Appendix C-1

Geohydrologic Framework and Hydrologic Conditions in the Albuquerque Basin, Central New Mexico

By Conde R. Thorn, Douglas P. McAda, and John Michael Kernodle

Citation:
Thorn, C.R., D.P. McAda, and J.M. Kernodle. Geohydrologic Framework and Hydrologic Conditions in the Albuquerque Basin, Central New Mexico. U.S. Geological Survey Water-Resources Investigations Report 93-4149, 1993.

Geohydrologic Framework and Hydrologic Conditions in the Albuquerque Basin, Central New Mexico

By Conde R. Thorn, Douglas P. McAda, and John Michael Kernodle

Summary

Recent investigations indicate that the zone of highly productive aquifer, on which the City of Albuquerque has depended for its water supply, is much less extensive and thinner than was formerly assumed. The investigation described in this report focused on gathering recent information to requantify the ground-water resources of the Albuquerque Basin in Central New Mexico. This report describes the geohydrologic framework and current (1993) hydrologic conditions in the Albuquerque Basin.

The Santa Fe Group aquifer system in the Albuquerque Basin is comprised of the Santa Fe Group (late Oligocene to middle Pleistocene) and post-Santa Fe Group valley and basin-fill deposits. The Santa Fe Group and post-Santa Fe Group deposits recently have been divided into four hydrostratigraphic units by other investigators: the lower, middle, and upper parts of the Santa Fe Group, and post-Santa Fe Group valley and basin-fill deposits. The hydrostratigraphic units were further divided into lithofacies units characterized by bedding and compositional properties that exhibit distinctive geophysical, geochemical, and hydrologic characteristics. The Santa Fe Group ranges from less than 2,400 feet in thickness near the margins of the basin to 14,000 feet in the central part of the basin.

Recent information from wells in the Albuquerque area indicate that the most productive part of the Santa Fe Group aquifer system is within the upper part of the Santa Fe Group and to some extent the middle part of the Santa Fe Group. The most productive lithologies are the fluvial axial channel deposits of the ancestral Rio Grande and, to a lesser extent, the pediment slope and alluvial-fan deposits. This most productive part of the aquifer system is now known to be 2 to 6 miles wide and has a remaining saturated thickness of about 600 feet. The basin-floor playa lake deposits of the lower part of the Santa Fe Group produce little ground water. Faul~ and cemented fault planes, where present, impede ground-water flow within the Santa Fe Group aquifer system.

Water levels declined 140 feet from 1960 to 1992 in the east Albuquerque area. Water levels declined 40 feet from 1989 to 1992 in eastern, northwestern, and south-central Albuquerque. The magnitude of these declines is due in part to shifts in pumping centers, the presence of fault barriers, and the limited extent of the axial channel deposits.

On the basis of an assumed storage coefficient of 0.2, the water-level declines in the Santa Fe Group aquifer system in the Albuquerque area represent a decrease in storage due to groundwater withdrawal of an estimated 994,000 acre-feet from 1960 to 1992. The decrease in storage due to ground-water withdrawal from 1989 to 1992 is estimated to be 305,000 acre-feet.

The average total annual surface- and ground-water inflow to the basin from 1974 through 1992 was estimated to be 1,458,400 acre-feet and the total outflow and consumptive loss was estimated to be 1,459,100 acre-feet. The average annual change in storage was estimated to be minus 31,100 acre-feet. The water budget components of inflow and outflow were estimated independently from that of change in aquifer storage. As a result the water budget does not balance; the error in the water budget is 2 percent.

Source: Thorn, C.R., D.P. McAda, and J.M. Kernodle. Geohydrologic Framework and Hydrologic Conditions in the Albuquerque Basin, Central New Mexico. U.S. Geological Survey Water-Resources Investigations Report 93-4149, 1993.

Appendix C-2

Simulation of Ground-Water Flow in the Middle Rio Grande Between Cochiti and San Acacia, New Mexico

By Douglas P. McAda and Peggy Barroll

Citation:
McAda, D.P. and Peggy Barroll. Simulation of Ground-water Flow in the Middle Rio Grande Between Cochiti and San Acacia, New Mexico. U.S. Geological Survey Water Resources Investigations Report 02-4200, 2002.

Simulation of Ground-Water Flow in the Middle Rio Grande Between Cochiti and San Acacia, New Mexico

By Douglas P. McAda and Peggy Barroll

Abstract

This report describes a three-dimensional, finite difference, ground-water-flow model of the Santa Fe Group aquifer system within the Middle Rio Grande Basin between Cochiti and San Acacia, New Mexico. The aquifer system is composed of the Santa Fe Group of middle Tertiary to Quaternary age and post-Santa Fe Group valley and basin-fill deposits of Quaternary age.

Population increases in the basin since the 1940's have caused dramatic increases in ground-water withdrawals from the aquifer system, resulting in large ground-water-level declines. Because the Rio Grande is hydraulically connected to the aquifer system, these ground-water withdrawals have also decreased flow in the Rio Grande. Concern about water resources in the basin led to the development of a research plan for the basin focused on the hydrologic interaction of ground water and surface water (McAda, D.P., 1996, Plan of study to quantify the hydrologic relation between the Rio Grande and the Santa Fe Group aquifer system near Albuquerque, central New Mexico: U.S. Geological Survey Water-Resources Investigations Report 96-4006, 58 p.). A multiyear research effort followed, funded and conducted by the U.S. Geological Survey and other agencies (Bartolino, J.R., and Cole, J.C., 2002, Ground-water resources of the Middle Rio Grande Basin, New Mexico: U.S. Geological Survey Circular 1222, 132 p.). The modeling work described in this report incorporates the results of much of this work and is the culmination of this multiyear study.

The purpose of the model is (1) to integrate the components of the ground-water-flow system, including the hydrologic interaction between the surface-water systems in the basin, to better understand the geohydrology of the basin and (2) to provide a tool to help water managers plan for and administer the use of basin water resources. The aquifer system is represented by nine model layers extending from the water table to the pre-Santa Fe Group basement rocks, as much as 9,000 feet below the NGVD 29. The horizontal grid contains 156 rows and 80 columns, each spaced 3,281 feet (1 kilometer) apart. The model simulates predevelopment steady-state conditions and historical transient conditions from 1900 to March 2000 in 1 steady-state and 52 historical stress periods. Average annual conditions are simulated prior to 1990, and seasonal (winter and irrigation season) conditions are simulated from 1990 to March 2000. The model simulates mountain-front, tributary, and subsurface recharge; canal, irrigation, and septic-field seepage; and ground-water withdrawal as specified-flow boundaries. The model simulates the Rio Grande, riverside drains, Jemez River, Jemez Canyon Reservoir, Cochiti Lake, riparian evapotranspiration, and interior drains as head-dependent flow boundaries.

Hydrologic properties representing the Santa Fe Group aquifer system in the ground-water-flow model are horizontal hydraulic conductivity, vertical hydraulic conductivity, specific storage, and specific yield. Variable horizontal anisotropy is applied to the model so that hydraulic conductivity in the north-south direction (along model columns) is greater than hydraulic conductivity in the east-west direction (along model rows) over much of the model. This pattern of horizontal anisotropy was simulated to reflect the generally north-south orientation of faulting over much of the modeled area. With variable horizontal anisotropy, horizontal hydraulic conductivities in the model range from 0.05 to 60 feet per day. Vertical hydraulic conductivity is specified in the model as a horizontal to vertical anisotropy ratio (calculated to be 150:1 in the model) multiplied by the horizontal hydraulic conductivity along rows. Specific storage was estimated to be 2 x 10-6 per foot in the model. Specific yield was estimated to be 0.2 (dimensionless).

A ground-water-flow model is a tool that can integrate the complex interactions of hydrologic boundary conditions, aquifer materials, aquifer stresses, and aquifer-system responses. This groundwater-flow model provides a reasonable representation of the geohydrologic processes of the basin and simulates many historically measured trends in flow and water levels. By simulating these complex interactions, the ground-water-flowmodel described in this report can provide a tool to help water managers plan for and administer the use of basin water resources. Nevertheless, no ground-water model is unique, and numerous sources of uncertainty remain. When using results from this model for any specific problem, those uncertainties should be taken into consideration.

Source: McAda, D.P. and Peggy Barroll. Simulation of Ground-water Flow in the Middle Rio Grande Between Cochiti and San Acacia, New Mexico. U.S. Geological Survey Water Resources Investigations Report 02-4200, 2002.

Appendix C-3

Ground-Water Resources of the Middle Rio Grande Basin, New Mexico

By James R. Bartolino and James C. Cole

Citation:
Bartolino, James R. and James C. Cole. Ground-Water Resources of the Middle Rio Grande Basin, New Mexico. U.S. Geological Survey Circular 1222, 2002.

Ground-Water Resources of the Middle Rio Grande Basin, New Mexico

By James R. Bartolino and James C. Cole

Executive Summary

The Middle Rio Grande Basin covers approximately 3,060 square miles in central New Mexico, encompassing p; of Santa Fe, Sandoval, Bernalillo, Valencia, Socorro, Torrance, and Cibola Counties. In this report, "Middle Rio Grande Basin" refers to the geologic basin defined by the extent of deposits of Cenozoic age along the Rio Grande from about Cochiti Dam to about San Acacia. In 2000, the population of the Middle Rio Grande Basin was abou1 690,000, or about 38 percent of the population of New Mexico (U .S. Census Bureau, 2001a, 2001b).

In 1995, the New Mexico Office of the State Engineer declared the Middle Rio Grande Basin a "critical basin"; that is a ground-water basin faced with rapid economic and population growth for which there is less than adequate technical information about the available water supply. Though the basin had been intensively studied for a number of years important gaps remained in the understanding of the water resources of the basin. In an effort to fill some of these gaps, the U.S. Geological Survey (USGS) and other Federal, State, and local agencies began the Middle Rio Grande Basin Study, a 6-year effort to improve the understanding of the hydrology, geology, and land-surface characteristics of the basin.

<u>Characteristics of the Middle Rio Grande Basin</u>

Much of the Middle Rio Grande Basin is classified as desert, with mean annual precipitation ranging from 7.6 inches at Belen to 12.7 inches at Cochiti Dam. Mean annual temperatures range from 54.0° Fat Corrales to 56.5° Fat Albquerque and Belen (National Weather Service, 2002).

Scurlock (1998) listed eight main plant communities in the present-day Middle Rio Grande Basin and bordering mountains. They are, in a progression from near the Rio Grande to the mountaintops: riparian, desert grassland, pIains mesa grassland, scrublands, juniper savanna, pinyon-juniper woodlands, ponderosa pine, and subalpine and mixed coniferous forest. The vegetation of the riparian woodland (or bosque) has evolved significantly since the introduction of exotic species prior to 1900 and the construction of flood-control and bank -stabilization projects. During the la: to 70 years, the bosque has developed in an area that was formerly semibarren flood plain.

The Albuquerque area began to grow significantly during and after the Second World War. Postwar growth expanded the economic base of the area and led to a population increase in Albuquerque from about 35,000 to about 200,0(people between 1940 and 1960 (Reeve, 1961). This population growth led to increased pumping of ground water

Geology

The Middle Rio Grande Basin lies in the Rio Grande rift valley, a zone of faults and basins that stretches from Me north to approximately Leadville, Colorado (about 150 miles north of the New Mexico border)-the modern Rio Grande follows this rift valley. The rift formed more than 25 million years ago and initially consisted of a succession of topographically closed basins. These closed basins filled with sediment from the adjacent mountain ranges, du deposits from windblown sand, and volcanic deposits from local volcanic areas such as the Jemez Mountains. Flowing southward into and through the successive basins in the rift, the Rio Grande deposited river-borne sediment and established the through-flowing river seen today. About 3 million years ago the Rio Grande began to erode into sediment, that it had deposited previously, suggesting that the river drained all the way to the Gulf of Mexico. Basin-fill deposit derived from all these sources (deposited in both open- and closed-basin conditions) are known as the Santa Fe G and range from about 1,400 feet thick at the basin margins to approximately 14,000 feet in the deepest parts of the Middle Rio Grande Basin. The Santa Fe Group, in addition to younger alluvial deposits along the Rio Grande, m up the Santa Fe Group aquifer system.

Each of the different settings in which sediment was deposited in the Middle Rio Grande Basin (such as mountainfront alluvial fans, rivers and streams, or sand dunes) resulted in a unique type of sedimentary deposit. These deposits are a complex mixture of different sediment types and grain sizes that change rapidly in the vertical and horizontal directions. Some of these deposits make better aquifer material than others, resulting in variations in the quantity and quality of water produced from wells installed in different locations.

Faults throughout the basin further increase the complexity of the aquifer system. Ground-water flow can be restricted across faults by offsetting units of different permeability or enhanced along faults by the presence of fractured rock. Over time, such fractures may become barriers to flow because of the precipitation of chemical cements in the fractures.

Surface, airborne, and borehole-geophysical techniques have been used to improve the understanding of the geologic framework of the Santa Fe Group aquifer system. Such properties as magnetism, gravity, electrical properties, and natural radioactivity have allowed scientists to better define the boundaries of the aquifer system, faults, and areas underlain by a more permeable aquifer material.

Geologic information collected for the Middle Rio Grande Basin Study has been incorporated into anew conceptualization of the composition of the aquifer system. This improved understanding has been formalized into a three-dimensional geologic model that is the basis for anew ground-water-flow model of the basin.

Surface Water

In the Middle Rio Grande Basin, the surface- and ground-water systems are intimately linked through a series of complex interactions. These interactions can make it difficult to recognize the boundary between the two systems, and changes in one often affect the other. The most prominent hydrologic feature in the basin is the Rio Grande, which flows through the entire length of the basin, generally from north to south. The fifth longest river in North America, its headwaters are in the mountains of southern Colorado. Flow in the Rio Grande is currently (2002) regulated by a series of dams and storage reservoirs. The greatest flows occur in late spring as a result of snowmelt and for shorter periods during the summer in response to rainfall. Historically, the Rio Grande has flowed year-round through much of the basin, except during severe drought. Within the basin, tributary steams, wastewater-treatment plants, flood-diversion channels from urban areas, and a large number of arroyos and washes contribute flow to the river.

The inner valley of the Rio Grande contains a complex network of irrigation canals, ditches, and drains. During irrigation season, water is diverted from the river at four locations in the basin and flows through the Rio Grande inner valley in a series of irrigation canals and smaller ditches for application to fields. This water recharges ground water, is lost to evaporation, is transpired by plants, or is intercepted by interior drains and returned to the river. Besides the Rio Grande, the inner-valley surface-water system also contains a system of riverside drains, which are deep canals that parallel the river immediately outside the levees. The drains are designed to intercept lateral ground-water flow from the river, thus preventing waterlogged conditions in the inner valley. The drains then carry this ground water back to the Rio Grande.

Estimated and measured annual surface-water inflow into the Middle Rio Grande Basin is about 1,330,000 acre-feet (for water years 1974-2000) and measured annual surface-water outflow is about 1,050,000 acre-feet (for water years 1974-2000). Currently (2002), the primary consumptive use by humans of surface water in the Middle Rio Grande Basin is irrigation in the inner valley of the Rio Grande. Other water is consumed by reservoir evaporation, recharge to ground water, and evapotranspiration by riparian vegetation. Other nonconsumptive uses include recreation, esthetics, and ceremonial use by Native Americans.

Ground Water

The Santa Fe Group aquifer system is divided into three parts: the upper (from less than 1,000 to 1,500 feet thick), middle (from 250 to 9,000 feet thick), and lower (from less than 1,000 to 3,500 feet thick). In places, the upper part and(or) the middle part of the aquifer has eroded away. Much of the lower part may have low permeability and poor water chemistry; thus, ground water is mostly withdrawn from the upper and middle parts of the aquifer. Only about the upper 2,000 feet of the aquifer is typically used for ground-water withdrawal. Ground water from the Santa Fe Group aquifer system is currently the sole source of water for municipal supply, domestic, commercial, and industrial use in the Middle Rio Grande Basin.

The depth to water in the Santa Fe Group aquifer system varies widely, ranging from less than 2 feet near the Rio Grande to about 1,180 feet in an area west of the river beneath the West Mesa. Effects of ground-water pumping are not evident on the earliest ground-water-level maps of the Middle Rio Grande Basin (1936 conditions). However, a ground-water-level map showing more recent conditions (winter 1994-95) shows well-defined cones of depression in the Albuquerque and Rio Rancho areas and marked distortion of water-level contours across the Albuquerque area. Water levels in a network of 255 wells are being measured to monitor further water-level changes.

Water enters the Santa Fe Group aquifer system in four main settings: mountain fronts and tributaries to the Rio Grande, the inner valley of the Rio Grande, the Rio Grande, and subsurface basin margins. Water entering the aquifer in the first three settings is usually termed recharge, whereas water entering the basin in the subsurface is typically termed underflow.

Ground water discharges from the Santa Fe Group aquifer system in several ways: pumpage from wells, seepage into the Rio Grande and riverside drains, springs, evapotranspiration, and subsurface outflow to the Socorro Basin. If ground-water pumpage from an aquifer exceeds recharge, water levels in the aquifer decline, as has been observed in the Middle Rio Grande Basin. These declining water levels can have adverse effects that influence the long-term use of the aquifer, including deterioration of water quality, water-well problems, and land subsidence.

Ground-Water Chemistry

A useful approach to characterizing ground-water chemistry in the Middle Rio Grande Basin is to divide the basin into 13 zones, or regions, of different water-chemistry characteristics. The median concentrations of two constituents (chloride and sulfate) exceed the U.S. Environmental Protection Agency (USEPA) secondary standards for drinking water in several zones. Arsenic concentrations in ground water exceeded the USEPA primary standard (finalized in 2001) of 0.010 milligram per liter (mg/L) of arsenic in one zone.

Most of the ground water in the basin is not very susceptible to contamination because the depth to water in most areas is greater than lOO feet. Deposits in the inner valley of the Rio Grande, however, are more susceptible to contamination because the depth to water is generally less than 30 feet. There are four Superfund sites, three RCRA (Resource Conservation and Recovery Act of 1976) sites, and about 700 former and present leaking underground-storage-tank sites in the Middle Rio Grande Basin.

Ground-Water-Flow Modeling

Several ground-water-flow models of the Middle Rio Grande Basin have been developed. The most recent (2002) is a USGS model that incorporates new hydrogeologic data collected since 1995 (McAda and Barroll, 2002). The model encompasses the entire thickness of the Santa Fe Group in order to simulate probable flow paths in the lower part of the aquifer. Model simulations show that (I) prior to installation of the riverside drains along the Rio Grande, the river was losing flow, though currently (2002) the drains intercept much of this flow and divert it back into the river; (2) the Rio Grande and riverside drains are so closely related, especially during the nonirrigation season, that they function as one system; (3) the hydrologic connection between the Rio Grande and underlying Santa Fe Group aquifer system is variable and changes with the lithology of a particular river reach; (4) in much of the Santa Fe Group aquifer system throughout the basin, water removed from storage is partially replaced during the nonirrigation season; and (5) mountain-front recharge to the Santa Fe Group aquifer system is less than amounts estimated by previous models.

The McAda and Barroll (2002) ground-water-flow model of the Middle Rio Grande Basin does not make any projections of future conditions, though it could be modified to do so. However, it does provide water-resource managers a more accurate and powerful tool than previous models to evaluate the potential effects of management decisions.

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McAda, D.p. and Peggy Barroll. 2002. Simulation of Ground-water Flow in the Middle Rio Grande Basin between Cochiti and San Acacia, New Mexico. U.S. Geological Survey Water Resources Investigations Report 02-4200.

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U.S. Census Bureau. 2001a. American Factfinder. http://factfinder.census./gov

U.S. Census Bureau. 2001b. State and County Quickfacts. http://quickfacts.census.gov

Source: Bartolino, James R. and James C. Cole. 2002. Ground-Water Resources of the Middle Rio Grande Basin, New Mexico. U.S. Geological Survey Circular 1222.

Appendix C-4

Future Water Use Projections for the Middle Rio Grande Water Planning Region

Prepared by the Middle Rio Grande Council of Governments in collaboration with the Middle Rio Grande Water Assembly for the New Mexico Interstate Stream Commission

September 2001

FINAL DRAFT

Future Water Use Projections for the Middle Rio Grande Water Planning Region

September 2001

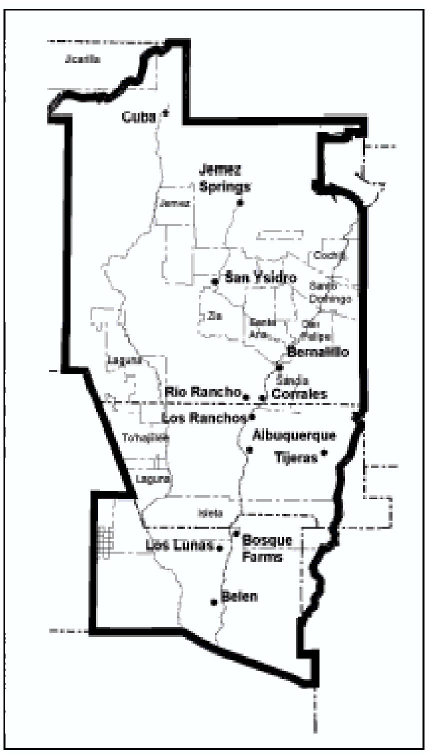
This report was prepared by the Middle Rio Grande Council of Governments staff, working in collaboration with the Middle Rio Grande Water Assembly; and was supported in part by funding from the New Mexico Interstate Stream Commission.

Future Water Use Projections
for the Middle Rio Grande Water Planning Region

Executive Summary

The Middle Rio Grande Water Planning Region is one of 16 water-planning regions in New Mexico. The planning region essentially consists of Sandoval, Bernalillo, and Valencia counties, an area encompassing 5,495 square miles. The planning region includes various federally owned lands as well as lands belonging to 13 different Native American Governments. The planning region includes all of the Jemez River watershed and portions of the Rio Grande and Rio Puerco watersheds. The planning region is subdivided along the boundaries of these watersheds.

Figure ES-1 - The Middle Rio Grande Water Planning Region



The Middle Rio Grande faces challenges of growing population, expanding urbanization, and increasing demands for scarce water. It is an arid region, averaging only 9 inches of rain per year. The Rio Grande, lifeblood for many, not only provides water to our region, but to many others both upstream and downstream. Two countries, three states, and several Native American entities rely on its waters. Our region alone contains three watersheds, each with its own characteristics and problems. Within this Middle Rio Grande water planning region, there are 13 Native American governments, three counties and several municipalities, each with varying responsibilities for managing water resources. The task of balancing water use and availability is necessary to maintain the quality of life throughout the region.

The Middle Rio Grande water-planning region is not alone in having to balance increasing demands for water. The State of New Mexico encourages regional water planning to manage those demands. In keeping with this effort, our region has undertaken the development of such a plan. In so doing, we are attempting to answer some basic questions:

- What is our available water supply?
- What historic demands have we made and are we presently making upon the water supply?
- What demands do we expect will be made upon the water supply in the next 40 years?
- How will we meet the future demands with supply?

The first two questions have been considered in other reports, and in the final plan the last question is to be addressed, with the alternatives reflecting the region's goals and objectives. The purpose of this report is to anticipate what the future demands on the water resource will be. The estimated demands are based upon projected trends in population growth and changes in land use, and are described in terms of withdrawals[1] and depletions[2]. Some variations of projections have been devised in order to illustrate a range of future water usage and the subsequent impacts on water supply. However, the primary purpose is to present a reference baseline of our future water situation given our current land and water management practices and the trends that exist today.

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[1] Withdrawal: water that is either diverted from the surface-water system or pumped from wells. Some of this water may return to either the surface-water or groundwater system.

[2] Depletion: that part of a withdrawal that has been evaporated, transpired, or incorporated into crops or products, consumed by people or livestock, or otherwise removed from the water environment. It includes the portion of ground-water recharge resulting from seepage or deep percolation (in connection with a water use) that is not economically recoverable in a reasonable number of years, or is not usable. Same as consumptive use.

Present Day Water Supply and Use

The population of the planning region has increased by 21% over the past 10 years, from 589 thousand to more than 712 thousand residents. Despite a decline in irrigated agriculture, our water supplies are already stretched to, or beyond, their limits. The water supplies of the Middle Rio Grande region have been documented in a number of reports prepared over the last several years. A group of technical experts, working on behalf of the Middle Rio Grande Water Assembly, prepared a water budget for the Middle Rio Grande region in 1999. Their report, entitled *Middle Rio Grande Water Budget*, was based on average flows for the period from 1972 to 1997. The report concluded that:

- We are depleting our reserves of groundwater in the region by approximately 70,000 acre-feet[3] per year.

Another report, entitled *Middle Rio Grande Water Supply Study*, was completed by the firm S.S. Papadopulos & Associates, Incorporated, in August 2000 for the U.S. Army Corps of Engineers and the New Mexico Interstate Stream Commission. This latter report concluded that:

- On average, the present water supply is barely adequate (including San Juan-Chama Project water and groundwater withdrawals) to meet the present demands in the Middle Rio Grande region, and

- The water supply is highly variable, due to the high variability in Otowi inflow[4] and the high variability in evaporation from the Elephant Butte Reservoir.

In the report entitled *Historical And Current Water Use In The Middle Rio Grande Region*, prepared by John Shomaker & Associates, Inc. together with PioneerWest in June 2000, our current (as of 1995) regional water use was assessed. The Shomaker

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[3] An acre-foot is the amount of water required to cover an acre (43,560 square feet) to a depth of one foot and equal to 325,851 gallons.

[4] Otowi inflow is the amount of water flowing in the Rio Grande at the Otowi stream gage located at the river crossing on the road between Santa Fe and Los Alamos.

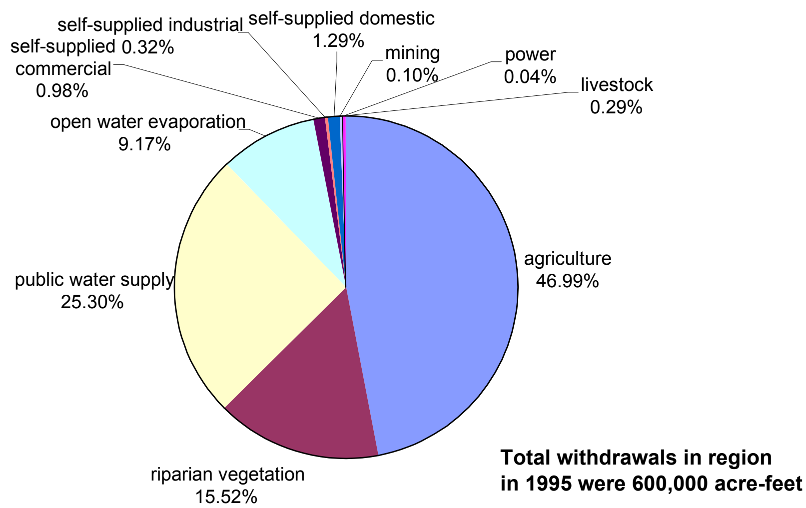
report utilized an adaptation of the water use categories defined by the State Engineer. Shomaker reported the withdrawals and consumptive use[5] of water under the following categories: public water supply, riparian vegetation, agriculture, livestock, power, mining, self-supplied domestic, self-supplied industrial, self-supplied commercial, and open water evaporation.

Shomaker concluded that:

- total withdrawals in the planning region in 1995 were 600,000 acre-feet
- total depletions (consumptive use) in the planning region in 1995 were 340,000 acre-feet.

The relative proportions of withdrawals reported by Shomaker are shown in Figure ES-2. This figure illustrates the significance of agriculture, riparian vegetation, public water supply, and open water evaporation as the major withdrawals in the region.

Figure ES-2 - Distribution of withdrawals by category in total region, 1995



Reference: Shomaker report, Figure 50 on page 88

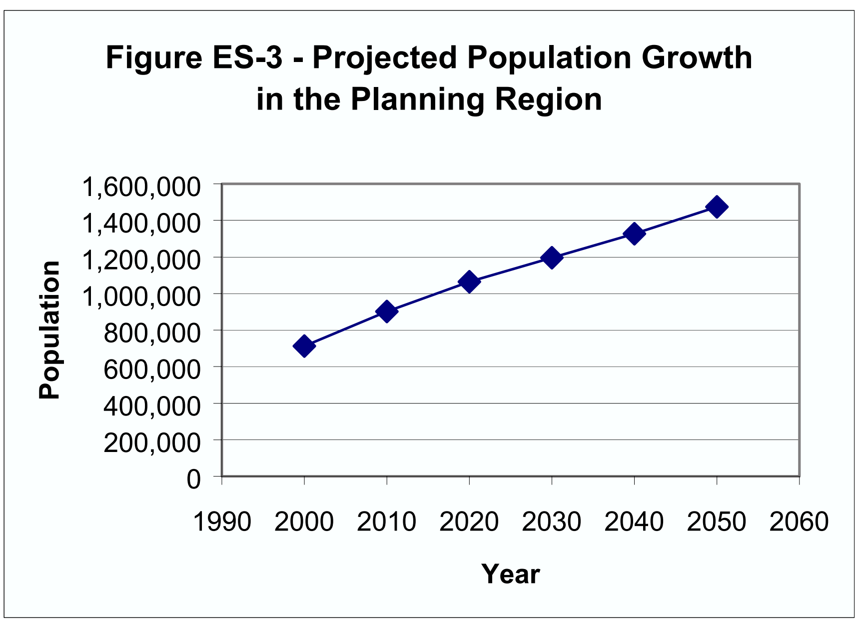
[5] Consumptive use means depletion.

Land Use and Future Projections

The Middle Rio Grande Council of Governments (MRGCOG) created an initial regional land-use map using 1996 as the base year for the *Focus 2050 Regional Plan* project. The purpose of the Focus 2050 project was "to create a long-range strategy for managing growth and development within the region through the year 2050" (Resolution of Board of Directors, February 10, 2000). MRGCOG's regional land-use map includes 18 land-use categories.

Water withdrawal and depletion coefficients for the land use categories were derived by correlating water-use information, as reported by Shomaker, with the land-use categories developed by MRGCOG.

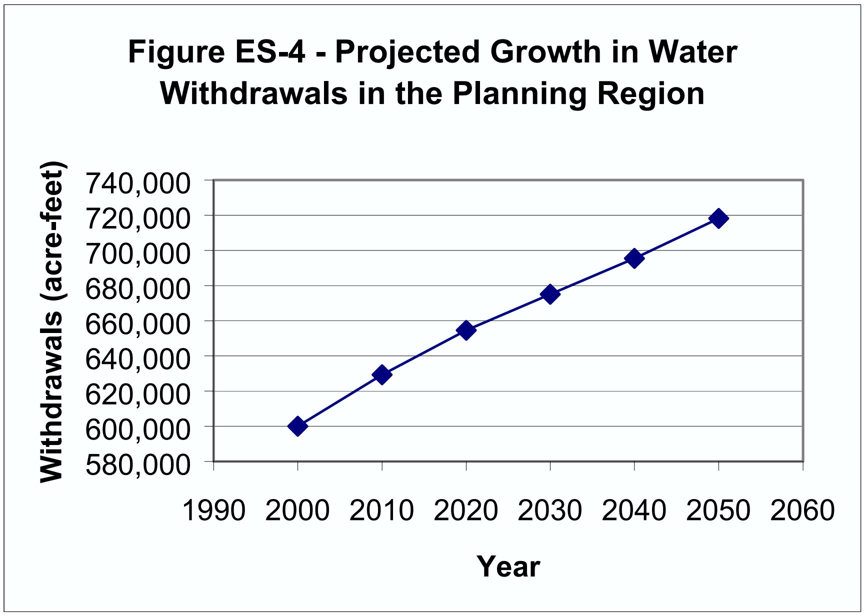
Projections of future withdrawals and depletions were calculated by combining withdrawal and depletion coefficients with a map of future land uses. The future land-use map used for this project was prepared in conjunction with the Focus 2050 project. This future is based on a projected future population of 1.47 million people in the planning region and assuming a continuation of the current trends in land development. The population projections used to calculate future water use are shown in Figure ES-3.



Significant factors influencing future water use include population and economic growth and anticipated decreases in irrigated agriculture. The projected withdrawals calculated at 10-year intervals of time for each of the regional land-use categories considered in this study are shown in Table ES-1. (Note: The numbers displayed in this table are not a representation of accuracy, but are the direct result of multiplying withdrawal coefficients by a specified amount of land under a specified land use category.) Also, as a comparison to the projected population growth, the projected water withdrawals for the region as a whole are shown in Figure ES-4.

Table ES-1 – Projected withdrawals at 10-year intervals for the planning region

	Withdrawals (acre-feet)					
Land-Use Category	**2000**	**2010**	**2020**	**2030**	**2040**	**2050**
Single-family residential	108,557	146,451	179,297	205,803	232,265	261,680
Multi-family residential	10,000	11,670	13,117	14,285	15,451	16,747
Major retail commercial	2,451	2,658	2,837	2,982	3,126	3,287
Mixed and minor commercial	19,149	23,382	27,051	30,012	32,967	36,253
Office	2,042	3,001	3,832	4,502	5,172	5,916
Industrial and wholesale	5,865	6,535	7,116	7,585	8,053	8,573
Institutions	1,602	1,690	1,767	1,829	1,890	1,959
Schools and universities	3,069	2,979	2,900	2,837	2,774	2,704
Airports	5,123	4,894	4,696	4,536	4,376	4,198
Transportation and major utility corridors	591	570	552	537	522	506
Irrigated agriculture	281,934	265,568	251,383	239,936	228,508	215,804
Rangeland and dry agriculture	0	0	0	0	0	0
Major open space and parks (with water use)	5,001	4,795	4,616	4,471	4,327	4,167
Major open space and parks (no water use)	0	0	0	0	0	0
Natural drainage and riparian systems	148,140	148,198	148,248	148,288	148,328	148,373
Urban vacant and abandoned	0	0	0	0	0	0
Landfills and sewage treatment plants	2,131	2,164	2,193	2,216	2,239	2,265
Other urban non-residential	1,347	1,697	2,001	2,246	2,490	2,762
Kirtland Air Force Base	3,000	3,002	3,004	3,005	3,006	3,008
Totals:	**600,002**	**629,254**	**654,608**	**675,069**	**695,496**	**718,202**



The forecast for future withdrawals shown in Figure ES-4 correlates directly with the slope of the graph shown in Figure ES-3, given the base case projection for water planning purposes in the Middle Rio Grande region. Again, this implies a decrease in irrigated agriculture associated with an increase in population, with no changes in water management. The base-case projection indicates that regional withdrawals could increase to 718 thousand acre-feet per year by the year 2050, an increase of 20% compared to current withdrawals. This projection will be used in future efforts to evaluate the effects of potential water-supply and water-management alternatives.

In addition to the base-case projection, several variations were calculated to show a range of potential projections for the future. In one variation, agricultural acreage was held constant rather than being reduced by the projected 8,800 acres as assumed in the base case projection. In two other variations, various levels of conservation (15% and 33%) were examined. These variations to the base-case projection indicate that if we were to stabilize our withdrawals at the current level, we may have to reduce our per capita consumption by 33% by the year 2050. In order to meet the goal of the regional water plan, balancing our use with renewable supply, then we will have to reduce total water consumption in the region even further.

Appendix C-5

Some Statistics on Attitudes and Preferences of Residents of the Middle Rio Grande Water Planning Region Regarding Water Issues

Summary from the report, Attitudes and Preferences of Residents of the Middle Rio Grande Water Planning Region Regarding Water Issues, prepared by the Institute for Public Policy at the University of New Mexico, June 2000.

Summary prepared by the Middle Rio Grand Water Assembly in collaboration with the Middle Rio Grande Council of Governments

MRGWA/MRGCOG

Some Statistics on Attitudes and Preferences of Residents of the Middle Rio Grande Water Planning Region Regarding Water Issues.

In December 1999, the Middle Rio Grande Water Assembly (MRGWA) in conjunction with the Middle Rio Grande Council of Governments (MRGCOG) recognized that a public opinion survey could be an effective means of determining public views on pertinent water issues. The MRGWA Action Committee believed that such views could be used, in part, to help shape a regional water plan. In turn, in order to achieve this objective, the MRGCOG contracted with the University of New Mexico Institute for Public Policy (UNM/IPP) to survey an "oversample" of residents in the Middle Rio Grande (MRG) water planning region as part of a broader statewide survey. Between March 21 and May 15, 2000, UNM/IPP conducted its semiannual statewide *Public Opinion Profile* survey of New Mexico Residents. Its major focus was water issues, and its results included responses from individuals in 1156 households randomly drawn from throughout the three counties in the MRG region.

To pinpoint what water issues people find important, the UNM/IPP asked respondents to rate seven potential issues on a one-to-seven scale, where one meant "not an important problem" and seven meant "an extremely important problem." Table 1 presents the results in order of MRG respondents' evaluation of their importance.

Table 1
Relative Importance of Specific Listed "Water Issues"
(1 = "not an important problem"; 7 = "extremely important problem")
(All results reported are "means," i.e. average responses)

	MRG	Statewide
The quality of the water that my family and I drink and bathe in.	6.19	6.09
Having enough water in our rivers to protect endangered fish and to keep the trees, vegetation, and other wildlife along the riverbanks healthy.	5.80	5.74
The rate at which we are using up the underground water supply.	5.67	5.67
Whether population and economic growth are out of balance with the limited water resources of the state.	5.14	5.23
Whether New Mexico can meet its legal obligations to Texas and Mexico, and still have enough water to meet the needs of New Mexicans.	4.96	4.98
Making enough water available to attract and keep high–tech industries that offer good–paying jobs in the region.	4.88	4.97
Whether there is enough water to maintain residential lawns and gardens.	4.14	4.27

Another section of the survey required respondents to make implicit choices among competing demands for a limited supply of water by rating the importance of various uses. The wording of the set-up question was as follows:

> As you probably know, there are many competing demands for the water found underground and in New Mexico's rivers, lakes, and streams. These demands come from cities, households, agriculture, industry, and from the environment. I will read you a list of possible uses of water. Using a scale from **zero** to **ten** where **zero means that you do not care whether water is available for that use** and **ten means that you want to be sure that water is available for that use**, please rate the value you personally place on each of the following uses of water.

In table 2, we summarize the results from thirteen possible water uses. The neutral or midpoint on this 0 to 10 scale is 5. Results are presented in order of the value assigned by MRG respondents.

Table 2
Values Assigned to Various Uses of Water
(Scale: 0 = "don't care whether water is available for that use;
10 = "want to be sure water is available for that use")
(All results reported are "means," i.e. average responses)

	MRG	Statewide
Indoor use in existing homes	8.17	8.32
Preserving the native cottonwood forest and vegetation along river banks known as the bosque, that creates habitat for a variety of different animal species	7.69	7.50
Irrigation for farms	7.59	7.99
Providing food and refuge for fish, birds, and other animals	7.54	7.56
Indoor use in new housing developments	6.62	6.94
Cultural and religious uses in some villages and pueblos	6.38	6.34
Recreation, such as fishing and rafting	6.14	6.40
Community parks and sports fields	5.66	5.52
New industrial uses, such as manufacturing processes	5.29	5.41
Watering existing yards and landscaping	4.40	4.57
Use for yards and landscaping in new developments	3.82	4.14
Watering golf courses	3.18	2.93
Swimming pools for individuals homes	2.68	2.58

Source: Brown, John R., Nancy Carrillo, and Hank Jenkins-Smith. Attitudes and Preferences of Residents of the Middle Rio Grande Water Planning Region Regarding Water issues. Summary Report to the Action Committee of the Middle Rio Grande Water Assembly and the Middle Rio Grande Council of Governments. UNM Institute for Public Policy/The University of New Mexico; Albuquerque, New Mexico, June 2000.

Appendix C-6

Middle Rio Grande Water Supply Study

Prepared by S.S. Papadopulos & Associates, Inc.

August 4, 2000

Middle Rio Grande
Water Supply Study

S.S. PAPADOPULOS & ASSOCIATES, INC.
Boulder, Colorado

August 4, 2000

1877 Broadway, Suite 703, Boulder, Colorado 80302-5245 • (303) 939-8880

Middle Rio Grande Water Supply Study

Prepared For:

U. S. Army Corps of Engineers
Albuquerque District

Contract No. DACW47-99-C-0012

And

New Mexico Interstate Stream Commission

Prepared By:

S.S. PAPADOPULOS & ASSOCIATES, INC.
Boulder, Colorado

August 4, 2000

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Executive Summary

Scope of Work

The Middle Rio Grande Water Supply Study develops a quantitative and probabilistic description of the conjunctive-use groundwater and surface water supply available to the Middle Rio Grande region, under the constraints of the Rio Grande Compact. The Middle Rio Grande region in New Mexico extends along the Rio Grande, north to south, from Cochiti Reservoir to Elephant Butte Reservoir, a distance of approximately 175 miles (Figure ES-1). This study, conducted for the U.S. Army Corps of Engineers (COE) and the New Mexico Interstate Stream Commission (ISC), provides information to support regional water planning efforts for the Middle Rio Grande and describes conditions relevant to maintaining compliance with the Rio Grande Compact.

An Executive Steering Committee (ESC) was commissioned to provide technical advice and guidance regarding preparation of the Middle Rio Grande Water Supply. The ESC, including technical representatives of a diverse group of stakeholders and agencies within the Middle Rio Grande region, and interested observers, met periodically to review the progress of the study and to provide interim comments.

The regional water planning process focuses on five questions:

- What is the water supply?
- What is the water demand?
- What alternatives exist to meet demand with available supply, including water conservation?
- What are the advantages and disadvantages to these alternatives?
- What is the best plan and how will it be implemented?

This study addresses the first of these questions: characterization of the water supply. Other studies will be conducted by regional planning entities to address the remaining water planning questions.

Key products generated in this study include:

- A summary of available data in the Middle Rio Grande Basin;
- A bibliography of water-resource reference material;
- A discussion of previous *water budget and depletion* studies;
- Quantification of the impacts on flow of the Rio Grande from groundwater pumping;
- Quantification of the natural variability of water sources for the Middle Rio Grande region;
- A *risk analysis* evaluation of the water supply, identifying the range of expected water supply conditions;
- Evaluation of the probability of achieving compliance under the Rio Grande Compact, given present water demands; and, under a hypothetical alternative.

These products provide an up-to-date integration of past and on-going technical studies that can be used in the regional water planning process. This study differs from previous water supply studies in that it considers a range of water supply conditions, rather than average conditions, or conditions in specific years. The range of water supply conditions considered in this study reflects the climatic variability experienced in this region over the past 50 years.

Probabilistic Description of the Water Supply

In this study, a probabilistic water budget is developed for the stream system in the Middle Rio Grande region. Water inflows and uses are quantified to reflect both climatic variability and present development conditions. For each water budget term exhibiting climate dependency, the range and nature of this variability is described. Some water budget terms are predominantly influenced by land use or development conditions. These terms were quantified according to the present development condition.

Groundwater conditions are linked to the stream flow system using the groundwater model of the Albuquerque Basin. Through this approach, hydrologic processes occurring in the aquifer that have effects on the stream, for example, precipitation, recharge and groundwater pumping, are integrated into the water supply analysis.

The available water supply to the Middle Rio Grande region is constrained by the terms of the Rio Grande Compact. Figure ES-2 illustrates the quantity of Rio Grande inflow at Otowi that is available for use in the Middle Rio Grande region, and compares this to the amount designated for use below Elephant Butte Reservoir. The Middle Rio Grande region's share of the Otowi inflow is capped at about 400,000 acre feet per year when the inflow exceeds 1.1 million acre feet per year.

Reflecting the variability in water budget terms, including both Otowi inflow and other inflows to the region, a profile is derived of the *available* water supply (the water available for complete use, or depletion) in the Middle Rio Grande region. This profile accounts for the Rio Grande Compact delivery obligations (the Elephant Butte Scheduled Delivery) corresponding to the range of water supply conditions (as related to the Otowi Index Supply). A profile of the expected range of Compact credit/debit conditions is also developed, by subtraction of the estimated water depletions from the available supply, and comparison to Compact delivery requirements.

This analysis provides the *mean* (average) water supply conditions and the range of water supply conditions that are likely to occur given the climatic variability in flow. Figure ES-3 provides a schematic of the mean annual Middle Rio Grande water supply under present use conditions. This figure shows the available water supply at various points along the river, after deducting the Compact obligation from expected flows. This figure also shows the magnitude of depletions to the flow resulting from present water uses within each reach. As shown on this figure, given present uses in the basin, the available supply (including trans-mountain diversions and wastewater returns), on average, is virtually consumed within the Middle Rio Grande region. This analysis reflects the non-linearity of the Rio Grande Compact schedule, and appropriately handles the calculation of the average obligation for a range of conditions.

Figure ES-4 illustrates the relative magnitude of consumptive uses within the Middle Rio Grande region, under current land use and groundwater development conditions and assuming reservoir evaporation as averaged over the 1950-1998 period. 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 accounts 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. Evaporation from Elephant Butte Reservoir ranges from 10% to 30% of the overall basin depletion, depending primarily on the reservoir pool elevation and associated surface area.

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 ES-5 illustrates the calculated credit/debit under the Rio Grande Compact as a *probability distribution function*. This type of graph is used to show how often a particular event will occur. In this case, the graph indicates how often the credit or debit will likely occur at various levels, given the climatic variability of water inflow and depletion terms. These analyses indicate that 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 stream. An analysis of continuation of the present use conditions to the year 2040 indicates that debit conditions will occur more often than credit conditions.

An alternative scenario involving increased groundwater pumping was evaluated with the probabilistic model, to evaluate the impacts of approximately doubling the withdrawal of groundwater from the aquifer. Under this scenario, within 40 years the stream-referenced water supply is expected to diminish by about 43,000 acre-feet per year, resulting in even more frequent occurrences of Compact debit conditions. The probability distribution function for this hypothetical alternative is illustrated on Figure ES-6. Clearly, this alternative would not be acceptable without offsets from another water use sector. In addition, such an alternative would result in extreme water level declines and potentially poor groundwater quality.

The analyses conducted for this study illustrate the general magnitude of the available water supply, and its expected variability, assuming the degree of climatic variations observed during the past 50 years. These results provide a realistic framework for water resource planning. At the same time, it is useful to understand what is not represented in these results:

- This study does not model hydrologic conditions resulting from a specific sequence of annual conditions; in other words, predictions based on antecedent conditions are not provided.

- This study does not represent hydrologic responses to extreme events. While the available record includes both wet and drought periods, and the modeled inflow encompasses this range of conditions, the development of water-budget relationships for extreme conditions was beyond the scope of this study.

- This study does not provide localized evaluations of the water supply. Study assumptions are based on existing data sets, most of which are adequate for basin-scale water supply evaluations. In evaluating specific water supply alternatives as part of the water planning process, additional information will be needed to refine understanding of hydrologic conditions and relationships as they relate to proposed alternatives.

- This study does not provide a "turn-key" water planning model. The probabilistic water budget model presented in this study is based on a series of empirical relationships and specific simulations with the Albuquerque Basin groundwater model. Assumptions and structuring of the underlying models may require re-specification, depending on the parameters of an alternative selected for evaluation.

As the water planning process progresses to the stage of water supply alternative analysis, additional evaluations in some of the above-noted areas may prove useful.

Summary of Conclusions

Key water supply and hydrologic concepts illustrated or derived from this study, with implications for water planning are:

- On average, *the present water supply is barely adequate* (including San Juan-Chama Project water and groundwater withdrawals) to meet the present demands in the Middle Rio Grande region.

- *The water supply is highly variable*, due to the high variability in Otowi inflow and the high variability in evaporation from the Elephant Butte Reservoir.

- Given the variability of water budget terms, Rio Grande Compact *debit conditions are expected to occur nearly as frequently as credit conditions.*

- *Under conditions of increased water use in any sector, a reduction of water use from other sectors is requir*ed to maintain overall water supply balance, and to avoid increasing the likelihood of incurring Rio Grande Compact debits.

- The groundwater supply is not an independent, disconnected water supply. *Use of groundwater results in diminished flows of the Rio Grande* that will occur in the present and continue into the future.

- The location of groundwater well fields affects short-term timing of impacts to the river; however, *regardless of location, the impacts of groundwater pumping eventually reach the river and require offset*.

- *Recharge of groundwater from the stream system reduces the flow of the Rio Grande* available to meet obligations under the Rio Grande Compact.

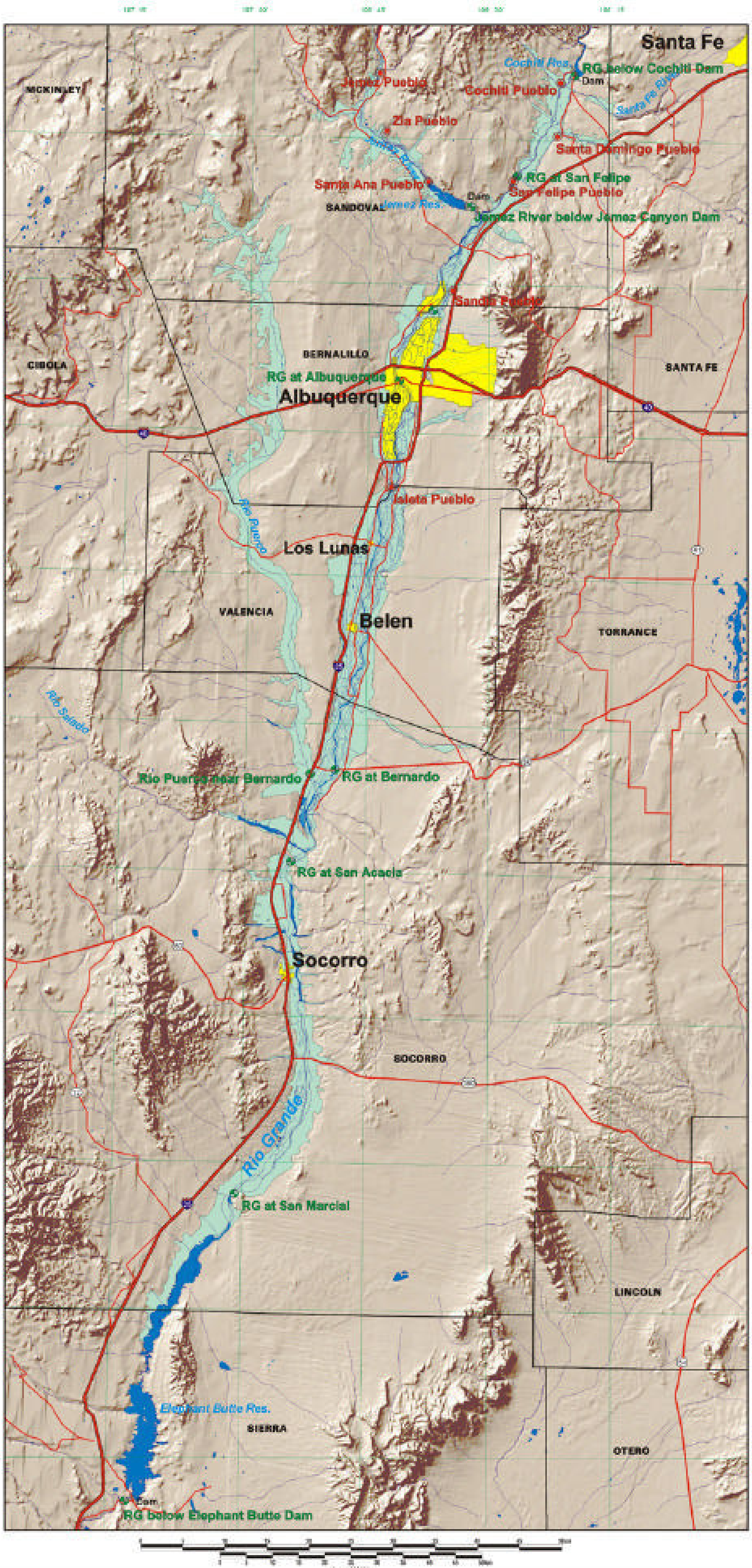
- *The water supply from Otowi to Elephant Butte is essentially a single supply*; water use in every sub-region of the Middle Rio Grande affects the water available to the entire region.

- *The water supply is only depleted by consumptive use*; reductions in diversions and return flows resulting in better delivery efficiency do not necessarily improve the water supply.

In summary, the water supply of the Middle Rio Grande is marked by limitation and variability. The successful water planning process will operate in recognition of these concepts.

Middle Rio Grande Water Supply Study

ES-1
Map of Study Area: Cochiti Reservoir to Elephant Butte Reservoir



LEGEND

- State Highway
- U.S. Highway
- Interstate
- County Line
- Perennial Stream/River
- Intermittent Stream/River
- Latitude/Longitude
- City
- Lake/Reservoir
- Valley Alluvium
- Pueblo
- Gage Station

The purpose of the Middle Rio Grande Water Supply Study is to prepare a quantitative description of the conjunctive-use ground and surface water supply available to the Middle Rio Grande from Cochiti Reservoir to Elephant Butte Reservoir. This will be conducted under the constraints of the Rio Grande Compact and upstream Rio Grande basin water use with New Mexico. The Middle Rio Grande Water Supply Study will identify, assemble, and evaluate existing pertinent water supply and water budget data sets and present them in a form that can be used by regional water planning entities in the Middle Rio Grande. The product of the study will be used by others to develop and evaluate alternatives that reconcile projections of water demand with available water supply by the Interstate stream Commission in developing strategies to meet new Mexico's delivery obligations to Elephant Butte Reservoir under the Rio Grande Compact.

Sources: Base data compiled from USGS 1:100000s DLG and DEM files. Land use data provide by the Earth Data Analysis Center and was derived from the 1992 Land Use Trend Analysis study performed by the Bureau of Reclamation. Note:Land use coverages not available south (approx.) of 33 32

S.S. Papadopulos & Associates, Inc.

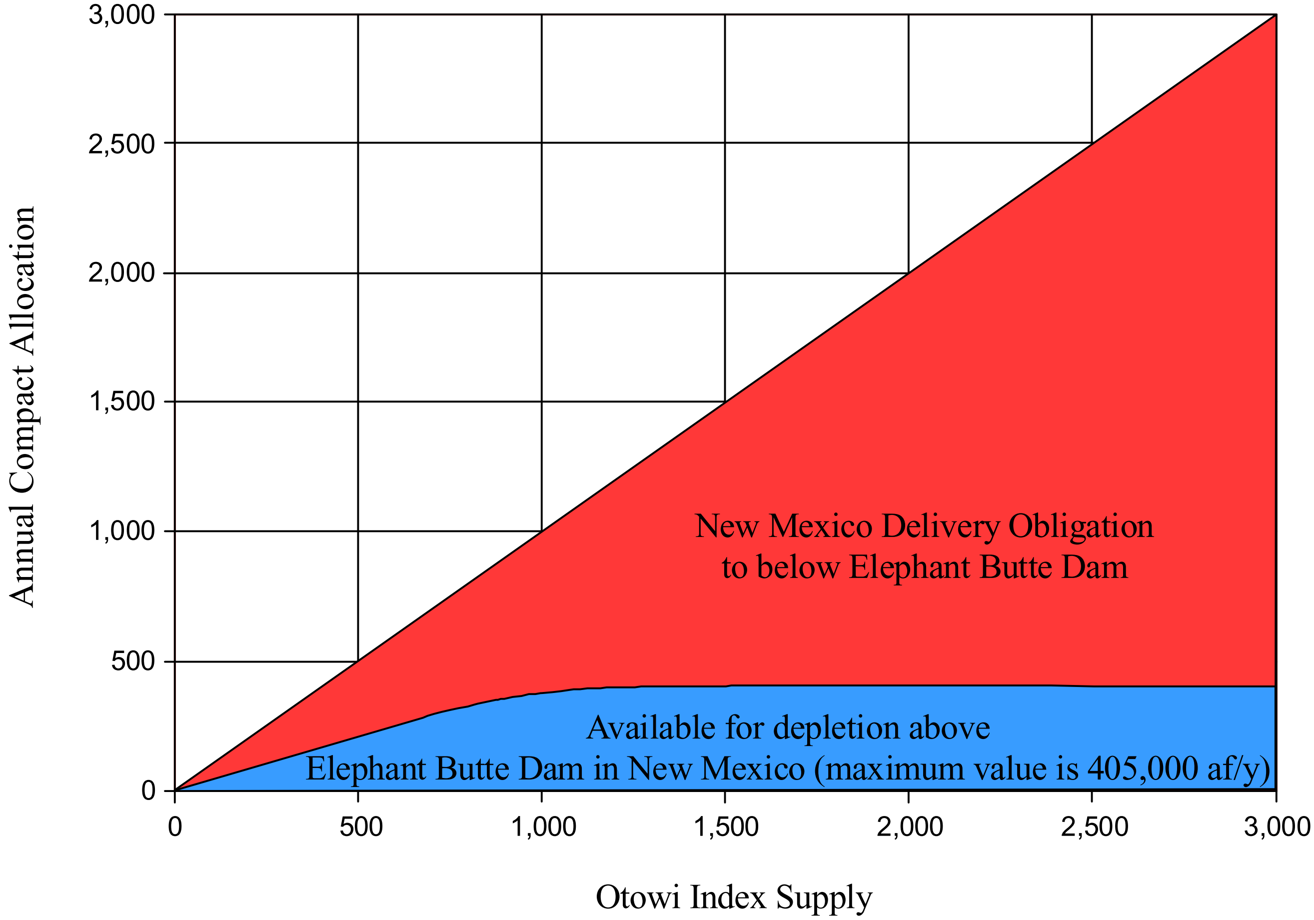
BBC Consulting Group, Inc.

Revised 11/23/00

ES-2

Rio Grande Compact Allocation

(quantities in thousands of acre-feet)



Tabulated values from Resolution Adopted by Rio Grande Compact Commission, 1948

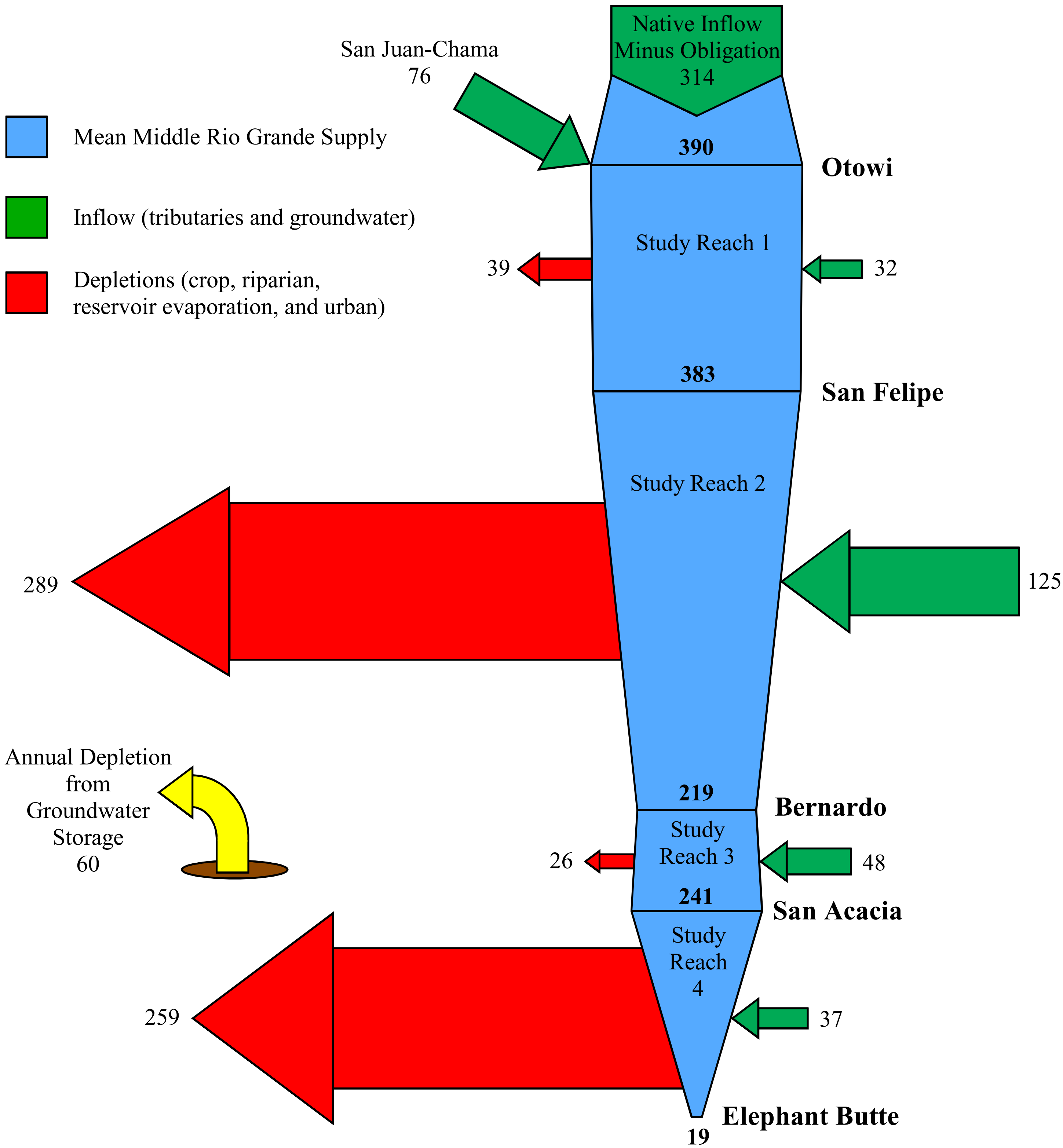
(Quantities in thousands of acre-feet)

Otowi Index Supply	Elephant Butte Scheduled Delivery
100	57
200	114
300	171
400	228
500	286
600	345
700	406
800	471
900	542
1,000	621
1,100	707
1,200	800
1,300	897
1,400	996
1,500	1,095

Otowi Index Supply	Elephant Butte Scheduled Delivery
1,600	1,195
1,700	1,295
1,800	1,395
1,900	1,495
2,000	1,595
2,100	1,695
2,200	1,795
2,300	1,895
2,400	1,995
2,500	2,095
2,600	2,195
2,700	2,295
2,800	2,395
2,900	2,495
3,000	2,595

ES-3

Mean Annual Middle Rio Grande Water Supply Under Present Conditions, Excluding Elephant Butte Scheduled Delivery (in thousands of acre-feet)



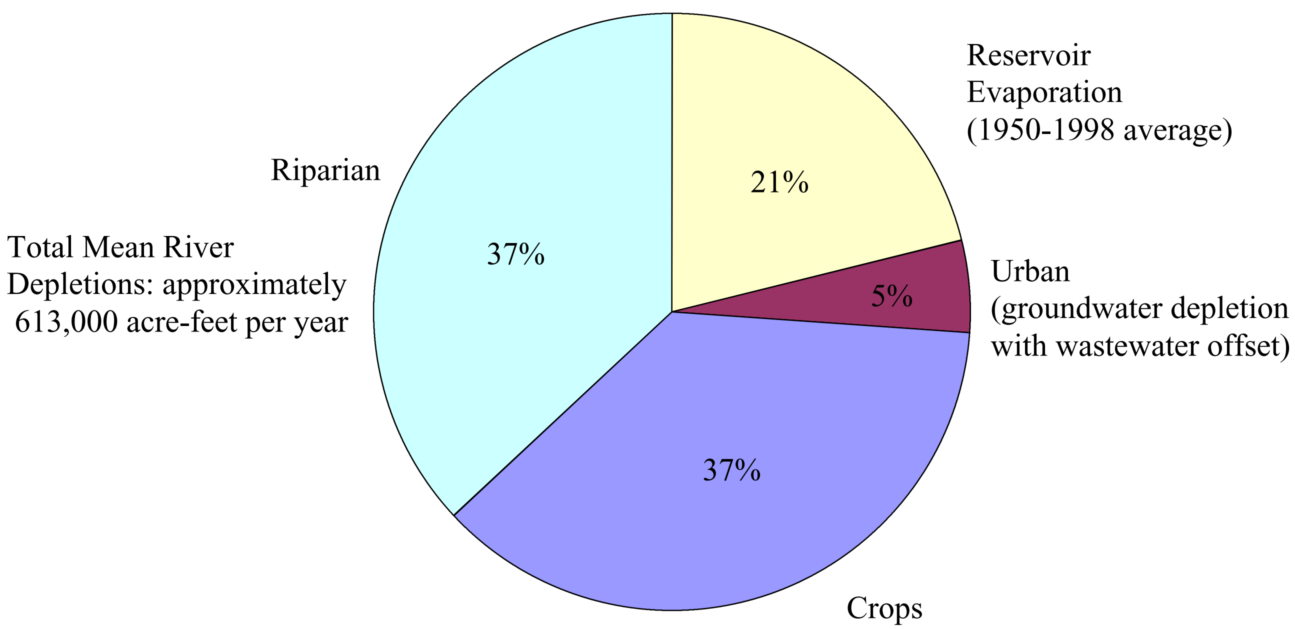
Assumptions:

- Present development conditions for groundwater pumping, irrigation, and riparian uses
- Inflows based on mean value of risk model output, sampling from probability functions incorporating climatic variability, 1950-1998
- Rio Grande native inflow and reach flows represent simulated flows minus mean Compact obligation derived from risk model output

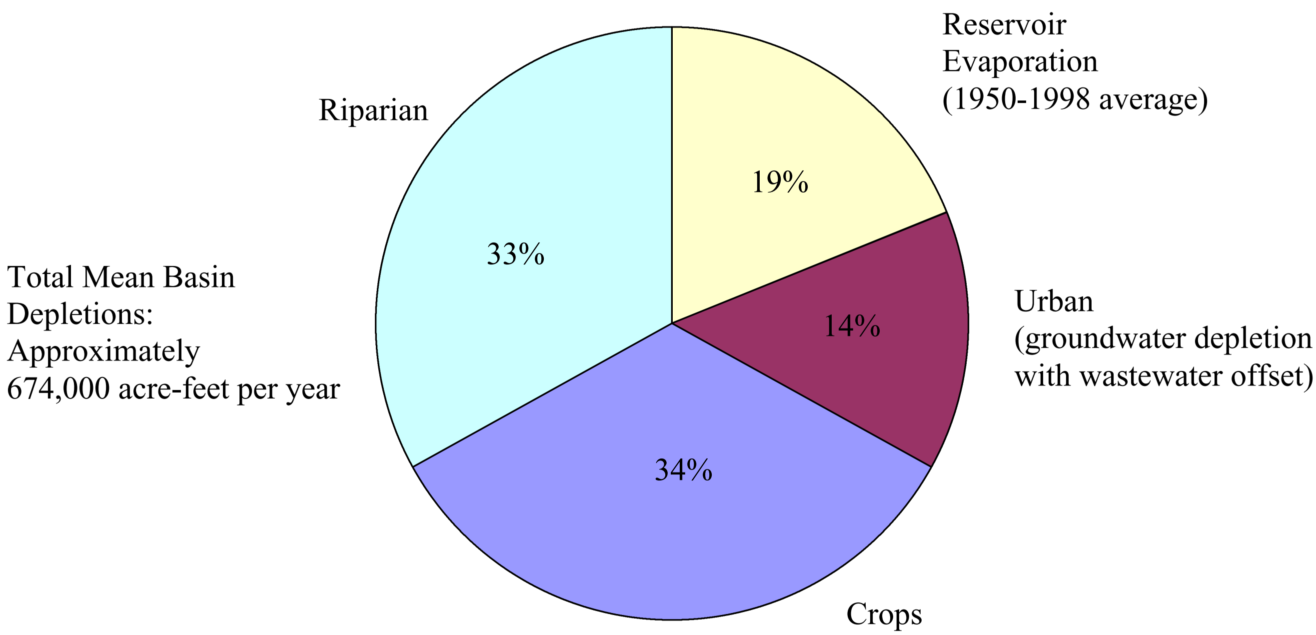
ES-4

Summary of Mean Depletions

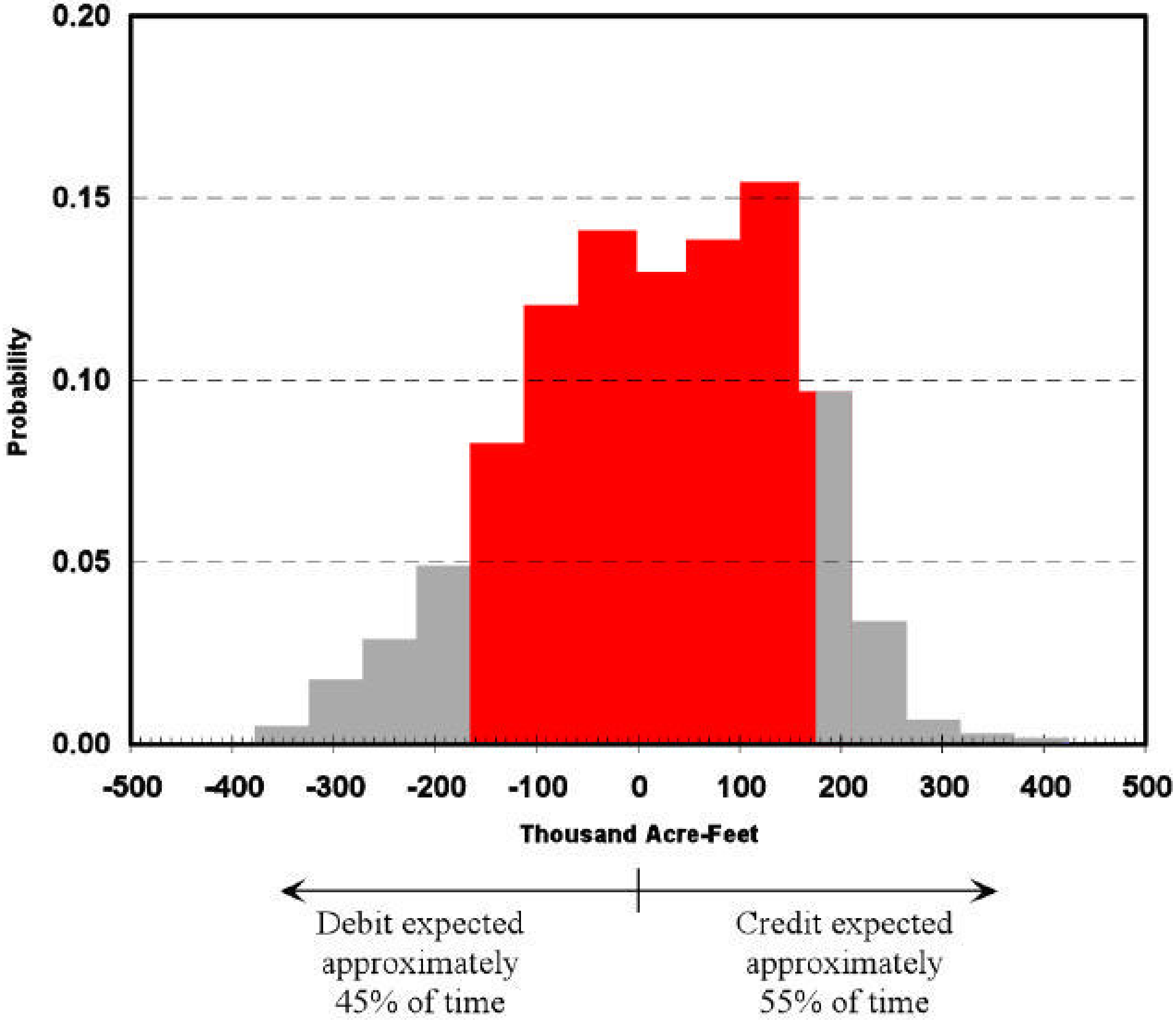
a) Mean depletions to river system under present land use and groundwater development conditions



b) Mean total Middle Rio Grande depletions (including depletion from groundwater storage),under present land use and groundwater development conditions

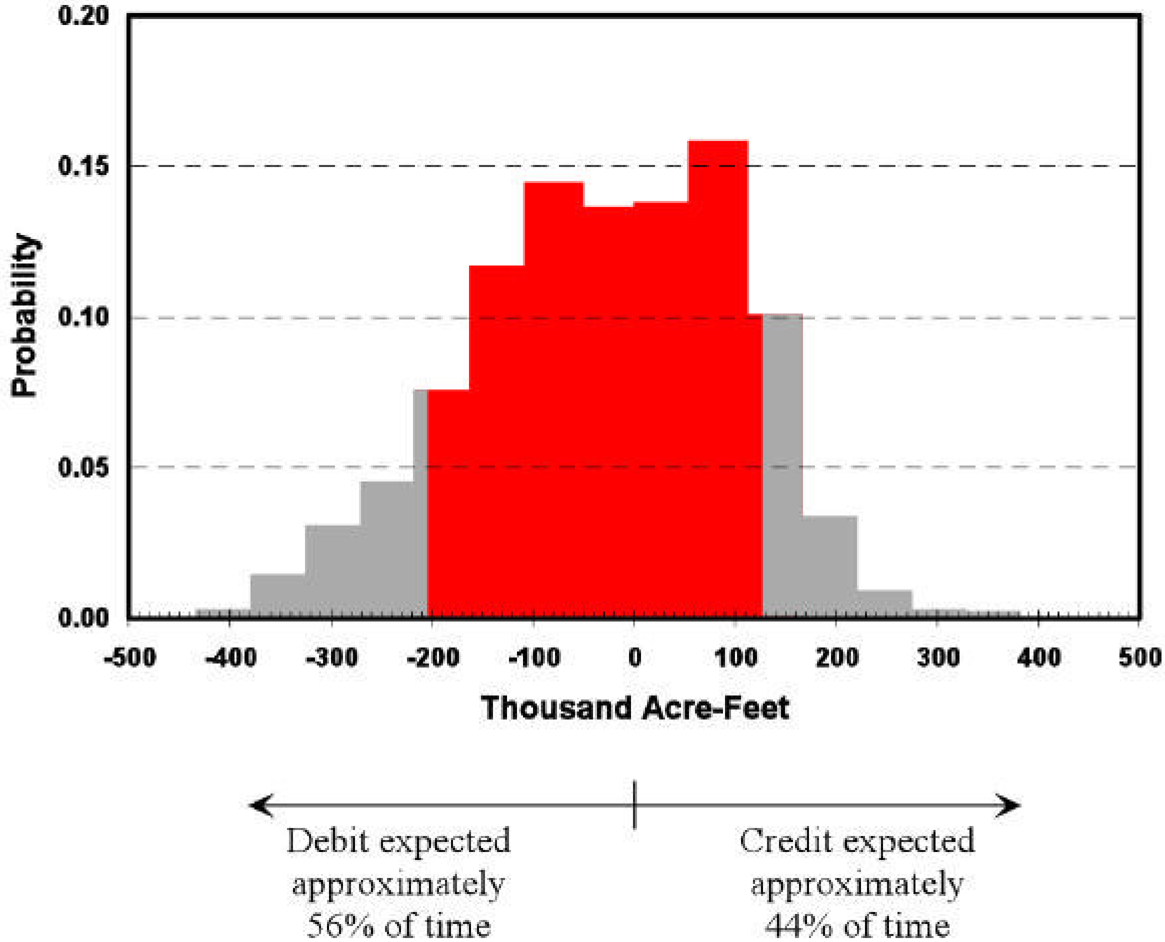


ES-5
Credit-Debit Probability Distribution
Present Development Condition, Year 2000



Some model assumptions may not apply under extreme conditions, particularly affecting results in gray area

ES-6
Credit-Debit Probability Distribution
Alternative Development Condition, Year 2040



Some model assumptions may not apply under extreme conditions, particularly affecting results in gray area

Appendix C-7

Historical and Current Water Use in the Middle Rio Grande Region

Prepared by John Shomaker & Associates, Inc. and PioneerWest

June 2000

HISTORICAL AND CURRENT WATER USE IN THE MIDDLE RIO GRANDE REGION

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June 2000

HISTORICAL AND CURRENT WATER USE IN THE MIDDLE RIO GRANDE REGION

EXECUTIVE SUMMARY

The Historical and Current Water Use in the Middle Rio Grande Region project was carried out under a Professional Services Agreement between John Shomaker & Associates, Inc. (JSAI) and the Middle Rio Grande Council of Governments (MRGCOG), working in cooperation with the Middle Rio Grande Water Assembly. This project is part of the Middle Rio Grande regional water planning process and is supported by funding from the Interstate Stream Commission (ISC). The project follows the ISC's Regional Water Planning Handbook (1994) and requirements of MRGCOG and the Middle Rio Grande Water Assembly Water Demand Working Group.

The Middle Rio Grande Region, as the term is used herein, encompasses the portion of the Rio Grande valley from Cochiti Dam south to the southern boundary of Valencia County. Almost all of three counties, Sandoval County, Bernalillo County, and Valencia County, as well as a small portion of Torrance County, are located within the region. Eleven tribal jurisdictions and twelve municipalities (including Albuquerque, the largest city in New Mexico) are located within the region. The Middle Rio Grande Region is subdivided into three subregions according to major watershed boundaries: the Rio Puerco, Rio Jemez, and Middle Rio Grande Valley (MRGV) (Fig. 1A in report).

The study includes a compilation of water-use data from many sources. These sources include publications and publicly-available data from the New Mexico Office of the State Engineer (NMOSE), the U. S. Bureau of Reclamation, the Middle Rio Grande Conservancy District (MRGCD), as well as publicly-available data from the U.S. Geological Survey, the City of Albuquerque, and numerous other public water suppliers. The historic and current water-use data found in these sources were divided into specific water-use categories, as defined by the NMOSE and the Interstate Stream Commission (ISC).

Water-use data are presented in the form of *withdrawal*, water pumped from ground water or diverted from surface water, and *consumption*, *consumptive use*, or *depletion*, which is water that is removed from the surface- and ground-water systems via evaporation, transpiration, or other processes. All water quantities are expressed in acre-feet, the volume of water necessary to cover an acre to the depth of one foot. There are 325,851 gallons in an acre-foot of water.

In 1995, within the study area, riparian vegetation accounted for 29 percent of consumptive use; irrigated agriculture, 28 percent; public water supply, 25 percent; open-water evaporation, 16 percent; and all other consumption categories fill out the remaining 2 percent of water consumption (Fig. A). Total consumption in 1995 was about 340,000 acre-feet.

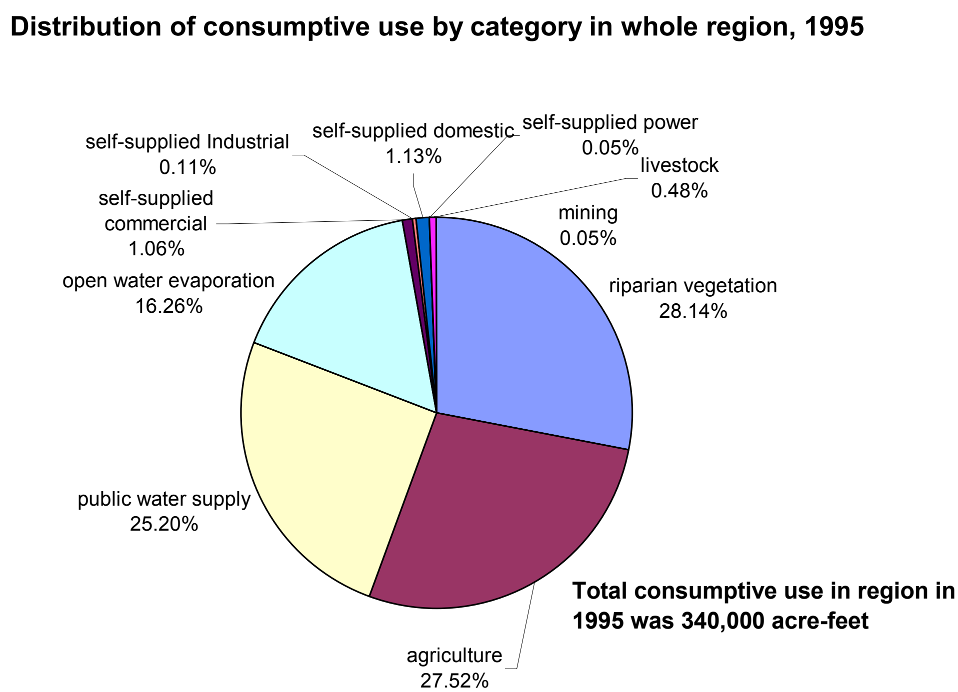
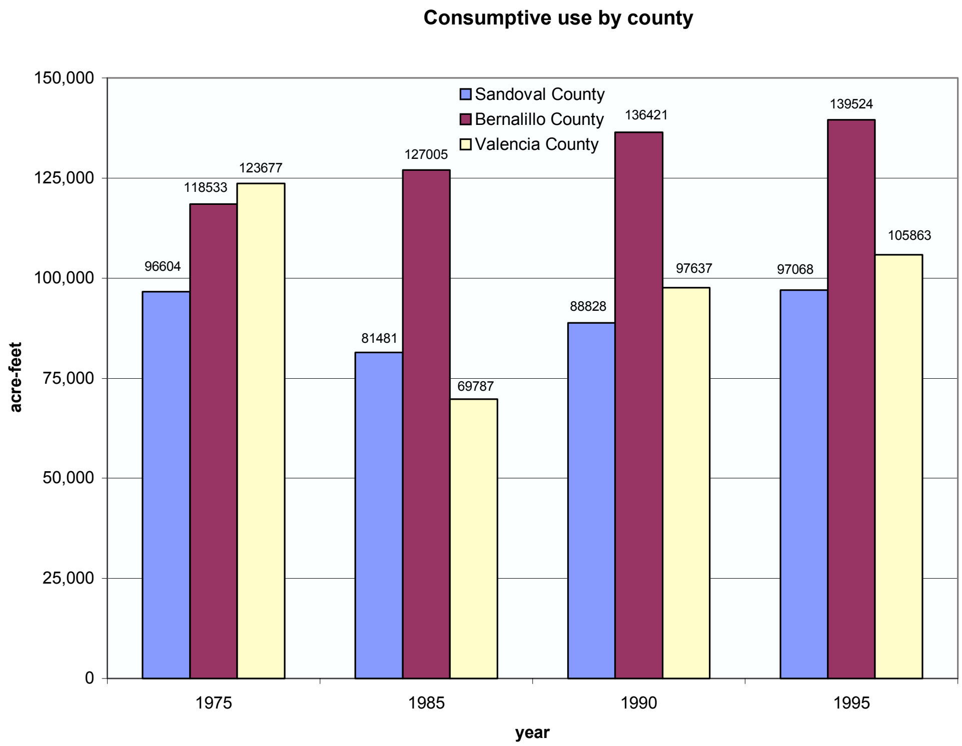


Figure A. (Fig. 52 in the text) Percentages of consumptive use by category in study region.

The amount of water withdrawn each year in Sandoval, Bernalillo, and Valencia counties combined is about 600,000 acre-feet. Roughly half of those withdrawals are for irrigated agriculture, and one quarter is withdrawn for public water-supply systems in the region. Sixteen percent of withdrawals are by riparian vegetation, and 9 percent represent open-water evaporation.

Water is supplied to the different categories from either ground- or surface-water sources. Irrigated agriculture derives its water mostly from the Rio Grande. Water diverted to, but not consumed by, irrigated agriculture either returns directly to the surface-water system or seeps into the shallow ground-water system. Open-water evaporation is obviously withdrawn and consumed from surface-water sources. All public water-supply and self-supplied commercial, industrial, domestic, mining, and power categories derive their water primarily from ground-water sources, except for a very small amount of surface water used for commercial fish hatcheries and public water supply. In general, return flow from self-supplied and municipal systems processed by municipal wastewater treatment facilities is returned to the Rio Grande. Some water evaporates and is lost during the treatment process, and some is reused for landscaping and crop irrigation. Some water is sent to septic systems and returns to the ground-water system. Finally, riparian vegetation (which includes indigenous vegetation like cottonwoods and exotic species such as salt cedar) extracts its water from both surface- and shallow ground-water sources. Overall, roughly equal amounts of water are consumed or depleted from surface- and ground-water sources.

Valencia County leads the Middle Rio Grande region with consumptive use of water, a result of its extensive agricultural development (Fig. B). Bernalillo County is second, with consumption driven by water demand for the City of Albuquerque, New Mexico's largest metropolitan area. Though Sandoval County water use today is less than in either of the other counties, significant population and industrial growth is occurring.



Sources: 1975--no data for self-supplied commercial, self-supplied domestic, and mining
1985--open water evaporation 1975 data; no data for self-supplied domestic
1990--open water evaporation 1993 data
1995--open water evaporation 1993 data; riparian consumptive 1994 data

Figure B. Consumptive use of water by county.

JSAI intends this work to form a basis for projecting water demand in the future, and to highlight the current status of water-demand data availability and quality. Many sources provide very good water-use data, and data collection and processing methods have improved over time. There is still room for improvement, however, and an increase in the quality of water-demand data and the development of a centralized data repository would greatly assist the water planning process in the Middle Rio Grande region. During the process of this project the study team did find inconsistencies in data, but the team would be surprised if improved data quality were to significantly change the currently reported amounts.

Appendix C-8

Framework for Public Input to a State Water Plan

Prepared by the New Mexico Office of the State Engineer
and the Interstate Stream Commission

Citation:
New Mexico Office of the State Engineer and the Interstate Stream Commission. Framework for Public Input to a State Water Plan. December 2002.

Framework for Public Input to a State Water Plan

New Mexico Office of the State Engineer and the Interstate Stream Commission

OVERVIEW

New Mexico's future depends on our ability to manage our water resources in a way that ensures a secure, reliable water supply. Achieving this will require forceful leadership that reflects a firm grasp of facts, the law and New Mexico's needs. Difficult decisions need to be made about complex and sensitive issues. It is critical that we leave behind our historical laissez faire style of water use management.

If we fail to more assertively manage our water resources, others are ready to step in and dictate how they will be managed. Our control over our own resources, as well as our economic vitality and quality of life, now depend m New Mexico completing the transition to forward-looking, Active Water Resource Management.

THIS DOCUMENT ARTICULATES A BROAD RANGE OF INFORMATION

This document is published to enable the greatest possible number of New Mexico's citizens to participate in shaping a State Water Plan. We are on the threshold of an intensive planning effort that lays out the commitments we choose to make, steps we must take to protect our water and our priorities for action. Our goal is to foster inclusive discussion about the practical realities and trade-offs before us as a state. We hope to stimulate new thinking about how New Mexico can make significant changes in our approach to water management.

This booklet summarizes the initial findings of a major re-assessment of the state's water resources—the first assessment done in 25 years and the first ever to integrate surface water (rivers and streams) and groundwater as complementary and inter-related supplies. *The New Mexico Water Resources Assessment*, *2001* will be completed in the summer of 2003 and available to the public on compact disc. A summary is provided basin-by-basin and focuses on key issues for discussion and resolution. Many of these issues have been raised by regional water planning groups in seeking to define the water supply, needs and priorities of their local communities. Other issues have arisen from the mandates to the Office of the State Engineer and Interstate Stream Commission (OSE/ISC): compliance with interstate compacts and federal laws such as the Endangered Species Act, to cite just two examples.

The following sections of this booklet address subject areas where study and public input have indicated specific needs. These include the urgent topic of developing the measurement programs required to provide the factual basis for defending and managing water resources, developing inclusive public processes that foster problem solving, and outlining capital commitments required for water development projects.

Not every important topic is discussed at length. For example, no section deals exclusively with adjudication of water rights, which has long been a knotty problem. On one hand, the adjudication backlog is a symptom of the State's failure to focus on the building blocks of Active Water Management. On the other, the logistics of resolving every aspect of adjudication would overwhelm even a much larger organization. This issue clearly requires anew frame of reference and creative approaches.

To enhance the value of this booklet, as a tool for the public and technical experts alike, background information and data are available in appendices on compact disc. The contents of these appendices range from a compilation of public comments received at outreach meetings regarding state water planning to technical data developed over the past year with regard to the location and effectiveness of individual stream gaging stations. A DVD containing two half-hour video presentations is also available. When the comprehensive resource assessment now in progress is completed in the spring of 2003, it will also be available on compact disc. To request these resources, contact the Interstate Stream Commission in Santa Fe at 505-827-6160.

THE KEY FACT ABOUT OUR WATER: DEMAND EXCEEDS SUPPLY

New Mexico's water supply is limited. Demand, needs, and rights to use water exceed the water supply available in most years. Many of New Mexico's difficult water dilemmas arise from these facts.

During drought conditions, the imbalance becomes acute. After decades of promoting water use, New Mexico lacks both the physical facilities and the administrative infrastructure to ensure available water is delivered on the basis of water rights priorities to senior water-rights holders. The other side of the coin is that in most places we lack the means to limit water uses by junior water rights holders whose demands cannot be met from the available supply. Nor have water users been adequately informed about the serious nature of problems sparked by unauthorized use.

> New Mexico uses about four million ac-ft of water every year. Irrigated agriculture receives about 75% of the total. About 12% evaporates from reservoirs. Public water supplies account for about 8% and remaining 5% is used for mining, power, domestic wells and other uses.
>
> —Norman Gaume

However, this is not the whole issue. In a state where 75% of water use is for agricultural purposes the problem becomes acute when considering the state's population has almost doubled since 1960. Growth has been the greatest in New Mexico's three Metropolitan Statistical Areas {MSAs), Albuquerque, Santa Fe and Las Cruces. Growth in each of these MSAs has at least doubled since 1960. These areas consist of one or more counties and often hold junior water rights that could be cut off during a dry year, yet supplying them is vital to public welfare. The State must therefore also provide a clearinghouse where voluntary leasing transactions can take place between senior water rights owners and municipalities and other engines of the state's economy.

A third difficulty is that simply enforcing the state's priority water rights administration produces unacceptable or unintended consequences. For example, priority administration may prevent groundwater users with junior water rights from pumping in dry years, even though the intended benefit of increased surface water flow may not occur until years—even decades—later.

This problem of demand exceeding supply affects virtually all water planning regions. Those that do not experience water shortages themselves are often viewed as a potential source of water by thirsty neighboring regions.

> New Mexico's rainfall is highly variable. Drought periods are common. On the other hand the 19805 and 19905 were unusually wet. We have averaged significantly more rainfall over the last 20 years, than the last 20 centuries.
>
> —Norman Gaume

The unusually wet decades of the 1980s and 1990s have allowed hard decisions to be deferred despite large increases in population and water demand. The Southwest is due for a drought on the order of a 1950s drought. Even the few dry years that have occurred in 1996, 2000 and 2002 have seriously taxed our ability to meet fundamental demand.

The priorities guiding the OSE that persisted through the early 1990s led the organization to neglect the development of the information and tools that comprise the basis of administration: workable procedures within a system of reliable measurement data and the means to limit water uses to valid, adjudicated water rights according to the available water supply and their seniority.

New Mexico must now act to complete the conversion to active management of New Mexico's water resources. We need to establish functional limits on the use of finite water resources, especially in areas where demand far outstrips supply or where failure to limit uses may create liability for the State and bad outcomes for water users.

Active Water Resource Management is the name we have given to the comprehensive, assertive approach that is needed to protect and enhance New Mexico's water supply.

Although many deficiencies are evident, New Mexico has made progress in recent years that lays the foundation for a State Water Plan that provides for Active Water Resource Management.

WATER RIGHTS AND PERMITS

The OSE has assembled an expert and effective team of lawyers, hydrologists and engineers who focus on moving controversial applications through the process while providing due process for both applicants and protestants. An intensive effort to automate all water rights documentation is taking place, but the resources needed to complete the job in a timely manner are not available.

DATA

One key building block we currently lack is the ability to measure water uses and return flows, which is vital to preventing unauthorized use of water. In addition, the section of this document entitled "Surface Water and Groundwater Measurement Programs" summarizes recent knowledge of what is needed with regard to cooperative programs with the US Geological

Survey. Furthermore, major advances have been made in updating and improving the WATERS and eGIS databases, which provide rapid access for agency staff and the public to information about water. The New Mexico Water Resource Atlas provides a graphic example of progress. Again, there is more to do in this area. All of these data sources are needed to realistically evaluate possible options for managing our water resources.

PLANNING

Regional water planning groups have been formed and are at various stages in preparing and evaluating their regional plans. Many have led outstanding public education efforts and are providing important forums for discussing local and regional needs and priorities. The ISC funds and provides technical assistance to these groups, which will continue to play a vital role in the water planning. The ISC has also built its water planning skills and staff in order to provide leadership in regional and State Water Plan development.

Without a State Water Plan to guide implementation of programs, set priorities and trace out the means of effecting controversial but essential changes, many issues cannot be adequately addressed.

FEDERAL REGULATIONS AND OPERATIONS

Federal agencies play a large role in managing reservoirs and water facilities, and as enforcers of federal laws. The OSE/ISC has taken a three-pronged approach to working with federal agencies: 1) litigating where necessary, 2) negotiating directly with individual agencies where possible, and 3) initiating and participating in collaborative efforts when they show promise. Maintaining knowledge of federal laws and regulations and creating strong working relationships with these agencies are needed to effectively implement water programs and projects. The challenges in this area are immense, as a review of the basin descriptions makes clear.

MANAGEMENT/INTEGRATION AND PUBLIC INVOLVEMENT

The legal documents, processes, information and administrative infrastructure that form the foundation for action must be efficiently managed and require the involvement of a wide variety of stakeholders. The OSE/ISC has taken the lead in collaborative action to seek optimum solutions.

To cite just one example, the OSE/ISC convened and worked with water users in the Lower Pecos to find a consensus solution to address problems in their area. Despite the lack of public information staff, the agency has conducted active outreach to civic groups, regional water planning groups and federal agency officials, as well as government-to-government outreach to Pueblos and Native American groups. For the State Water Plan, a variety of avenues for public involvement and education will be needed. See the Public Involvement section of this document for further information on successes to date and what remains to be done.

CORE ACTIVITIES IMPROVE OUTCOMES

The activities discussed in the previous paragraphs are essential, but they are not ends in themselves. Rather, they make it possible for the State to take effective action to preserve and develop water supplies and to facilitate water transfers. This is where the real benefits accrue.

WATER DISTRIBUTION

Ensuring that water is distributed to those with the most senior water rights when the available supply is not adequate for all uses is one of the core services that the OSE/ISC was created to perform. Without the ability to secure deliveries on a priority basis, water anarchy would prevail when supplies are limited by drought.

WATER MARKETS

Because virtually all water supplies are already allocated, providing supplies to new uses requires reducing the amount of water dedicated to an existing use. This can be done on a purely voluntary basis if we have a streamlined mechanism for leasing and sales of water rights. However, we must guard against water transfers that actually increase water depletions by converting paper water rights to new wet water uses. The institutional arrangements for efficient and proper transfers must create a fair and open market that can benefit all New Mexicans. Here is another area where participation by a wide range of stakeholders should make it possible to find workable consensus solutions.

WATER SUPPLY DEVELOPMENT

While in many areas water users are gradually exhausting underground aquifers, the State is not now taking advantage of the opportunities to develop renewable surface water supplies. As will be evident in the section on the Capital Needs Assessment, many projects lack funding or are impeded by other factors. Fostering conservation and developing ways to enhance existing supplies are essential to accommodating New Mexico's growing population.

SEVERAL ISSUES MAY COME TO A HEAD IN 2003

The "Issues for State Water Resources Management" section of this document sets forth generic and specific questions that the State Water Plan must begin to address. Some of the State's most immediate challenges are outlined below.

PECOS RIVER COMPACT AND DECREE COMPLIANCE

There is no alternative to compliance with the Pecos River Compact and US Supreme Court Amended Decree, but there are three ways to achieve it, each with considerably different costs. The first two choices are: (a) implementation of the Pecos Consensus Plan, or (b) priority administration.

The Consensus Plan is dependent on funding and on settlement of a longstanding regional dispute, but if these can be secured, compliance will have a manageable economic impact. Priority administration alone would produce harsher conditions in the Pecos Basin and would be certain to trigger costly litigation. It would also require a major commitment of personnel and resources.

The third way is: (c) place decision-making and imposition of penalties in the hands of the US Supreme Court. Alternative (a) is clearly preferable to (b) or (c). With alternative (c), the court-appointed river master will take control of the river.

SAN JUAN RIVER "SHARING SHORTAGES" AND PREVENTION OF UNAUTHORIZED USES

"Sharing shortages" are reductions in water availability on the San Juan River system that are required by federal law whenever water supply for the Navajo Indian Irrigation Project is inadequate. Drought is likely to trigger sharing shortages for the first time in 2003.

This could affect diversions for the San Juan-Chama Project and San Juan County electrical generating plant water uses. Drought also creates the necessity for the OSE/ISC to limit water users with rights only to direct river flow from improperly using storage water from Navajo Reservoir that has been released for other purposes, including downstream flows for endangered fish.

DEFENSE IN RIO GRANDE COMPACT LITIGATION

Drought shortages are expected to affect water users in the Lower Rio Grande below Elephant Butte Dam for the first time since 1979. These shortages imperil southern New Mexico water users, as well as others further downstream. New Mexico must assure that Texas receives its proper share of the limited water supply.

Texas has appropriated $6.2 million for litigation against New Mexico to obtain more water. Texans have claimed that New Mexico uses are impairing both the quantity of water that Texas has received and the quality of that water. Texas' consistent failure to use its entitlement-among other factors-provides a strong defense. However, New Mexico must gather more and better hydrologic information to support its case. Moreover, management and limitation of uses in New Mexico are required to ensure that Texas receives its proper share.

MIDDLE RIO GRANDE AND RIO CHAMA PRIORITY ADMINISTRATION

The federal government is insisting that New Mexico enforce water rights limits below El Vado Dam in order to protect water destined for the six Middle Rio Grande Pueblos. If the State fails to do so, the federal government has indicated it will store enough water to meet the unauthorized uses plus the Pueblos' prior and paramount water rights. This federal action would decrease water deliveries to Elephant Butte Reservoir and be likely to prompt Texas to claim a violation of the Rio Grande Compact-setting yet another lawsuit in motion. Clearly, New Mexico must make every effort to ensure water rights enforcement in this area.

ENDANGERED SPECIES ACT (ESA) COMPLIANCE

Recent court rulings and stays affecting management of the Middle Rio Grande in favor of the silvery minnow are just the most newsworthy example of this issue. On several New Mexico rivers, the federal government is changing previous water operations regimes as a means of providing habitat for endangered species. The result is a decrease in the water supply for other uses, including for compact compliance. ESA issues are both under negotiation and in litigation. Whatever the outcome, ESA compliance is likely to have a significant impact on both the future of water management and water users along most New Mexico rivers.

THE STATE WATER PLAN PROCESS WILL FACILITATE DECISION-MAKING

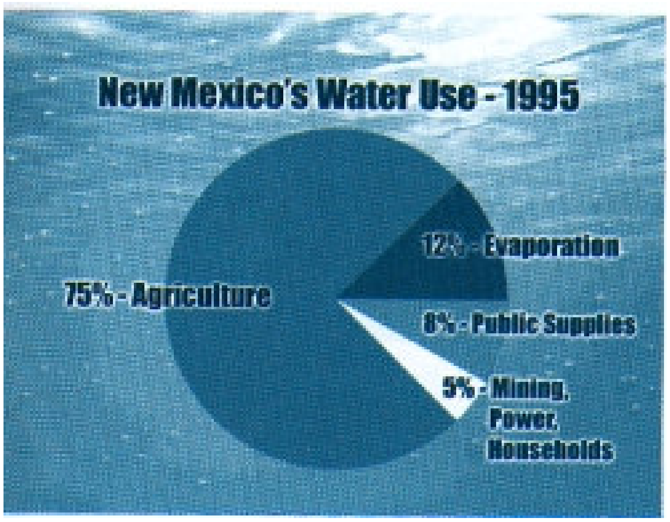
State government, including its water agencies, has not addressed and decided with water stakeholders a host of questions about how New Mexico's water supply will be managed for the benefit of all. Confronting tough issues and setting priorities for the use of scarce water, human and financial resources is vital to our ability to move forward economically while maintaining our diversity, culture and quality of life.

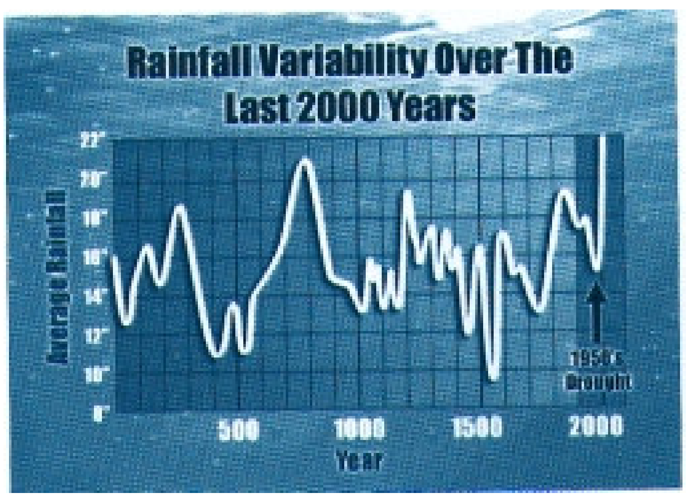
The Policy Issues for State Water Resources Management section of this document includes:
- § Governor-elect Richardson's water policy platform; and
- § New Mexico's Water: Perceptions, Reality and Imperatives, Twenty-eighth New Mexico First Town Hall (May 2002).

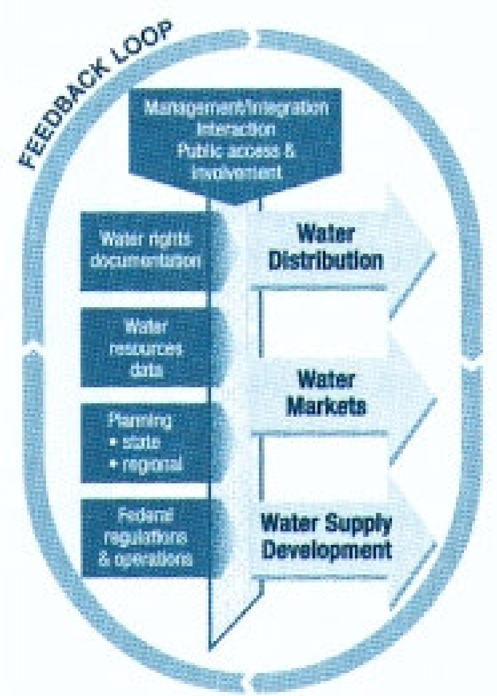
A report of the OSE/ISC staff's summary of key issues and questions developed in late 2002 at a series of strategic planning meetings is included in the Appendices.

This document helps us to focus on:
- § Using the State Water Plan process to increase interaction with stakeholders and hone our understanding of workable bases for consensus.
- § Addressing critical matters that, if left unresolved, will damage New Mexico's future.
- § Setting priorities.
- § Building a stronger foundation of staff and data resources for key functions, including strengthening teams that are moving adjudications forward, improving the water rights application processes and defending our resources from other states and the federal government.

The State must take great care not to perpetuate the laissez faire policies of the past by limiting itself to expedient, short-term actions that increase the water deficit or make long-term solutions more difficult.


New Mexico's Water Use - 1995
75% - Agriculture
12% - Evaporation
8% - Public Supplies
5% - Mining, Power, Households


Rainfall Variability Over The Last 2000 Years
Average Rainfall
22"
20"
18"
16"
14"
12"
10"
8"
500
1000
1500
2000
Year
1950's Drought



Active Water Resources Management

Appendix C-9

Water Management Study: Upper Rio Grande Basin

By Ernie Niemi and Tom McGuckin

Citation:
Niemi, Ernie and Tom McGuckin. Water Management Study: Upper Rio Grande Basin. Report to the Western Water Policy Review Advisory Commission, July 1997.

Executive Summary

In September, 1996, the Western Water Policy Review Advisory Commission contracted with ECONorthwest to study the major problems associated with the growing competition for scarce water and related resources in the Upper Rio Grande Basin, and to make recommendations for appropriate federal policies and actions for- addressing the problems. This is our final report. The study covers the area from the headwaters, in Colorado, to Ft. Quitman, Texas (see map).

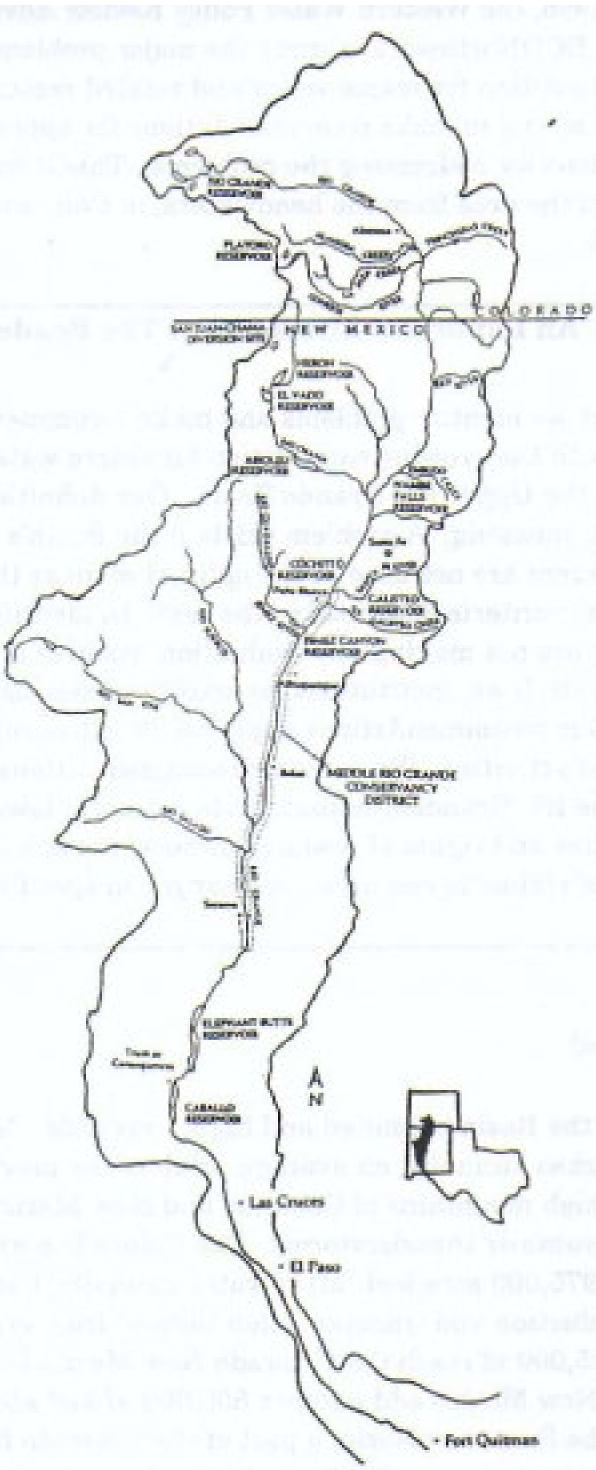
An Important Message For The Reader

In this report we identify problems and make recommendations associated with the growing competition for scarce water and related resources in the Upper Rio Grande Basin. Our definition of problems has a specific meaning. A problem exists if the Basin's water and related resources are not used in the optimal manner that meets the three economic criteria described in the text. In identifying the problems we are not making any evaluation, positive or negative, of any individuals, laws, institutions, or activities, associated with the problems. Our recommendations apply solely to federal policies, agencies, and activities. We make no recommendations whatsoever regarding the Rio Grande Compact, state and local laws, the responsibilities and rights of resource owners, the substantive merits of disputants' claims to resources, or changes in specific resource uses.

A. Background

Precipitation in the Basin is limited and highly variable. Most of the Basin receives 7-15 inches annually, on average. Half of the precipitation occurs as snowfall in the high mountains of Colorado and New Mexico and the other half as intense, summer thunderstorms. The Colorado portion of the Basin produces about 975,000 acre-feet (at) of water annually, but, because of agricultural production and transportation "losses" from evaporation and seepage, only 325,000 a f reach the Colorado-New Mexico border.[1] Streamflows in New Mexico add another 650,000 af and about 100,000 af are imported from the San Juan Basin, apart of the Colorado River Basin. About two-thirds (on average, 700,000 af/yr) of the water entering the Middle Rio Grande Valley surrounding Albuquerque reaches Elephant Butte .

[1] An acre-foot ofwater is the amount of water that would cover one acre of land one foot deep. It is equivalent to 326,000 gallons and 43,560 cubic feet of water.



Map of the Upper Rio Grande Basin.
Source: Finch and Tainter (1995).

The U.S. must deliver 60,000 af of this to Mexico. Heavy agricultural use in southern New Mexico and western Texas, together with growing municipal consumption in the El Paso-Ciudad Juarez area, deplete the river so that it generally goes dry before reaching Ft. Quitman.

Agriculture accounts for about 89 percent of the major water uses (typically associated with withdrawals or diversions) in the Basin. The remainder goes to municipal and industrial use, primarily in the Middle Rio Grande Valley and in the El Paso area. The Basin's cities have relied on groundwater but El Paso (population about 650,000) and her Mexican neighbor, Ciudad Juarez (more than 1.5 million), as well as Albuquerque (about 650,000) recently recognized they cannot long continue mining groundwater at historical rates. El Paso has begun using surface water from the Rio Grande and Albuquerque is examining similar options.

Sediment levels in the river are high for most of its length. Intense agricultural use in the southern parts of the Basin increase the water's salinity and add nutrients and agricultural chemicals. The shallow aquifers near urban centers, which provide water for many low-income households, exhibit pollution from septic systems and hazardous-chemical spills. Effluent from municipal wastewater-treatment plants frequently fails to meet water-quality standards and surface water near urban centers is not potable and often not suitable for human contact. Water from the deep aquifers under Albuquerque and El Paso-Ciudad Juarez often includes elevated levels of dissolved solids, such as arsenic.

Human settlements in the Basin have diverted water from the river for centuries, and competition for water has long been intense. Friction among the states led to the 1938 Rio Grande Compact, which stipulates the fractions of available water that Colorado must deliver to New Mexico, and New Mexico to Texas. The allocations in the Compact reflect the agrarian economy and the distribution of agricultural activity that existed at the end of the 1920s, not today's highly urbanized economy. Much of the agricultural development reflected in the Compact occurred in the upper end of the Basin, but most of today's economic growth is occurring farther south, in El Paso-Ciudad Juarez and Albuquerque.

Diversions of water from the river, construction of dams and other structures in the river bed, manipulation of the hydrograph, modification of the channel, and control of vegetation have extensively modified the riverine-riparian ecosystem. The reach below Elephant Butte Dam is largely a network of canals and 71 percent of the native fish species no longer can be found in this area. Only one portion of the Basin's ecosystem, the riparian cottonwood forest known as the bosque in the Middle Rio Grande Valley, has been examined extensively. The forest no longer is dispersed throughout the historical floodplain, much of it is disconnected hydrologically from the river, and significant changes in ecological structure and function are expected to occur if current management regimes continue. In 1994, the U .S. Fish & Wildlife Service listed the Rio Grande silvery minnow as an endangered species.

The prior-appropriation doctrine underlies most water movement in the Basin, but it does not apply uniformly to all resources or in all areas. Also important is the influence of aboriginal rules and custom, Spanish and Mexican laws antedating the 1848 Treaty of Guadalupe Hidalgo that ceded much of the Basin to the U .S., international treaties, the Rio Grande Compact, the federal government's trust responsibilities for Pueblo tribes and as stewards of many resources, and the unique laws and institutions of the three states.

Water-management issues are especially complex in New Mexico. The state does not recognize instream flows as a beneficial use and, hence, it does not protect in stream flows. Furthermore, it has not adjudicated most water rights in the Basin and there is little infrastructure for measuring flows and diversions. Particularly disturbing to many is the lack of adjudication for Pueblo water rights which, at some places and times of the year, probably would embrace all surface flows.

Competition for the Basin's water and related resources is far more intense and complex than in the past. Decades ago, demand came primarily from agriculture, but it now competes with demands reflecting the spiritual value Indians and others place on the river, the contributions the river makes to the Basin's quality of life, and the myriad uses of water in a modern metropolitan city. Some of the competition manifests itself through market mechanisms, but most does not. Powerful economic forces are changing the character of the competition for resources by reducing the ability of traditional resource-intensive industries, such as agriculture, and increasing the ability of non-consumptive and passive uses, such as recreation, to generate new jobs and higher incomes. Increasingly, the economic prospects of communities are determined by their ability to produce, attract, and keep a highly qualified workforce and, as both firms and households become more footloose, communities that offer a high quality of life outperform those that do not. Water-related recreational opportunities and aesthetics are important elements of the quality of life in the Basin, where economic activity is concentrated near the narrow ribbon of water flowing through the desert.

Throughout the report, we use the term "value" to mean more than just price. We take a broad view of the term, employing it to refer not just to goods and services associated with the Basin's water and related resources that are measured in monetary terms, such as bales of hay produced from irrigated fields, but also to those that are not measured in monetary terms, such as recreational opportunities, protection of endangered species, and maintenance of cultural traditions. Consistent with this approach, we also employ the term "use" to refer both to conventional uses associated with physical manipulation of the Basin's water and related resources, such as withdrawing water from a stream for irrigation, and to more passive or nonquantifiable uses, such as dilution of pollutants or maintaining riparian habitat. We recognize that individuals have multiple perspectives on the "values" and "uses" associated with the Basin's resources. These multiple perspectives give support to a central message of the report-the competition for the resources is complex.

Much of the water in the Basin is not being used in the manner that would generate the bundle of goods and services with the greatest value or the highest levels of jobs, incomes, and standards of living. The prices of water and related resources generally do not reflect these resources' scarcity and, hence, resources often are put to a low-value use while other uses with a higher value go unsatisfied. Much of the water used at the economic margin for irrigation yields crops whose value is less than the cost of growing them. The fundamental legal and institutional structure overseeing water uses tends to favor agricultural and other diversionary uses, however, and does not facilitate voluntary transactions that would release resources from low-value uses and direct them toward high-value ones.

Much of the emphasis on diversionary uses stems from traditions that see irrigation not in economic terms but as a necessary support for human life and an essential element of local cultures. These traditions are being challenged, especially near metropolitan centers, where many farmers see the inevitability, if not the economic advantage, of transferring water to municipal-industrial users.

Issues related to perceptions of the fairness of different resource uses and competing demands abound in this Basin. Many farmers and advocates of irrigation believe those who would restrict irrigation in favor of instream flows and other environmental amenities are latecomers with no right to interfere with the activities of those with a prior claim to water. Many instream advocates counter by arguing that diversionary uses impose environmental damages on all of society and the institutional-legal framework unfairly favors such users. Public officials in Albuquerque and elsewhere are hoping that residents' sense of fairness toward future generations will encourage them to curtail their consumption of finite groundwater resources. Supporters of Indians' rights believe the federal government's failure to defend these rights as it helped finance the development of others' rights is deplorable.

B. Major Problems

The problems affecting the competition for the Basin's water and related resources are so numerous and intertwined that it is impossible to demonstrate cleanly where one stops and another starts. Whatever the approach for describing and evaluating the problems, one first must define the criteria for determining if a problem exists and for measuring its severity. We use three criteria that are standard hallmarks of this nation's economic system to assess the competition for water and related resources in the Basin. These criteria also reflect three major types of arguments raised during controversies over water and other resources. This framework indicates that the outcome from this competition is optimal if: (1) the resources are used in the manner that yields the highest net value for the bundle of goods and services derived from the resources; (2) the resources are used in the manner that yields the highest standard of living; and (3) the resources are used in the manner that is perceived to be fair.

We separate the problems into two sets. We first describe two problems that represent the most serious, fundamental aspects of the past and current failure to meet the three criteria described above. We call these the bottom-line problems. One of them focuses on the resources themselves, and the other on the economies and communities dependent on the resources. We then describe several of the factors that create, exacerbate, or prevent mitigation of the bottom-line problems. We call these the contributory problems.

1. Bottom-Line Problem #1: The Resources are Finite, but the Demands are Not

The Basin's water and related resources are components of, and produced by an ecosystem. This ecosystem, like all others, has limits on how much water and other resources can be extracted from it to support and sustain humans. Within the past decade, the edges of the ecosystem's carrying capacity have become more clear. The designation of the Rio Grande silvery minnow as an endangered species reflects the extreme stress within the ecosystem. The low snow pack during 1995-96 showed that the supply of water can fall far short of current consumption levels, and the prospect of global climate change promises to exacerbate the shortfall. Both the Albuquerque area and the El Paso-Ciudad Juarez area have bumped against the limits of the supply of readily accessible groundwater, and are expecting rapid population growth. Many locations within the Basin have either encountered declines in water quality or recognized that such declines may materialize in the foreseeable future.

2. Bottom-Line Problem #2: The Basin's Water and Related Resources are Persistently Allocated in a Manner That is Less Than Ideal

If the Basin's water and related resources reflected the nation's ideals of competitive markets, they consistently would go to their highest-value uses. As the economy changes over time, some demands for a resource would grow, others would diminish, and the resources would shift accordingly through multiple, voluntary transactions. Reality, however, is far different from this ideal. For most, if not all, of the Basin's water and related resources the prevailing prices do not tell the economic truth about either the overall scarcity of the resources or the strength of one demand relative to another. As a result, the local, regional, and national economies forgo valuable goods and services as well as opportunities for more jobs, larger incomes, and higher standards of living. Some groups, especially the Pueblos, assert that the system is grossly unfair.

Many additional factors contribute to the bottom-line problems. These contributory problems include:

— The Basin's Resources Have Not Been Managed as Elements of an Ecosystem

— Past and Current Practices Have Rendered Water and Related Resources Unsuitable for Some Uses Without Corrective Action

— Resource-Demands that Come From Industrial Activities and Are Measured in Monetary Terms Are Difficult to Reconcile with Those that Are Not

— Many Groups Feel They Are Unable to Participate Effectively in Resource-Management Decisionmaking

— There Is Widespread Uncertainty about the Hydrosystem and Ecosystem of the Upper Rio Grande Basin

— The Relationship Between the Resources and the Economy Is Poorly Understood

— There Is Pervasive Distrust Among Stakeholders

C. Conclusions and Recommendations

We make three major recommendations regarding federal resource-management policies and activities in the Upper Rio Grande Basin. Each embraces several components.

1. Recommendation #1: Federal Policies and Actions Should Reflect the Ecosystem's Complex Role in a Complex Economy

We intend this recommendation to provide fundamental guidance for future federal policies and actions in this Basin. It has two essential features. The first is that federal policies and actions should view the Basin's water and related resources as elements of an ecosystem, not as independent resources separate from the ecosystem. The second is that federal policies and actions should recognize the full set of competing demands for the Basin's water and related resources and, wherever appropriate, strive to optimize these resources' contribution to the economy.

Federal policies and actions should account for the uncertainty surrounding the quantity and availability of the Basin's water and related resources and make an effort not to step beyond the bounds of current knowledge. Federal agencies should adopt the broad view of the term "use" to ensure that nonquantifiable or passive uses are not ignored in resource-management decisions. In a similar manner, we recommend that federal agencies also adopt the broad view of the term "value" to include not only the goods and services associated with the Basin's water and related resources that are measured in monetary terms, but also those that are not monetized.

We believe four changes in how federal agencies do business will expedite policies and actions with a broader view of the ecosystem and economy. Federal agencies with a significant impact on the Basin's resources should (1) promote institutions that take a broad view of the economy and environment; (2) initiate an integrated scientific assessment of ecological and economic conditions in the Basin; (3) describe tradeoffs more clearly; and (4) communicate ecological and economic issues more clearly. Effecting these changes will require funding, staff, and attention to reducing the confusion generated by various agencies' conflicting policies.

2. Recommendation #2: Strive to Mitigate or Correct Anticompetitive Factors

We recommend federal agencies in the Basin do more to mitigate the constraints to competition that keep water and other resources in low-value uses while high-value demands go unmet. We recognize, however, that the Rio Grande Compact with its preeminent legal position over interstate water decisions in the Basin is an impediment to competition across state boundaries, and will continue to be, absent change by the three signatory states and Congress. Resource managers should work to reduce the transaction costs that restrict the ability of willing "buyers" and "sellers" of resources from consummating mutually beneficial transactions. We believe they can do this by identifying "hotspots" where the discrepancy between the value of resource use and unmet demand are greatest and helping potential "buyers" and "sellers" come together.

Resource managers also should work cooperatively to curtail the externalities of federal resource-management activities. They should continue to work in multi-agency groups, recognizing that the concerns of all must be dealt with jointly. Federal resource-management agencies, acting individually or jointly, periodically should prepare a summary of how their activities affect the value of resource-related goods and services and their impact on jobs, incomes, and other indicators of standard of living. We also recommend that the Bureau of Reclamation (BuRec), the Army Corps of Engineers (CoE), and other resource-management agencies, working with Congress, broaden the scope of activities authorized for federal dams and other facilities. Congress should specify economic and ecosystem goals for the Basin, identify priorities for how the facilities should contribute to the attainment of these goals, and give the agencies greater leeway to work toward them.

We recommend that federal agencies support institutional innovations to facilitate voluntary transfers of resources from low-value to high-value uses. In particular, we encourage federal resource managers to anticipate proposals, and even develop their own, for the devolution of resource-management responsibility and authority from federal agencies to state and local ones. To participate successfully in a devolution process, federal agencies must be prepared to specify the outcomes they want to see.

Then they must have appropriate mechanisms for measuring progress toward individual outcomes, and actions for holding state and local agencies accountable.

3. Recommendation #3: Clarify Federal Interests in the Basin's Water and Related Resources

We recommend that the federal resource-management agencies initiate meaningful steps to clarify the federal interests in the Basin's water and related resources. There are at least five general categories of federal interest in the Basin's resources to be clarified: stewardship, corporate, Pueblo trust responsibilities, economic-welfare, and public-participation. Each of these is affected by risk and uncertainty, to the point that the distribution of risk, itself, constitutes a federal interest in the resources that should be clarified.

We recommend that each agency prepare a statement of its interest in the Basin's resources. This statement should be informed by the results of adopting an ecosystem-management approach, completing the assessment of the Basin's ecological and economic conditions, and setting priorities. It should explicitly address each types of potential federal interest, including those associated with risk and uncertainty. Where necessary, it should identify where the federal interest remains ambiguous and explore mechanisms for resolving the ambiguity.

Appendix C-10

From the Rio to the Sierra: An Environmental History of the Middle Rio Grande Basin

By Dan Scurlock

Citation:
Scurlock, Dan. From the Rio to the Sierra: An Environmental History o f the Middle Rio Grande Basin. USDA Forest Service General Technical Report RMRS-GTR-5, May 1998.

CONTENTS

Appendix C-11

Assessment of Regional Water Quality Issues and Impacts to the Water Supply

Prepared by Daniel B. Stephens and Associates, Inc.
for the Mid-Region Council of Governments

Assessment of Regional Water Quality Issues and Impacts to the Water Supply

Prepared for

Mid-Region Council of Governments
Albuquerque, New Mexico

October 19, 2003

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Assessment of Regional Water Quality Issues and Impacts to the Water Supply

Assurance of availability to meet future water demands requires both a sufficient quantity of water and water that is of sufficient quality for the intended use. Contaminants impacting surface water or groundwater quality may impair the use of available water resources. This assessment was prepared for the Mid-Region Council of Governments (MRCOG) by Daniel B. Stephens & Associates, Inc. (DBS&A). The scope of work for this report includes (1) an assessment of water quality issues for the Middle Rio Grande (MRG) planning region and (2) an examination of the water quality impacts on the region's water supply.

Most drinking water supplies in the MRG planning region are derived from groundwater sources within the basin fill sediments of the Santa Fe Group and younger alluvial deposits. Generally, this groundwater is of high quality and suitable for drinking water supply without additional treatment. Surface water in the Rio Grande and its smaller tributaries is of suitable quality to provide most of the irrigation water supply, with groundwater also providing a small part of the irrigation supply. In the past, surface water has not been a primary drinking water source; however, this will change under the City of Albuquerque's plan to begin treating Rio Grande water for municipal use.

Where drinking water supply options are limited, water quality impairment can be a significant and expensive problem if the drinking water supply becomes degraded to the point where additional and costly treatment must be provided or additional water supplies located. Although standards are generally not as high for irrigation and livestock uses as for drinking water, water quality must, nevertheless, be suitable to meet these uses.

Water quality for the MRG planning region was assessed for this report mainly through existing documents and databases. Two surface water studies prepared pursuant to Section 305(b) of the Federal Clean Water Act were especially helpful: (1) a list of surface waters within New Mexico that do not meet or are not expected to meet water quality standards (NMED, 2002a) and (2) *Water Quality and Water Pollution Control in New Mexico, 2002,* a report prepared by the State of New Mexico for submission to the United States Congress (NMWQCC, 2002). Information regarding groundwater quality was obtained primarily from the latter document and information on specific sites and facilities that may have the potential to impact surface water or groundwater quality was obtained from various NMED databases.

Water quality issues place constraints on the water available to the MRG planning region in two ways: (1) contaminant impacts on water supplies and (2) naturally occurring water quality constraints. Contaminant impacts clearly render a portion of the region's water unsuitable for use and require extensive remediation efforts. Only a portion of the region's groundwater has suitable naturally occurring quality to meet current drinking water and agricultural uses; much of the deeper water in the Santa Fe Group basin fill deposits or outlying formations is too saline for most uses. The widespread natural occurrence of arsenic in the region's aquifers is an extremely important emerging issue, which will require extensive treatment of drinking water supplies and be a key issue in all future water supply development plans.

This report addresses key water quality issues for the MRG planning region and the associated impacts on water supply. Section 1 presents water quality issues related to contamination sources. Section 2 presents water quality issues related to naturally occurring water quality. Finally, Section 3 summarizes the water quality impacts on available water supplies.

1. Contaminant Impacts on Water Quality

Contaminant issues affect both the region's surface water and groundwater supplies. Sources of contamination are considered point sources if they originate from a single location or nonpoint sources if they originate over a widespread or unspecified location. Groundwater remediation is needed at many sites in the region to minimize impact to the region's water supplies.

In addition to numerous known and potential contaminant sources, the evolving understanding of water quality issues and the ongoing re-evaluation and updating of water quality standards bring continuing changes that water supply planners must address. Water quality standards for surface water and drinking water are periodically revised, requiring new approaches to maintain environmental protection and safe water supplies. Some new potential contaminants, such as pharmaceuticals and endocrine disrupters, are a growing concern, and water quality standards for these substances have not been adopted for surface water or drinking water.

This section describes the regulatory programs that directly protect water supplies from contaminant releases that could impact water quality. Many other regulatory programs also institute measures for environmental protection, public health, and safety. For example, the Endangered Species Act does not directly regulate water quality, but influences the development of water quality protection requirements to help protect endangered species. Together, existing regulatory programs provide broad water quality protection, although improvements can always be made. The primary water contaminant issues affecting the MRG planning region are discussed in the following sections.

1.1 Surface Water Quality

Potential sources of contamination and measured impacts to surface waterbodies are described in Sections 1.1.1 and 1.1.2, respectively.

1.1.1 Potential Sources of Surface Water Contamination

Point source discharges must comply with the Clean Water Act and the New Mexico Water Quality Standards by obtaining a permit to discharge. These permits are referred to as National Pollutant Discharge Elimination System (NPDES) permits. A summary of NPDES permitted discharges in the MRG planning region is included in Table 1 (NMED, 2002c).

Nonpoint sources of pollutants are a major concern for surface water in the MRG planning region. Potential sources of pollutants or threats to surface waters include activities related to agriculture, recreation, hydromodification, road and highway maintenance, silvicultural activities, resource extraction, land disposal, and road runoff (NMWQCC, 2002). Other natural and unknown sources also affect surface water in the planning region. Specific pollutants or threats to surface water quality resulting from these nonpoint sources are turbidity, stream bottom deposits, metals, total ammonia, pathogens, plant nutrients, and abnormal water pH, temperature, and conductivity (NMWQCC, 2002).

1.1.2 Existing Surface Water Quality

The MRG planning region is drained by portions of the Rio Grande and Rio Puerco watersheds. Water quality in the area is generally good; however, several reaches of rivers within the middle

Table 1. Municipal and Industrial NPDES Permittees
Middle Rio Grande Planning Region

County	Municipality/Industry	Permit No.
Municipalities		
Bernalillo	Albuquerque	NM0022250
Sandoval	Bernalillo	NM0023485
	Cuba	NM0024848
	Rio Rancho # 2	NM0027987
	Rio Rancho # 3	NM0029602
	Jemez Springs	NM0028011
	Cochiti Pueblo Sewage Lagoon	NM0029831
Valencia	Belen	NM0020150
	Los Lunas	NM0020303
	Village of Bosque Farms	NM0030279
Industries		
Bernalillo	Public Service Co. of N.M., Reeves Station	NM0000124
	Sandia Peak Ski Company	NM0027863
	GCC Rio Grande, Inc.	NM0000116
	Public Service Co. of New Mexico, Cobisa Station	NM0030376
	Public Service Co. of New Mexico, Person.	NM0030384
	Reddy Ice Company – Sparkle Ice	NM0030228
Sandoval	Jemez Springs Schools	NM0028479
	Seven Springs Fish Hatchery	NM0030112
	Public Service Co. of NM, Algodones Station	NM0000132
	Uranium King, Rio Puerco Mine	NM0028169
Valencia	B.N. & S.F. Railroad, Belen	NM0000078
	Central New Mexico Correctional Facility	NM0028851
	New Mexico Water Services – Rio Communities	NM0027782
	New Mexico Water Services – UNM Valencia	NM0030414

portion of the Rio Grande Basin have been listed on the 2000-2002 New Mexico 303(d) list (NMED, 2002a). This list is prepared by the NMED to comply with Section 303(d) of the federal Clean Water Act, which requires each state to identify surface waters within its boundaries that do not meet or are not expected to meet water quality standards. Table 2 summarizes information about each of the reaches in the planning region on the 303(d) list.

Section 303(d) further requires the states to prioritize listed waters for development of total maximum daily load (TMDL) management plans. A TMDL documents the amount of a pollutant a waterbody can assimilate without violating a state water quality standard. It also allocates that load capacity to known point sources and nonpoint sources at a given flow. As shown in Table 2, numerous TMDL management plans have already been developed for streams in the planning region, such as the Rio Grande, the Santa Fe River, and listed streams in the Jemez watershed.

The TMDL management plan for the Rio Grande (from the northern border of Isleta Pueblo to the southern border of Santa Ana Pueblo) was developed to address exceedances of fecal coliform. Impairment to the abovementioned stream segment primarily originates from municipal point sources, urban runoff, and storm sewers. There are 12 existing NPDES permits and 1 pending NPDES permit on this reach. The management plan outlines various structures that, once implemented, would reduce the input of fecal coliform to the river.

Two TMDL management plans have been developed for the Santa Fe River (from Cochiti Pueblo to the Santa Fe wastewater treatment plant [WWTP]) to address exceedances of chlorine, stream bottom deposits, pH, and dissolved oxygen. The lower part of this listed reach lies within the MRG planning region. The main sources of impairment are municipal point sources, agriculture, and resource extraction. The only permitted NPDES discharge on this reach is for the Santa Fe WWTP.

In evaluating the impacts of the 303(d) list on the regional water planning process, it is important to consider the nature of impairment and its effect on potential use. Problems such as stream bottom deposits and turbidity will not necessarily make the water unusable for irrigation or even for domestic water supply (if the water is treated prior to use). However, the presence of the impaired reaches indicates that degradation can occur in the water supply.

Table 2. State of New Mexico 2000-2002, §303(d) List for Assessed Stream and River Reaches in the Middle Rio Grande Planning Region

Water Body Name	Total Size Affected (mi^2)	Probable Source(s) of Pollutant	Specific Pollutant	Date T
Rio Grande from northern border of Isleta Pueblo to the southern border of the Santa Ana Pueblo	34.7	Municipal point sources Urban runoff/storm sewers	Fecal coliform	TMDL w app
Rio Cañon de Frijoles from mouth on the Rio Grande to headwaters	2.8	Land disposal	Pesticides (DDT)	Decembe
Santa Fe River from the Cochiti Pueblo to the Santa Fe WWTP	12.7 (6.1) [a]	Municipal point sources Rangeland Resource extraction	pH	TMDL w app
		Municipal point sources	Dissolved oxygen (DO)	TMDL w app
Rio Puerco from Rio Olguin to the headwaters	39.6	Rangeland Road maintenance/runoff Removal of riparian vegetation Streambank modification/ destabilization	Temperature Stream bottom deposits	Decembe
San Pablo Creek from the mouth on the Rio Puerco to the headwaters	10.8	Rangeland Resource extraction Removal of riparian vegetation Streambank modification/ destabilization	Stream bottom deposits Plant nutrients	Decembe
Rio Leche, perennial portions	2.9	Rangeland Removal of riparian vegetation Streambank modification/ destabilization	Stream bottom deposits	Decembe

[a] Area within State of New Mexico jurisdiction.
[b] Proposed to be removed from the 2000-2002 §303(d) list.

mi^2 = Square miles
TMDL = Total maximum daily load
LWWF = Limited warmwater fishery
SC = Secondary contact
IRR = Irrigation
HQCWF = High quality coldwater fishery
WWTP = Wastewater Treatment Plant
MCWF = Marginal coldwater fishery
WWF = Warmwater fishery
LW = Livestoc
CWF = Coldwa
USFS = U.S. Fo

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Table 2. State of New Mexico 2000-2002, §303(d) List for Assessed Stream and River Reaches in the Middle Rio Grande Planning Region

Water Body Name	Total Size Affected (mi^2)	Probable Source(s) of Pollutant	Specific Pollutant	Date T
Nacimiento Creek from USFS boundary to San Gregorio Reservoir	4.6	Rangeland Removal of riparian vegetation Streambank modification/ destabilization	Stream bottom deposits Plant nutrients	Decembe
Las Huertas Creek from Placitas to Capulin Canyon	8.8	Road maintenance/runoff Recreation Removal of riparian vegetation Streambank modification/ destabilization	Stream bottom deposits	Decembe
Galisteo Creek, perennial portions	5.5	Rangeland Hydromodification Removal of riparian vegetation Streambank modification/ destabilization	Stream bottom deposits	Decembe
Sulphur Creek above Redondo Creek to the headwaters	6.8	Unknown Natural	pH Conductivity	Draft TM
Redondo Creek from the mouth on Sulphur Creek to the headwaters	5.2	Rangeland	Turbidity	Draft TM
		Removal of riparian vegetation	Temperature	
San Antonio Creek from the confluence with the East Fork of the Jemez River to headwaters	23.6	Removal of riparian vegetation	Temperature	Draft TM
		Silviculture Land development Natural Recreation Removal of riparian vegetation Streambank modification/ destabilization	Turbidity	

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mi^2 = Square miles
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WWF = Warmwater fishery
LW = Livestoc
CWF = Coldwa
USFS = U.S. Fo

Table 2. State of New Mexico 2000-2002, §303(d) List for Assessed Stream and River Reaches in the Middle Rio Grande Planning Region

Water Body Name	Total Size Affected (mi ^{2})	Probable Source(s) of Pollutant	Specific Pollutant	Date T
East Fork of the Jemez River from the confluence with San Antonio Creek to the headwaters	16.3	Rangeland Silviculture Recreation Streambank modification/ destabilization	Turbidity	Draft TM
Jemez River from Rio Guadalupe to the confluence of the East Fork of the Jemez River and San Antonio Creek	13.4	Natural Unknown	Metals (acute aluminum)	Draft TM
Rio Cebolla from confluence with the Rio de las Vacas to Fenton Lake	9.1	Rangeland Road maintenance/runoff	Stream bottom deposits	Draft TM
Rio Cebolla from confluence with the Rio de las Vacas to Fenton Lake	7	Agriculture Road maintenance/runoff	Stream bottom deposits	Draft TM
		Removal of riparian vegetation	Temperature	
Calaveras Creek from the confluence with Rio Cebolla to the headwaters	5	Road maintenance/runoff	Stream bottom deposits	Propose Decembe
Rio de las Vacas from the confluence with Rio Cebolla to Rio de las Palomas	14	Rangeland Removal of riparian vegetation	Temperature	Draft TM
		Natural Unknown	Total organic carbon (TOC)	
Clear Creek from the confluence with the Rio de las Vacas to San Gregorio Reservoir	4.6	Streambank modification/ destabilization	Turbidity	Draft TM
		Natural Unknown	Total organic carbon (TOC)	

[a] Area within State of New Mexico jurisdiction.
[b] Proposed to be removed from the 2000-2002 §303(d) list.

mi ^{2} = Square miles
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Table 2. State of New Mexico 2000-2002, §303(d) List for Assessed Stream and River Reaches in the Middle Rio Grande Planning Region

Water Body Name	Total Size Affected (mi^2)	Probable Source(s) of Pollutant	Specific Pollutant	Date T
Rio Peñas Negras from the mouth on the Rio de las Vacas to the headwaters	11.6	Rangeland Road maintenance/runoff Removal of riparian vegetation Streambank modification/ destabilization	Stream bottom deposits	Draft TM
		Removal of riparian vegetation	Temperature	
		Unknown Natural sources	Total organic carbon (TOC)	
Rio Guadalupe from the mouth on the Jemez River to the confluence of the Rio de las Vacas and Rio Cebolla	12.4	Natural	Metals (chronic aluminum)	Draft TM
American Creek from the mouth on the Rio de las Palomas to the headwaters	3.8	Rangeland Removal of riparian vegetation Streambank modification/ destabilization	Stream bottom deposits [b] Turbidity [b] Temperature [b]	Draft c letter
Paliza Creek from the headwaters to Paliza Campground	4.5	Removal of riparian vegetation	Temperature [b]	Draft c letter
Vallecito Creek from the eastern Jemez Pueblo boundary to the Village of Ponderosa	5.7	Removal of riparian vegetation	Temperature [b]	Draft c letter
		Rangeland Hydromodification Removal of riparian vegetation Streambank modification/ destabilization	Turbidity [b] Stream bottom deposits [b]	

[a] Area within State of New Mexico jurisdiction.
[b] Proposed to be removed from the 2000-2002 §303(d) list.

mi^2 = Square miles
TMDL = Total maximum daily load
LWWF = Limited warmwater fishery
SC = Secondary contact
IRR = Irrigation
HQCWF = High quality coldwater fishery
WWTP = Wastewater Treatment Plant
MCWF = Marginal coldwater fishery
WWF = Warmwater fishery
LW = Livestoc
CWF = Coldwa
USFS = U.S. Fo

In addition to the 303(d) listings, the State of New Mexico has listed Fenton Lake on the impaired lakes list and has issued fish consumption advisories for Cochiti Reservoir (Table 3). These advisories pertain to mercury, which has been found in some fish at concentrations that could lead to significant adverse human health effects. Although the levels of mercury in waters of these lakes are insignificant, very low levels of elemental mercury found in bottom sediments are passed through the food chain progressively from smaller to larger fish, resulting in elevated levels in the larger fish. The advisories are guidelines only; no associated legal restrictions on catching or eating fish from these lakes have been issued. The State continues to recommend fishing and camping at these lakes, but urges that those who catch and eat fish from these lakes make an informed decision as to what fish they can safely eat. Although the occasional consumption of fish from these lakes poses little risk and the water quality standards for mercury are not exceeded, repeated ingestion over a long period could result in serious health problems.

Table 3. Impaired Lakes and Waters with Fish Consumption Guidelines Proposed for the 2000-2002 §303(d) List

Water Body Name	Total Size Affected [a]	Probable Source(s) of Pollutant/Threat	Specific Pollutant(s) or Threat	Toxics at Chronic Levels	Acute Public Health Concern
Fenton Lake	27	• Agriculture • Recreation • Road Maintenance • Land Disposal • Reduction of riparian vegetation	• Total phosphorus • Siltation • Nuisance algae	NA	No
Cochiti Reservoir	1,240	• Atmospheric deposition • Agriculture	• Fish guidelines • Siltation • Nuisance algae • Pesticides	Hg	No

Source: NMED, 2002a.
[a] Acres within the jurisdiction of the State of New Mexico.
NA = Not applicable Hg = Mercury

1.2 Groundwater Quality

Current and potential uses of the MRG planning region's groundwater resources require that groundwater be protected from contamination. Groundwater contamination has already occurred from both point and nonpoint sources in some areas of the planning region. For this assessment, information about existing facilities that may have the potential to impact groundwater quality was examined through a review of NMED records.

1.2.1 Point Sources of Groundwater Contamination

Within New Mexico, NMWQCC (2002) reports the following statewide frequency of point source groundwater impacts from various contaminant sources:

- Underground (fuel) storage tanks (USTs) 58.5 percent
- Oil and gas 13.7 percent
- Miscellaneous industry 10.1 percent
- Centralized sewage works 4.5 percent
- Mining 3.7 percent
- Aboveground (fuel) storage tanks/pipelines 3.4 percent
- Dairies and meat packing 2.8 percent
- Landfills 0.8 percent
- Unknown/other 2.5 percent

NMWQCC (2002) reports 28 cases of point source contamination of groundwater and 86 contaminated supply wells in Sandoval County and 239 cases of point source contamination of groundwater and 513 contaminated supply wells in Bernalillo County. In addition, 52 cases of point source contamination of groundwater and 161 contaminated supply wells are reported in Valencia County (NMWQCC, 2002).

Underground Storage Tanks

Leaking underground storage tanks (USTs) are one of the most significant point source contaminant threats. As of September 2002, NMED (2002d) had reported 734 leaking UST cases in the planning region (Table 4). These leaking USTs represent releases of gasoline, jet fuel, diesel, gasoline additives, and petroleum constituents such as benzene, toluene, ethyl benzene, and xylene. The leaking UST sites do not necessarily signify that groundwater contamination or water supply well impacts have actually occurred, but that the potential exists. Details indicating whether groundwater has been impacted and the status of site investigation and clean-up efforts for individual sites can be obtained from the database, which is accessible from the NMED website (www.nmenv.state.nm.us/ust/leakcity.htm).

Table 4. Summary of Leaking Underground Storage Tank Sites in the Middle Rio Grande Planning Region

County	City	Number of Sites	Number of Sites with Water Supply Impacts
Bernalillo	Albuquerque	600	12
	Cedar Crest	1	0
	Kirtland Air Force Base	18	0
	Tijeras	10	3
Sandoval	Bernalillo	12	0
	Corrales	1	0
	Cuba	16	0
	Jemez Springs	5	1
	Rio Rancho	9	0
	San Ysidro	3	1
Valencia	Belen	33	2
	Bosque Farms	10	2
	Los Lunas	16	2

Source: NMED, 2002d

Most leaking UST sites in the planning region are concentrated around developed municipal areas such as Albuquerque and are inherently in close proximity to the water supply sources serving these communities. Many additional facilities with registered USTs that are not leaking are also included in the NMED UST database. These USTs present a potential for groundwater quality impacts that could affect available water resources in and near the population centers in the region.

Groundwater Discharge Plans

The NMED Groundwater Quality Bureau regulates facilities with wastewater discharges that have a potential to impact groundwater quality. These facilities must comply with NMWQCC regulations and obtain an approved discharge plan that stipulates measures to be taken to prevent, detect, and if necessary, remediate groundwater contamination. Facilities that are required to provide discharge plans include mines, sewage discharge facilities, dairies, food processors, sludge and septage disposal operations, and other industries. A summary list of the discharge plans in the MRG planning region is provided in Table 5.

The NMWQCC regulations have requirements for the clean-up of groundwater contamination that is detected under an approved discharge plan. However, these facilities still have the potential to contaminate groundwater in ways that may affect the quantity and availability of water supplies. Details indicating the status of discharge plan, waste type, and treatment for individual permittees can be obtained from the NMED website (www.nmenv.state.nm.us/gwb/Web%20Site-DPs.xls).

Superfund Sites

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) was enacted by the U.S. Congress on December 11, 1980. This law created the Superfund program to respond directly to releases or threatened releases of hazardous substances that may endanger public health or the environment. Information regarding the location and status of sites within the MRG planning region listed by EPA as Superfund hazardous waste sites is provided in Table 6. In addition, the EPA prepares a National Priorities List (NPL) that identifies, through a hazard ranking system, which of these sites warrants remedial action. Currently, there are 3 sites within the planning region on the NPL and 12 sites that have either been removed from the list or have no further action planned. The remaining 16 sites either need investigation or are under investigation to determine if the site will be placed on the NPL.

Landfills

Landfills used for the disposal of municipal and industrial solid waste can contain a variety of potential contaminants that may impact groundwater quality. Landfills operated since 1989 have been regulated under the New Mexico Solid Waste Management Regulations. Many small landfills throughout New Mexico, including landfills in the planning region, closed before the 1989 deadline to avoid more stringent final closure requirements. Within the planning region, there are currently 5 operating landfills and 43 closed landfills (NMED, 2000, 1996, and 1990;

Table 5. Summary of Discharge Plans in the Middle Rio Grande Planning Region

County	Closest City	Number of Permits
Bernalillo	Albuquerque	96
	Cedar Crest	6
	Coralles	1
	Edgewood	3
	Los Padillas	1
	Rio Rancho	1
	San Antonito	2
	Sedillo	1
	Tijeras	7
	not listed	1
Sandoval	Albuquerque	1
	Algodones	1
	Bernalillo	7
	Canon	1
	Corrales	6
	Cuba	3
	Marquez	2
	Pena Blanca	1
	Placitas	2
	Rio Rancho	9
	San Ysidro	1
	Santa Fe	1
	Seboyeta	1
	White Rock	1
	not listed	4
Valencia	Belen	20
	Bosque Farms	3
	Grants	2
	Jarales	1
	Los Chavez	1
	Los Lunas	16
	Peralta	1
	Tome	2
	Veguita	3

Source: NMED, 2002b

Nelson, 1997) (Table 7). Landfills present concerns for water quality, because impacts can occur from leachate, landfill gas, and storm water runoff.

1.2.2 Nonpoint Sources of Groundwater Pollution (Septic Systems)

A primary water quality concern in the planning region is shallow groundwater contamination due to septic systems in Bernalillo, Corrales, Albuquerque, Carnuel, Bosque Farms, Los Lunas, and Belen (NMWQQC, 2002). In shallow water table areas, septic system discharges can percolate rapidly to the underlying aquifer and increase concentrations of:

- Total dissolved solids (TDS)
- Iron, manganese, and sulfides (anoxic contamination)
- Nitrate
- Potentially toxic organic chemicals
- Bacteria, viruses, and parasites (microbiological contamination)

Because septic systems are generally spread throughout rural and urban areas, they are considered a nonpoint source. Most of the serious septic system impacts have occurred where groundwater is shallow. Collectively, septic systems and other on-site domestic wastewater disposal constitute the single largest known source of groundwater contamination in New Mexico (NMWQCC, 2002), with many of these occurrences in the shallow water table areas along the Rio Grande valley. Protection of shallow groundwater quality in the populous valley areas of the planning region plays an important role in maintaining the available water resources in these areas.

Measures are being taken to lessen the impacts of septic systems on water quality in the planning region. Bernalillo County has recently enacted a strengthened wastewater ordinance (Bernalillo County Municipal Code, 2001) to address this issue. The new ordinance is performance-based in that treatment requirements are determined by on-site physical conditions and an assessment of the potential risk that effluent will contaminate groundwater. Ongoing progress is also being made to connect expanded areas to centralized sewer systems, and vacuum sewer designs have been implemented to minimize leakage that occurs in pressurized sewage lines. The Bernalillo County wastewater ordinance and progress in expanding centralized sewer systems can be used as a model for similar ordinances to address

Table 7. Landfills in the Middle Rio Grande Planning Region

County	Landfill Name	Operating Status
Bernalillo	Cerro Colorado	operating
	Southwest	operating
	Kirtland AFB	closed
	Kirtland AFB (6 old landfills)	closed
	Sandia Laboratories	closed
	South Broadway	closed
	City River Landfill	closed
	South Eubank	closed
	South Yale	closed
	Los Angeles	closed
	San Antonio	closed
	Coronado	closed
	Sacramento	closed
	Nazareth	closed
	Atrisco	closed
	Riverside Construction	closed
	Nine Mile Hill	closed
	Seay Brothers	closed
	Chilili	closed
	Crawford	closed
	Tijeras Canyon	closed
	Russ Pitney	closed
	WW Cox Wrecking	closed
	Coronado Wrecking	closed
	Albuquerque Downs	closed
	Santa Fe Pacific Coal	closed
Sandoval	Sandoval County	operating
	Rio Rancho	operating
	Cuba	closed
	San Ysidro	closed
	Cochiti Lake	closed
	Pena Blanca	closed
	Jemez Mountain	closed
	Cochiti Pueblo	closed
	Jemez Pueblo	closed
	Sandia Pueblo	closed
	Santa Ana Pueblo	closed
	Santa Domingo Pueblo	closed
Valencia	Tri-Sect	operating
	Belen	closed
	Los Lunas	closed
	Valencia County	closed
	Isleta Pueblo	closed

Sources: NMED, 1990, 1996, and 2000.
Nelson, 1997.

the issue of groundwater contamination from septic tank discharges in vulnerable areas throughout the planning region.

2. Naturally Occurring Water Quality

Water resources within the MRG planning region are constrained by naturally occurring water quality conditions. Most surface water is suitable to provide irrigation supplies, but can only be used as a drinking water supply with treatment. The planning region has groundwater supplies that can be used for drinking water without treatment (other than chlorination for municipal systems). Other groundwater in the region is of unsuitable quality, without treatment, for most uses because of high salinity or the presence of trace metals, as discussed in the following sections.

2.1 Groundwater Salinity

The largest source of fresh groundwater suitable for drinking water supplies and most other uses is the middle and upper Santa Fe Group alluvial sediments of the Middle Rio Grande basin. The terminology used for classification of water quality based on the total dissolved solids is presented in Todd (1980) and summarized in Table 8.

Table 8. Classification of Saline Groundwater

Classification	Total Dissolved Solids (mg/L)
Fresh water	0 - 1,000
Brackish water	1,000 - 10,000
Saline water	10,000 - 100,000
Brine	>100,000

mg/L = Milligrams per liter

Groundwater meeting the New Mexico drinking water standard of 1,000 mg/L occurs up to a depth of approximately 3,000 feet below ground surface (ft bgs) in the middle Rio Grande basin (Kelley, 1974; U.S. Department of the Interior, 1970). At greater depths in the Santa Fe Group sediments, groundwater becomes progressively more saline.

Saline and brackish groundwater exists in formations at the western boundary of the MRG planning region. This saline water is present in deeper portions of the San Andres Limestone and Glorieta Sandstone aquifers in the western portions of Sandoval, Bernalillo, and Valencia Counties. Outside the planning region, the San Andres and Glorieta are important aquifers, but where they occur in the region, they contain highly mineralized water. Constraints on groundwater availability at the eastern margin of the planning region are primarily related to the uplift of the Sandia and Manzano Mountains and the limited water production of formations that overlie the uplifted Precambrian basement rocks. A number of formations provide good water quality in the East Mountain portion of the planning region; however, the yield of these formations to small public water supply systems and domestic wells is relatively small compared to the yield from the central basin Santa Fe Group aquifer.

Desalination can be used to convert brackish or saline water to fresh water by removing dissolved minerals (e.g., sodium and chloride ions). Sources of brackish and saline groundwater are available within the planning region, and desalination can make these currently unused water sources usable. The ability to develop these sources depends largely on whether pumping the brackish or saline groundwater will affect existing freshwater sources within the middle Rio Grande basin. Brackish and saline groundwater in the lower Santa Fe Group sediments of the middle Rio Grande basin, below approximately 3,000 ft bgs, has been considered as a potential water resource (U.S. Department of the Interior, 1970). However, pumping this deep groundwater within the basin could draw shallow groundwater of good quality into deeper portions of the aquifer, adversely impacting the fresh water quality and contributing to water level declines in the upper fresh water aquifer. Whether or not pumping of deep saline groundwater will have an adverse impact on fresh water must be evaluated on a case by case basis.

2.2 Arsenic and Other Trace Metals in Groundwater

Trace metal constituents occurring in New Mexico groundwater at concentrations that sometimes exceed drinking water standards include arsenic, iron, manganese, radium, and uranium. EPA's primary maximum contaminant levels (MCLs) for these constituents, which must be met by all public water supplies, are listed in Table 9.

Table 9. Drinking Water Standards for Selected Trace Constituents

Constituent	EPA MCL [a]
Arsenic	10 µg/L [b]
Iron	0.3 mg/L [c]
Manganese	0.05 mg/L [c]
Radium	5 pCi/L
Uranium	30 µg/L [d]
Gross alpha radiation	15 pCi/L

[a] Pursuant to the Safe Drinking Water Act, 42 U.S.C. 300f *et seq.*
[b] New arsenic MCL becomes effective in January 2006.
[c] Secondary (non-enforceable) standard established for aesthetic reasons.
[d] New uranium MCL takes effect December 8, 2003.

EPA = U.S. Environmental Protection Agency
MCL = Maximum contaminant level
µg/L = micrograms per liter
mg/L = milligrams per liter
pCi/L = picocuries per liter

These constituents are widespread as a result of their natural occurrence in groundwater, although they may also occur as anthropogenic contaminants. Iron and manganese are mobilized from soils under anaerobic conditions that can be caused by septic systems and other organic contaminant releases (NMWQCC, 2002).

Arsenic is currently the most significant naturally occurring contaminant for two reasons. First, it is widespread in areas that are currently used for drinking water supplies in the planning region. Second, in January 2001, the U.S. Environmental Protection Agency (EPA) lowered the arsenic drinking water standard from 50 µg/L to 10 µg/L. The new standard applies to both community water systems and non-transient, non-community water systems. Public drinking water supplies must comply with the new 10 µg/L arsenic MCL within five years of promulgation of the new rule, that is, on or before January 22, 2006. However, certain provisions for extensions due to technical or economic hardship are available.

An extensive study of the occurrence of arsenic in the Middle Rio Grande basin is presented by Bexfield (2001). This study included sampling groundwater from 288 wells and springs distributed across the basin. The source of arsenic-rich waters is recognized as the Jemez Mountains volcanic center, from which arsenic-bearing sediments have been distributed throughout the Santa Fe Group sediments in the Rio Grande basin (Bexfield, 2001). Arsenic concentrations tend to be highest in the northwestern and central portions of the basin, where they may exceed 20 µg/L (Bexfield, 2001).

Approximately one-third of the supply wells in the planning region may exceed the new arsenic standard of 10 µg/L (Bexfield, 2001) and will need to be brought into compliance with treatment. Without treatment, water supplies in the planning region will be substantially limited and the continued use of many existing public water supply wells will not be possible. Many of the same technologies used for arsenic treatment are also applicable to the removal of the other constituents such as dissolved iron, manganese, and uranium. Specific arsenic treatment technologies and costs are discussed in Section 3.3.

Secondary Water Quality Implications of Arsenic Treatment

All types of arsenic treatment produce wastes that can have secondary implications for potential water quality degradation. The primary environmental concern for arsenic treatment (and treatment to remove other trace constituents) involves the management of waste residuals, such as reverse osmosis (RO) brine, coagulation/microfiltration sludge, or spent ion exchange resins.

Generation and disposal of RO brine (highly concentrated, saline water) may be undesirable for several reasons including potential impacts on groundwater or surface water quality, water conservation, and economic considerations. Alternatives for the disposal of brine and the associated water quality issues include:

- *Deep subsurface injection*: Must meet regulatory requirements to prevent impacts on other water resources and requires a Class V well permit from the NMED Underground Injection Control (UIC) Program.

- *Discharge to surface watercourses:* Requires an approved NPDES permit. Within the MRG planning region, it appears that this type of discharge may not be permitted because of degradation of surface water quality.

- *Discharge to sanitary sewer:* Brine disposal to sanitary sewers may not require a permit if the quantities are small enough to ensure that there is no significant salinity change in total flow to the wastewater treatment plant.

- *Discharge to evaporation ponds:* Disposal of brine in lined evaporation ponds requires an approved Ground Water Discharge Plan from NMED under the NMWQCC regulations.

- *Evaporation, crystallization, and disposal of solid salt in a solid waste landfill:* Solid salt is generated from the brine, but water is lost to evaporation.

Solid wastes generated by the alumina absorption, coagulation/microfiltration, or ion exchange processes require disposal in a permitted landfill. The most important consideration is whether the waste sludge or solids are classified as hazardous wastes under the Resource Conservation and Recovery Act (RCRA) regulations. This determination is based on the results of laboratory testing using the Toxicity Characteristic Leaching Procedure (TCLP) to determine if the arsenic concentration exceeds the TCLP limit of 5 mg/L. If the waste fails the TCLP test, it is classified as a RCRA hazardous waste based on the toxicity characteristic for arsenic. Wastes that pass the TCLP test would be classified as non-hazardous municipal waste and could potentially be disposed of at any permitted municipal landfill. This regulation also applies to waste products generated from treatment processes to remove trace constituents other than arsenic.

3. Water Quality Impacts on Water Supply

The water supply available in the MRG water planning region is limited, since the quality of surface water and groundwater restricts supplies to certain uses that are suitable for the quality available. Surface water provides much of the irrigation supply in the planning region, but requires treatment and incurs higher costs to meet drinking water standards. High quality groundwater from the Santa Fe Group aquifer in the Middle Rio Grande basin provides most of the drinking water in the planning region. In total, more than 700,000 residents rely almost exclusively on groundwater for drinking water supplies (Bexfield, 2001). However, the quantity of high quality groundwater is limited, and in portions of the MRG planning region groundwater supplies are more saline and are unsuitable for most uses. Additionally, some of groundwater currently used for drinking water supplies within the planning region contains arsenic at concentrations that exceed the new MCL of 10 µg/L.

This section addresses the most significant water quality issues that affect water supply availability in the MRG planning region. First, a summary of contamination impacts in the planning region is provided. This is followed by discussions of programs currently being implemented and potential approaches to address the following key issues:

- Groundwater quality protection
- Arsenic treatment
- Septic system impacts

3.1 Contaminant Impacts on Water Supply

Numerous contaminant sources exist in the planning region that have caused or have the potential to cause adverse water quality impacts. Within the planning region, the NMWQCC (2002) reports 760 contaminated supply wells. These include both public supply and domestic wells and constitute a significant loss of water supply capacity.

The overall effect on water supply from contaminant impacts is uncertain. There are many contaminated sites, not all of which are well defined, and the extent of future contaminant migration and impacts cannot be predicted with certainty. Within the planning region, the number of sites where groundwater is contaminated or threatened can be summarized as follows:

Bernalillo County

- 239 cases of contamination
- 513 contaminated supply wells
- 629 leaking underground storage tank sites
  - 15 sites that impact water supply
- 21 CERCLA Superfund sites
- 119 groundwater discharge plans (potential point source)
- 31 landfills

Sandoval County

- 28 cases of contamination
- 86 contaminated supply wells
- 46 leaking underground storage tank sites
  - 2 sites that impact water supply
- 8 CECRLA Superfund sites
- 41 groundwater discharge plans (potential point source)
- 12 landfills

Valencia County

- 52 cases of contamination
- 161 contaminated supply wells
- 59 leaking underground storage tank sites
  - 6 sites that impact water supply
- 2 CERCLA superfund sites
- 49 groundwater discharge plans (potential point source)
- 5 landfills

Another variable that can be used to assess water quality impacts on water supply is the rate and success of contaminant remediation efforts. Remediation is important to prevent expansion of groundwater contaminant plumes and further migration of soil contaminants. Within the planning region, soil and/or groundwater remediation projects have been implemented as follows (NMWQCC, 2002):

- *Bernalillo County:* 87 projects
- *Sandoval County:* 15 projects
- *Valencia County:* 24 projects

The value and importance of remediation efforts should not be overlooked in the efforts to provide a safe water supply, as it is generally less costly to remove contaminants before they have become widespread than afterward. The full long-term impact of contaminants on water supply availability and costs for remediation and/or development of replacement water supplies is uncertain.

3.2 Groundwater Quality Protection

Groundwater protection and permitting requirements under New Mexico regulatory programs provide for technical review and permitting of nearly all contaminant sources that have a significant potential to impact water quality. These established programs provide critical protection of water supplies, preventing losses of water resources that, in some cases, may be irreversible.

Within Bernalillo County, the importance of water supply protection has led the County and City of Albuquerque to adopt stringent measures under the Albuquerque/Bernalillo County Ground-Water Protection Policy and Action Plan (GPPAP) (Policy Coordinating Committee, 1995). The GPPAP limits certain potential contaminant sources within areas that are vulnerable to aquifer contamination or are designated for current or future water supply. Aquifer vulnerability has been analyzed for Bernalillo County using a numerical ranking system that considers depth to groundwater and aquifer and soil properties (Aller et al., 1987) to map the County. The GPPAP calls for delineation of specified wellhead protection areas to be established around each public supply well, within which potential contaminant sources are restricted. Wellhead protection areas include the estimated 10-year capture zone around each well, providing additional protection of the water supply system and protecting significant volumes of water for future use.

Delineation of aquifer vulnerability and wellhead protection areas has not been implemented for Sandoval and Valencia Counties. The New Mexico Source Water Assessment and Protection Program (SWAPP) could be employed by communities in these counties to monitor and control development near public supply wells to protect against possible sources of contamination. This is a federally funded program, overseen by the U.S. EPA, that assists communities in protecting their drinking water supplies. The New Mexico SWAPP will assist local communities in:

- Determining the source water protection area for the water system
- Taking inventory of actual and potential contaminant sources within the source water protection area
- Determining the susceptibility of the source area and water system to contamination
- Reporting the SWAPP findings to the water utility, its customers, and the community

- Working with the community and other stakeholders to implement source water protection measures that safeguard and sustain the water supply into the future.

More information about this existing program, which can be used to address protection of public supply wells with minimal additional cost to the local community, is available at the SWAPP website (http://www.nmenv.state.nm.us/dwb/swapp.html).

Installation of individual supply wells by property owners has not been restricted to date, but water quality impacts could lead to regulatory restriction on installing wells where contaminants may be present or in areas vulnerable to groundwater contamination. A property owner's right to drill a domestic well falls under the purview of the New Mexico Office of the State Engineer (OSE), but local governments can implement additional controls. The issue of restricting wells in sensitive areas is as much a social and political issue as it is a technical one.

Restricting wells can limit public exposure to contaminated groundwater, but will not alleviate the water contamination issue. Moving the point of groundwater withdrawal may bypass the contamination, but does not replace the loss of the water supply resources within the impacted area. Instead, groundwater depletions must be increased elsewhere, in areas of higher quality groundwater. Any restrictions that may be placed on supply well locations to protect against contaminant exposure will impact water supply systems and the location of water production.

3.3 Arsenic Impacts on Water Supply

As mentioned in Section 2, the dominant water quality issue now facing the planning region is how to achieve compliance with the new federal arsenic standard of 10 µg/L, beginning in 2006. Naturally occurring arsenic impacts a far greater volume of the planning region's water supply than all of the other contaminant sources combined. Bexfield (2001) estimates that approximately one-third of water supplies in the planning region may exceed the new standard. For example, nearly half of the City of Albuquerque's 92 supply wells have arsenic concentrations that exceed 10 µg/L (Bexfield, 2001).

Because arsenic affects groundwater that the planning region relies on for its water supply, the development of plans and technologies for cost-effective arsenic treatment is critical to maintain the existing supply. In addition, future water supply development will be strongly influenced by the distribution of arsenic in the aquifer, causing development plans to shift to areas where supply wells are most likely to meet the arsenic standard. The added cost of arsenic treatment for groundwater will also make surface water more attractive as a drinking water supply source, although it has been more costly than groundwater in the past because of the need to treat the water prior to use.

3.3.1 Arsenic Treatment Technologies

Treatment technologies to reduce arsenic concentrations are relatively new. In recent years, considerable research has been conducted in this area, leading up to adoption of the new, more stringent MCL for arsenic. Technologies for arsenic removal are still evolving rapidly, and technology breakthroughs are likely in the coming years. Both the U.S. EPA and the American Water Works Association Research Foundation (AWWARF) have investigated available technologies for the removal of arsenic from groundwater and currently support the development of new technologies.

The U.S. EPA has identified the following types of processes as applicable to the removal of arsenic from drinking water (U.S. EPA, 2000):

- Precipitation processes (e.g., coagulation/filtration, lime softening, etc.)
- Sorption processes (e.g., activated alumina)
- Ion exchange processes
- Membrane processes (e.g., nanofiltration, RO)
- Alternative technologies

AWWARF has identified the following technologies as the most promising for aboveground arsenic removal: (1) sorption on activated alumina or other solid media, (2) ion exchange, (3) coagulation/microfiltration, and (4) nanofiltration/RO (Amy et al., 2000). Subsurface arsenic treatment is an innovative and potentially cost-effective technology for in situ arsenic treatment in a zone surrounding an affected supply well (Miller, 2001). In areas with water quality impacted by trace constituents such as fluoride, nitrate, or uranium, treatment processes for arsenic removal can also be used to remove these other constituents.

3.3.2 Selection of Preferred Arsenic Treatment Technology

Many factors must be considered in selecting the most appropriate arsenic treatment technology for a given site including source-water arsenic concentration, total flow rate, general water chemistry, and proximity to an approved disposal site for waste sludge. Water conservation is an important consideration in selecting the preferred technology for a given site, since some technologies for arsenic removal, such as RO, result in a large wastewater stream, while others, such as activated alumina adsorption or coagulation/microfiltration, waste very little water (Chwirka et al., 2000). The high water loss from some technologies may be a significant detriment in a planning region with limited water supplies.

Another consideration is whether the situation requires numerous separate treatment facilities or a single large facility. In many communities in the MRG planning region, the dispersed locations of supply wells, coupled with the large elevation difference between wells, requires that arsenic treatment systems be installed at each wellhead or storage tank rather than at a single large treatment plant (Chwirka et al., 2000). This restriction limits the possibility of economy of scale, making certain technologies more appropriate than others.

Small communities may be able to use point-of-use, ion exchange, or RO systems to remove arsenic within the home. However, treatment costs for small systems will always be higher per household served than centralized systems (Gurian and Small, 2002). Therefore, where feasible, the regionalization of water treatment systems benefits consumers.

3.3.3 Financial Considerations

Communities in the MRG planning region that rely on groundwater with high concentrations of arsenic face increased costs for treatment when the new MCL goes into effect. While federal funding may become available to assist communities in complying with the new drinking water standard, the operation and maintenance costs for arsenic treatment plants will ultimately be passed on to customers. Bitner (2001) has investigated anticipated arsenic treatment costs in New Mexico and found that in addition to the variables mentioned above, the most cost-effective technology for arsenic treatment at a particular location depends largely on system capacity. For example, RO may prove the most cost-effective for small point-of-use systems, whereas large public water supplies may find the coagulation/microfiltration technology most economical.

The American Water Works Association (AWWA) arsenic work group developed a tool to help communities estimate their costs to comply with the new drinking water standard (AWWARF, 2000; Chwirka and Narasimhan, 2000). The tool helps calculate capital and operations and maintenance (O&M) costs, as well as monthly rate increases that can be expected by customers. CH2M-Hill (1999) has investigated arsenic treatment costs ease of implementation for the City of Albuquerque and concluded that coagulation/microfiltration is the preferred technology. Ion exchange was rejected because of the large volumes of generated waste brine and salt that would require disposal.

3.4 Septic System Impacts on Water Supply

Another dominant water quality issue that affects water supply in the planning region is the degradation of shallow groundwater by septic systems. Septic systems and other on-site domestic wastewater disposal systems constitute the single largest known source of groundwater contamination in New Mexico (NMWQCC, 2002). The impact of septic systems is an issue that must be addressed at the local level, because New Mexico regulatory programs do not cover widely distributed septic systems with the same stringent water quality protection that point-source dischargers receive.

Septic system impacts affect the Rio Grande valley, where groundwater is particularly vulnerable, and other areas where numerous septic systems are used. The impact of septic systems is compounded by the fact that areas with numerous septic tanks also have numerous domestic supply wells. The close proximity of domestic wells to septic systems represents a serious regional water contamination and public health issue. Broad areas of the valley and hundreds of supply wells have been affected (Policy Coordinating Committee, 1993). Domestic supply wells tend to be shallow and are easily contaminated by nitrate, iron, manganese, and coliform bacteria that result from septic tank releases. Elevated contaminant concentrations and impacted supply wells have also occurred in areas with deeper groundwater and in the East Mountain area (Policy Coordinating Committee, 1993).

Ongoing efforts to reduce septic system use by extending centralized sewage systems in Bernalillo County seek to improve groundwater quality in affected areas (Hansen and Gorbach, 1997). The future enactment of strengthened on-site wastewater treatment ordinances in Sandoval and Valencia Counties, modeled after the Bernalillo County ordinance discussed in

Section 1, may help address the issue of regional water contamination from septic tanks within the planning region.

3.4.1 Alternative Technologies for Septic System Replacement

Alternative technologies are available to replace conventional septic systems with systems that provide better protection of groundwater quality. Two general alternatives are available, and both have been implemented to some degree within the planning region, demonstrating their feasibility. In broad terms, these alternative technologies include:

- *Construction of expanded regional wastewater collection systems.* Under this approach, septic systems are replaced with connections to centralized wastewater collection, treatment, and disposal facilities. In some areas, this involves expansion of collection systems tied to existing wastewater treatment facilities. In areas distant from existing treatment facilities, entirely new systems would need to be designed and constructed. This infrastructure is costly, although funding may be available from a variety of sources. Actual costs depend on the location and density of the septic systems being replaced and on the distance to the treatment facility. A benefit of this approach is that treated wastewater may be put to secondary use for irrigation purposes or to obtain return flow credits from the OSE.

- *Advanced on-site wastewater treatment systems.* A wide variety of commercially available secondary and tertiary wastewater treatment systems are suitable for individual wastewater systems at a cost of approximately $5,000 to $15,000 for installation (Rose, 2001). These systems use filtration, disinfection, and other biological processes to improve effluent quality. Ongoing operation and maintenance of the on-site treatment systems is also required. An excellent resource on this subject is the National Onsite Wastewater Recycling Association, Inc. (http://www.nowra.org/who.shtml).

To address serious groundwater pollution problems in vulnerable areas, local governments may consider adopting regulations that call for advanced on-site wastewater treatment technologies for most new residences that would otherwise install simple septic systems. Ordinances may also include wording that requires existing systems to convert to new technologies over time.

3.4.2 Water Quality and Water Supply Enhancements

Protection of groundwater quality is the predominant reason to implement alternatives to conventional septic systems; however, other water supply enhancements could be realized by addressing this issue. Managing the use of groundwater in impacted areas can also be beneficial. Impacted groundwater may not be of suitable quality for domestic wells without treatment, but may be suitable for irrigation. Pumping impacted water for irrigation can reduce withdrawals of surface water for irrigation and help to remove contaminants from the shallow aquifer.

An important issue for the planning region is the use of wastewater for return flow credits or secondary reuse. Collecting wastewater for centralized treatment could increase the allowable diversion for water supply, based on the amount of return flow to surface water. Another beneficial approach is the reuse of treated effluent for irrigation or other suitable uses to meet growing demands and offset the use of high quality groundwater.

With increased wastewater flows for centralized treatment, most municipalities in the planning region would be eligible for increased return flow credits to the Rio Grande. Water supply diversions may be increased under OSE approval of a return flow plan. Such a plan can credit a user with return flows and allow diversions to increase by the same amount. Increased return flow credits would allow a municipality to increase diversions for use elsewhere in its water system. Such offsets could allow additional pumping from municipal wells or increased surface water withdrawals.

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S

March 2004 Supplement

Between fall 2003 and spring 2004 a number of parties reviewed the preliminary version of the Middle Rio Grande Regional Water Plan and proposed changes. This document provides the revised content in the form of a supplement. Recipients of this supplement can use the changes provided to replace pages in the original version of the water plan.

The editors reduced the text size in some places in the supplement in order to facilitate page replacement with the December 2003 version. No further significance should be inferred from the modified text size.

A full copy of the revised version is available on CD-ROM.

Additional copies of the supplement or the full revised version may be obtained by contacting the Mid-Region Council of Governments, Albuquerque, New Mexico.

Updates to the December 2003 Version

Replace the listed pages in the original version with the new pages provided. Following is the list of changes.

Front Matter

Replace this entire section.

General Summary

???????????????

Chapter 1

Section 1.1, page 1

Add:

It is important to emphasize that there are very significant uncertainties involved in this planning process. Among them are:

- Precision of measurements
- Predictions of future water supplies and demands
- Quantification of pueblo rights and other private property rights
- Assumptions about use of private property rights
- Institutional concerns such as unused water permits, localized water supply and demands, etc.
- Assumptions about importation of water
- Pending decisions in various litigations
- Priority administration with or without adjudication
- Political will

Section 1.3.1, page 3

Remove “through”

Section 1.3.4, page 5

Add:

The nature of the collaborative water planning process and institutional water planning issues in the Middle Rio Grande Region is discussed in some detail in John Brown’s article, "Whiskey's fer drinkin'; water's fer fightin'!" Is it? Resolving a collective action dilemma in New Mexico (Brown 2003).

Section 1.3.8, page 6

Remove "such"

Section 1.3.9, page 9

Add:

The Placitas area, offset from the mainstem Rio Grande, has conducted three community water planning workshops and performed a current/historical water demand study. These efforts were designed to lead to a subregional water plan as identified in a Memorandum of Understanding with the Water Assembly. The reports of these efforts appear in Supporting Document S.

Section 1.4.3, page 15

Replace "taken" with "made"

Section 1.8, page 18

Add "Normally synonymous with Consumption. The Water Budget document defines it as"

And add:

Diversion	A turning aside or alteration of the natural course of a flow of water, normally considered physically to leave the natural surface channel or aquifer.

And add:

"or plant tissue"

References, page 20

Add:

Brown, John R. "Whiskey's fer drinkin'; water's fer fightin'!" Is it? Resolving a collective action dilemma in New Mexico. 43 Natural Resources Journal 185-221 (2003).

Chapter 5

Section 5.4.2, page 7

Add " 'except in case of extraordinary drought.' "

Section 5.4.4, pages 9-10

Remove:

Over 75 percent of the storage amount in Elephant Butte Reservoir belongs to the states of Colorado and New Mexico as Rio Grande Compact credit waters; therefore, there is very little storage water to allocate to irrigators of the Rio Grande Project. The present allotments are only 15 percent of a full supply for irrigation for Elephant Butte Irrigation District, El Paso County Water Improvement District No. 1, and

Mexico (under the 1906 Treaty). Reclamation has not started with an allotment this low to irrigators of the Rio Grande Project since 1978.

Section 5.6.1, page 13

Add:

As of spring 2004, more recent court decisions and congressional action changed the status of San Juan Chama project water making it unavailable for ESA requirements.

Delete:

- If the Court allows the Rio Grande to dry this year as proposed by the FWS and Bureau, the federal agencies will have violated the ESA, and the Court will have failed in its Congressionally-mandated duty to afford injunctive relief to prevent further harm to the species (See TVA v. Hill).

Section 5.8.1, page 14

Replace "Elephant Butte" with "El Vado"

Section 5.8.1, page 15

Remove:

It works on the same principle as a money-based bank. Individuals within the MRGCD who have rights that they are not using can "deposit" them in the bank so that individuals who need water can "borrow" water from the bank. The right holder receives payment for the loan.

And add:

However, as of spring 2004 the OSE has taken the position that the Conservancy Act does not allow reallocation of use outside of MRGCD boundaries. In addition the OSE has further taken the position that the quantity of rights vested within the MRGCD water bank cannot be quantified until the total beneficial use of MRGCD is established.

Section 5.9.7, page 18

Rename section 5.9.7 title to "5.9.7 Potential New Reallocations of Water Sources"

Replace "new water sources" with "potential reallocations of water"

References, page 28

Replace "(D.N.M. Apr 19, 2002)" with "(D.N.M. Sep. 11, 2002)"

Chapter 6

Section 6.1.2, page 2

Replace:

- 70,000 San Juan-Chama Inflow (incl. approx. 400/26 added to account for filling Heron)

with:

- 70,000 San Juan-Chama Inflow (incl. approx. 15,000 afpy used but not required to fill Heron Reservoir)

Section 6.1.3, page 3

Replace “It” with “We”

Add “This 15,000 afpy would have been available to contractors, had they called for it.”

Remove:

- Following direction from ISC, it excluded water that evaporates from Elephant Butte Reservoir from both inflows and losses.

Section 6.1.4, page 4

Add:

Note: This is a calculated value that does not consider changes in storage in Elephant Butte Reservoir from 1972 to 1997. However, given the uncertainties in water measurements, the calculated value is within acceptable margin of error.

Section 6.1.5, page 5

Replace “Carl” with “Karl”

Figure 6-3, page 9

Remove “Note that the 1950s drought didn’t even drop to the 2200-year average.”

Chapter 7

Section 7, page 1

Replace “by” with “for” (in two places)

Section 7.2, page 1

Replace “by” with “for”

Section 7.2, page 2

Add:

In spring of 2004, the official Biological Opinion regarding the silvery minnow indicates that there is a new requirement for an average additional 50,000 acre feet per year of Rio Grande flow. The implications of this new requirement on the Regional Water Plan have not been evaluated.

Section 7.3, page 2

Replace "by" with "for"

Section 7.4.1, page 5

Replace "30-year average" with "26-year average"

Section 7.4.1, page 5

Add "This 15,000 afpy would have been available to contractors, had they called for it"

Figure 7-4, page 8

Add:

NOTE: "Units" in the model were: acres for Elephant Butte Evaporation, for Riparian Use, for Open Water Evaporation and for Irrigated Agriculture; jobs for Business and Government, and population for Residential Uses.

Table 7-4, page 16

Add "(renewable minus consumption)"

Table 7-5, page 19

Add "(renewable minus consumption)"

Table 7-6, page 22

Add "(renewable minus consumption)"

Table 7-7, page 24

Add "(renewable minus consumption)"

Table 7-8, page 26

Add "(renewable minus consumption)"

Table 7-9, page 28

Add "(renewable minus consumption)"

Table 7-10, page 31

Replace "Total Surplus" with "Net (renewable minus consumption) "

Chapter 8

Section 8.1, page 1

Replace "alternatives" with "suggested alternative actions"

And remove "alternatives"

Section 8.1, pages 1-2

Replace "the most complex, in terms of technical, physical, hydrological and environmental attributes" with "most appropriate for detailed analysis"

Section 8.1, page 2

Remove "in relation to the others"

Section 8.1.1, page 3

Replace "17,000 acres" with "13,000 acres"

And replace "17,680 afpy" with "13,900 afpy"

And replace "$2500/acre" with "$600/acre"

And remove

- . . . in areas with high success rates. Maintenance costs increase in less successful sites where the re-growth must be removed more frequently.

Section 8.1.1, page 4

Remove

- Obtaining city of Albuquerque concurrence, which would be dependent upon whether any excess space is available given city storage needs and commitments of storage space to other entities
- Obtaining legal permission from landowners
- Obtaining a permit from the New Mexico State Engineer
- Concurrence of the Rio Grande Compact Commission
- Environmental compliance

Section 8.1.1, page 12

Remove:

- Potential legal restrictions facing water utilities. For example, the City of Albuquerque water utility must legally deliver water at the cost it takes to produce it.

Section 8.1.1, page 14

Remove

- Legal technicalities regarding "banked" water rights

Section 8.1.1, page 17

Remove

- . . . or fulfilling this need for alfalfa with hydroponic forage could save 99% of the water traditionally used on alfalfa

Section 8.1.1, page 20

Replace "as" with "particularly"

And remove:

The State Engineer has the power, through permit conditions, to allow the commingling of water rights and the conjunctive use of water. Conjunctive management could be strengthened through the passage of legislation, which would allow for the augmentation of surface waters depleted by groundwater pumping.

Section 8.1.1, page 21

Replace:

As the fact sheets in Supporting Document J discuss in more detail**,** in 1948 the Compact Commission made the evaporative losses more equitable to New Mexico when the gaging points were moved from San Acacia and San Marcial to a new gaging station at Elephant Butte Dam.

with

Per the Rio Grande compact, NM is required to keep a certain amount of water in Elephant Butte reservoir A large amount of the water in the reservoir is lost to evaporation. The evaporative loss would normally be shared among all water users, both Texas and New Mexico. Change the Compact so that Texas is responsible for some of the evaporative loss, which would reduce the delivery amount that New Mexico owes Texas. Renegotiating the Compact is highly unlikely.

Section 8.1.1, page 21

Replace:

Water:

- Not Applicable

Cost:

- Not Applicable

Time:

- Not Applicable

Tradeoffs:

- Not Applicable

Other Considerations:

- It may not be in New Mexico's interest to open negations on the Rio Grande Compact because other issues may arise.

With:

Water:

- Reduction in evaporative losses of water in Rio Grande system
- Storage location changes

Cost:

- Cost undetermined

Time:

- Medium to long range period to implement

Tradeoffs:

- Impact on lake recreation uses

Other Considerations:

- Rio Grande Compact issues
- River management
- Fair distribution of consumptive accounting

Section 8.2, page 27

Add "Attribute Ratings are based on professional judgment of technical team."

Chapter 9

Section 9.3.1, page 22

Replace "1959" with "1956"

And replace "8 and 7 inches" with "6 and 5 inches"

And replace "89%" with "67%"

Section 9.3.2, page 22

Add "Unless there is a priority call,"

Section 9.3.3, page 22

Replace "sinks" with "faucets"

Section 9.3.4, page 23

Add:

Spring 2004 information from the ISC indicates that the compact has already apportioned the waters of the basin; evaporative losses are considered neither an asset nor a liability. Therefore, this does not seem to be a viable option.

Section 9.4.2, page 27

Replace "a surface flow model of the" with "a probabilistic model of the water supply available to the"

And replace "the water budget" with "stream flow"

Chapter 10

Section 10.1.2, page 2

Add "Unless there is a priority call"

Section 10.2.2, page 5

Add "including whether"

And add:

Spring 2004 information from the ISC indicates that the compact has already apportioned the waters of the basin; evaporative losses are considered neither an asset nor a liability. Therefore, this does not seem to be a viable option.

And replace “any water management entity” with “all interested parties”

Section 10.2.2, page7

Replace “quality of regional airshed and viewshed” with “regional air quality and regional vistas”

Section 10.2.7, page11

Add “usable”

And add:

Usable water is that water legally available for release for downstream use and is defined as the combined content of Elephant Butte and Caballo Reservoirs less any New Mexico or Colorado credit wate r and less any San Juan/Chama project water in Elephant Butte Reservoir.).

Chapter 11

Add the entire chapter.

Appendices

Appendix C-3

This supplement contains a corrected version of C-3 by Bartolino and Cole.

Appendix R

This supplement contains a hard copy of the <u>entire</u> updated Supporting Docujment R Water Projects.

The new version contains new or updated material as follows:

pp 11-17	Middle Rio Grande Water Assembly, Proposed Projects Directly Related to the Recommendations in Section 10.2.
pp 18-20	Tohajiilee Water Supply Project
pp 21-23	Las Huertas Creek Watershed Project

Appendix S

Public Comments on the preliminary version of the Middle Rio Grande Regional Water Plan.

Supplemental Material

Updates to supporting documents are available on CD-ROM.

Supporting Document T

Final Draft, Technical Memorandum, Tohajiilee Water Supply Project.

Supporting Document U

Historical and Current Water Use in the Placitas Area, Sandoval County, New Mexico.