Rio Grande by the Rio Grande Compact is 'reach-blind", in that delivery is "tallied" only at the downstream point of the reach. The distribution of consumption within the Otowi to Elephant Butte Reservoir reach is not constrained, other than by the nature of uses established under the law of prior appropriation.

New Mexico water law provides for the protection of existing water rights from detriment or impairment by later-priority uses, and administrative procedures accordingly require evaluation of proposed new appropriations and transfers. The Rio Grande is considered fully appropriated under the present state of development; thus, offset of impacts of additional water use is necessary to support new uses.

Additional constraints on water supply are posed by endangered species/habitat restoration issues and pueblo claims. Endangered species and habitat restoration issues frequently involve actions increasing consumption of water; or, seek to attain reach-specific flows. In 2001, Federal agency representatives acknowledged the need to comply with applicable state water laws regarding these projects (Engineer Advisors, 2001). A Conservation Water Agreement between the State of New Mexico and the United States, executed June 29, 2001and a Programmatic Biological Opinion issued by the U.S. Fish and Wildlife Service that same day, both in effect until the end of 2003, provide for actions to meet needs of the endangered Rio Grande silvery minnow and the southwest willow flycatcher. These programs and a Rio Grande Water Management Agreement between the United States and the Middle Rio Grande Conservancy District executed July 3, 2001 have resulted in close monitoring and management of flows in specific reaches to maintain minimum and target flows.

Pueblo "prior and paramount" rights are not presently quantified; thus, they place an additional and uncertain future demand on the water supply. Constraints resulting from exercise of pueblo rights are likely to be reach-specific with respect to individual pueblos.

PHYSICAL CONSTRAINTS ON SUPPLY

Physical constraints relate to water quality, aquifer yield and the variability of surface water supply. The major component of the water supply available to this region is the highly variable mainstem inflow at Otowi. This water supply is supplemented with (a) trans-mountain diversions of the San Juan-Chama Project, and, (b) highly variable quantities of tributary inflow to the region. A probability density function of New Mexico's share of the supply to the region is shown on Figure 2.

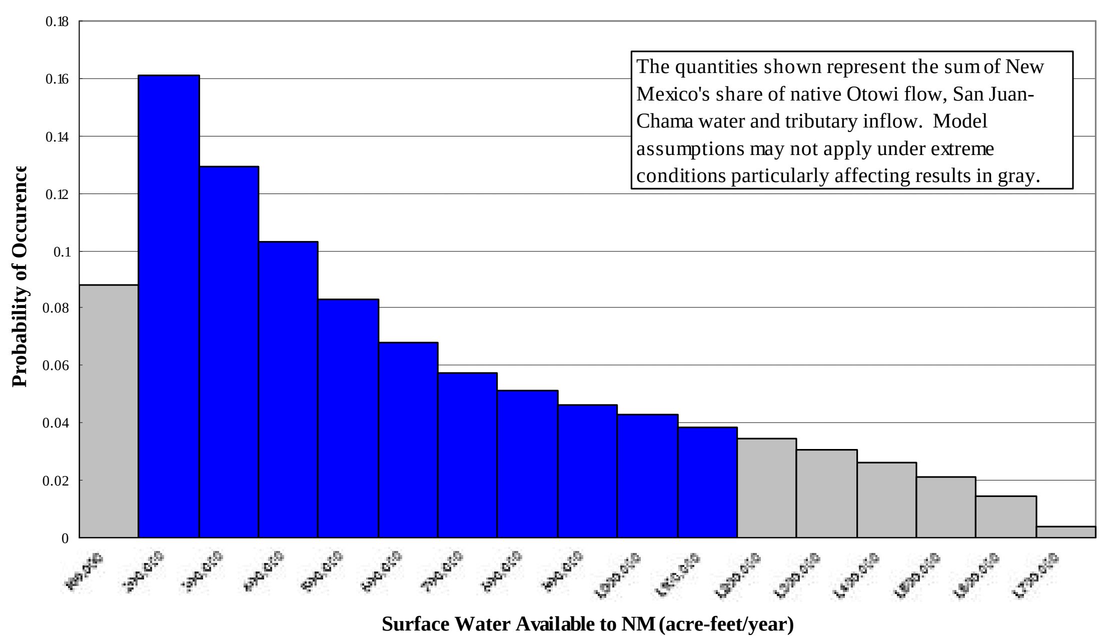

Figure 2: The NM (Middle Rio Grande) share of surface water supply: Probability Density Function

This function shown above was developed with a risk modeling approach, described in a later section of this paper.

Vast quantities of groundwater are present in aquifers, but, on average, can be extracted only to the extent stream depletion from pumping is offset. Figure 3 illustrates the lagged impact of groundwater pumping in the Albuquerque Basin on the flow of the Rio Grande determined by numerical modeling of present development and hypothetical future conditions. Wastewater returns from extracted groundwater

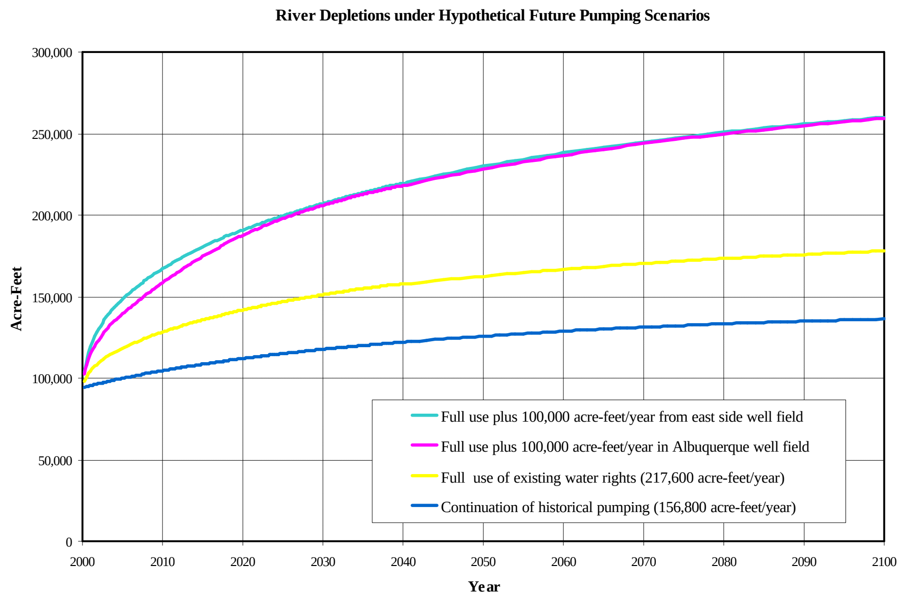

Figure 3: River Depletions due to Groundwater Pumping Alternatives

offer a partial credit to offset groundwater impacts; but the relative benefit of this offset decreases with time as lagged effects reach the river. The current level of groundwater pumping has not reached a "steady-state condition"; thus, depletions to the river from current levels of pumping will continue to increase for many years, even if pumping rates are not increased beyond current levels. In this region, the groundwater "supply" is limited by the availability of offsets for river impacts. Water quality and aquifer yield both limit the ability to tap into portions of the aquifer (deep or distant from the river) that would provide significant lag time benefits for conjunctive management.

CONJUNCTIVE SUPPLY IN THE MIDDLE RIO GRANDE REGION

Methods for Quantifying the Supply and its Variability

The Middle Rio Grande Water Supply Study (S.S. Papadopulos & Associates, Inc., 2000) developed a quantitative and probabilistic description of the conjunctive-use groundwater and surface water supply available to the Middle Rio Grande region in New Mexico. The study area extends from Cochiti Reservoir to Elephant Butte Reservoir, a distance of approximately 175 miles. The probabilistic description of the water supply is developed through a risk analysis model, incorporating the climatic-dependent variability in individual water budget components. Present and future impacts of groundwater pumping on surface water conditions are simulated through modeling analyses and are incorporated into the probabilistic water budget analysis.

The quantified water supply is the amount of water potentially available for use, or depletion, within the study area. This conceptualization represents both the hydrologic supply and the legal limitations imposed by the Rio Grande Compact. The supply is the difference between the basin inflow and the downstream flow obligation determined by the Rio Grande Compact.

The supply is quantified as a set of probability density functions, taking into account the historical variability of inflow components. The period of record used for the modeling is 1950-1998; this period both represent average conditions in the region, as assessed using extended flow and climate records, and coincides with a period for which consistent administrative rules under the Rio Grande Compact have been in effect. To relate the supply to reach specific demands, the available supply is compared to depletions under both current river and future development conditions.

Once the current and future development scenarios were established and the groundwater inputs for each scenario are run, risk modeling was conducted. Risk modeling consisted of 10,000 Monte Carlo simulations for each water development scenario. Results are probability density functions for each individual inflow and outflow term, for total inflow and outflow to the region, and for annual Compact credit-debit. This allowed assessment of Compact delivery probabilities while maintaining and tracking the variability in the water budget for the region.

Results

The study illustrates that variability in several dominant water budget terms leads to significant variability in the water supply (Figure 2). High variability in supply is well recognized in this region and stems both from the highly variable flow in the Rio Grande mainstem, driven primarily by variability in the winter snowpack, and variable summer inflow due to variation in the summer monsoon. There is also high variability in consumption, primarily due to Elephant Butte Reservoir evaporation. Evaporation from the reservoir ranges from 10 to 30% of the overall basin depletion and is a function of reservoir pool elevation and associated surface area.

Consumptive use in the region is predominantly agricultural and riparian water use and evaporation from Elephant Butte Reservoir. An evaluation of the mean depletions occurring within the Middle Rio Grande region, given these assumptions, indicates that consumptive use by crops and riparian vegetation account for approximately 67% of the total use. Consumptive use by reservoir evaporation accounts for approximately 19% of the total, with the remainder of about 14% comprised of urban consumptive use. Of these uses, reservoir evaporation is subject to the largest variability.

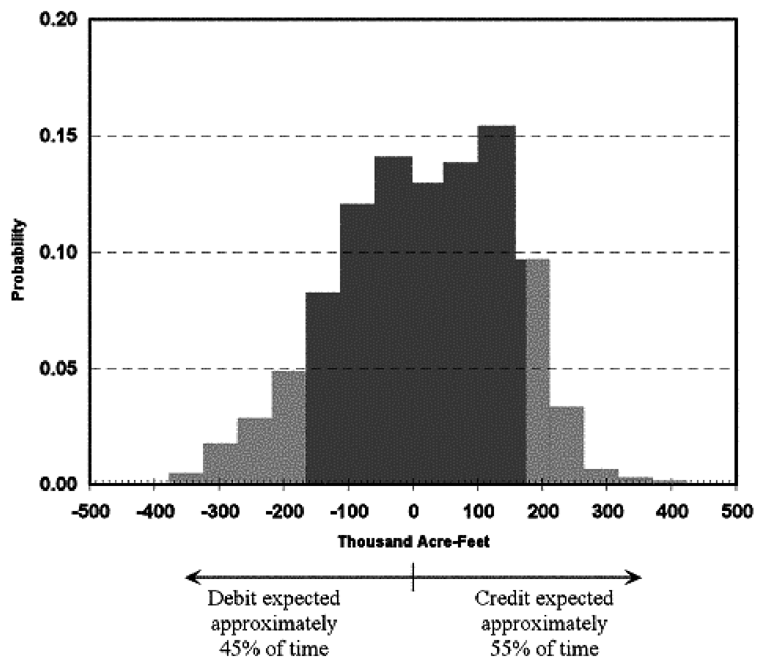

Figure 4: Rio Grande Compact credit-debit probability density function, present development conditions, 2000.

While on average the water supply is approximately equal to the present water demand, this study provides a measure of the variability in water supply conditions. Figure 4 illustrates the calculated credit/debit under the Rio Grande Compact for current conditions as a probability density function. As can be seen, over the long term debits are expected to occur nearly as often as credits, given the present water use conditions and the historic climatic variability.

The prognosis for water supply in future years, without significant intervention, is less favorable. The impact of current levels of groundwater pumping on the Rio Grande flow system continues to grow. Even without an increase in groundwater withdrawal rates, increased depletions will occur to the Rio Grande throughout the next 100 years and beyond. While significant quantities of groundwater are available within aquifer storage, the water cannot be utilized without affecting the river. An analysis of continuation of the present use conditions to the year 2040 indicates that debit conditions will occur more often than credit conditions.

Additional information generated from the risk analysis includes the probability density functions generated for each scenario. These functions indicate that debits and credits exceeding 50,000 acre-feet per year are not uncommon under the growth alternatives. Since Compact rules limit the accumulation of debits, a series of poor years may result in violation, even under the most favorable of these scenarios.

SUMMARY

Legal and physical constraints on the conjunctive use water supply are such that it is unlikely that additional consumptive use can be accommodated in the Middle Rio Grande region. Rather, as lagged impacts of past and present groundwater pumping are translated to the river, it may be necessary to reduce consumptive use within the region to maintain Compact compliance. However, active conjunctive management may provide some opportunity for modulation of variability in supply, thus optimizing the presently available supply. Successful conjunctive management plans will present significant challenges in light of the legal and physical constraints on the water supply in this region.

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