NATURAL RESOURCES JOURNAL

Volume 15
Issue 2 *Spring 1975*

Spring 1975

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A SOCIO-ECONOMIC EVALUATION OF ALTERNATIVE WATER MANAGEMENT POLICIES ON THE RIO GRANDE IN NEW MEXICO*

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INTRODUCTION

The complexity of today's resource systems makes it almost mandatory that their management be achieved through the application of the talents and technology of a variety of disciplines. The legal and institutional structures of water use make the understanding and application of them a further requisite to good management. Although economic justification should be one foundation of decisions on alternative uses of water, the social and cultural implications must be fully considered, since the optimal use of water implies maximization of benefits returned to society through a broad range of beneficial uses. In order to formulate plans and policies for future water resources development in the Rio Grande Basin of New Mexico, the assessment of future water supplies and requirements necessitates a major consideration of future rates and patterns of economic development.

Making the best use of the fully appropriated water supply in most areas of the Rio Grande remains the major problem facing the State of New Mexico. A continuing and succeeding effort in this direction is being made by a number of state and federal agencies, particularly the New Mexico State Engineer, the New Mexico Interstate Stream Commission, the Bureau of Reclamation, the U.S. Army Corps of Engineers, the United States Geological Survey, and the Soil Conservation Service.

Certain aspects of the problems of the Rio Grande system have been subject to detailed investigation; however, the interrelationships

*The work upon which this article is based was supported in part by funds provided through the New Mexico Water Resources Research Institute by the Office of Water Resources Research, United States Department of the Interior, as authorized under the Water Resources Research Act of 1964, 42 U.S.C. §§ 1961 through 1961c-7 (1970), under project number A-045-NMEX.

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among the hydrologic, economic, and social systems have not been defined. Consequently, this interdisciplinary study was designed to evaluate the social and economic impacts of alternative water-use policies for solving the water scarcity problems of the Rio Grande Region of New Mexico. This objective was achieved through the development of a socio-economic model to evaluate alternative water-use patterns in the region. Research procedures developed for the study were closely coordinated by the investigators, and inputs into the socio-economic model were obtained from separate studies covering the hydrological system and the agricultural, municipal, and industrial sectors. This article represents an in-depth look at the water and related sources in the Rio Grande Region of New Mexico (Figure 1).

For purposes of this article the Rio Grande Region in New Mexico was divided into four subregions (Figure 1). The Upper Rio Grande Region extends from the New Mexico-Colorado state line to Otowi Bridge and includes the counties of Rio Arriba, Taos, and Santa Fe; the Middle Rio Grande Region from Otowi Bridge to the Socorro-Valencia county line includes the counties of Sandoval, Bernalillo, and Valencia; the Socorro Region, which includes Socorro County; and the Lower Rio Grande Region from the Socorro-Sierra county line to the New Mexico-Texas state line. This differs from other previous divisions in that the Middle Rio Grande Basin generally includes the designated Socorro Region. The change was made primarily because the Socorro Region, even though served by the Middle Rio Grande Conservancy District, is essentially a separate area in relation to the type of agriculture, hydrology, geology, and the influence of the Albuquerque metropolitan area.

DESCRIPTION OF THE SOCIO-ECONOMIC MODEL

A mathematical programming model was developed to project future water-use patterns and economic development under alternative legal, institutional, social, and environmental assumptions. This model is essentially a linear programming model designed to represent the New Mexico economy with special emphasis placed upon the Rio Grande region. The model consists primarily of an input-output table of technical coefficients for five subregions (four are within the Rio Grande region and one encompassing the rest of the state). Each subregion is subject to several water-oriented constraints. These constraints include the availability of human, water, and recreational resources.

A major component of the model is an interregional input-output

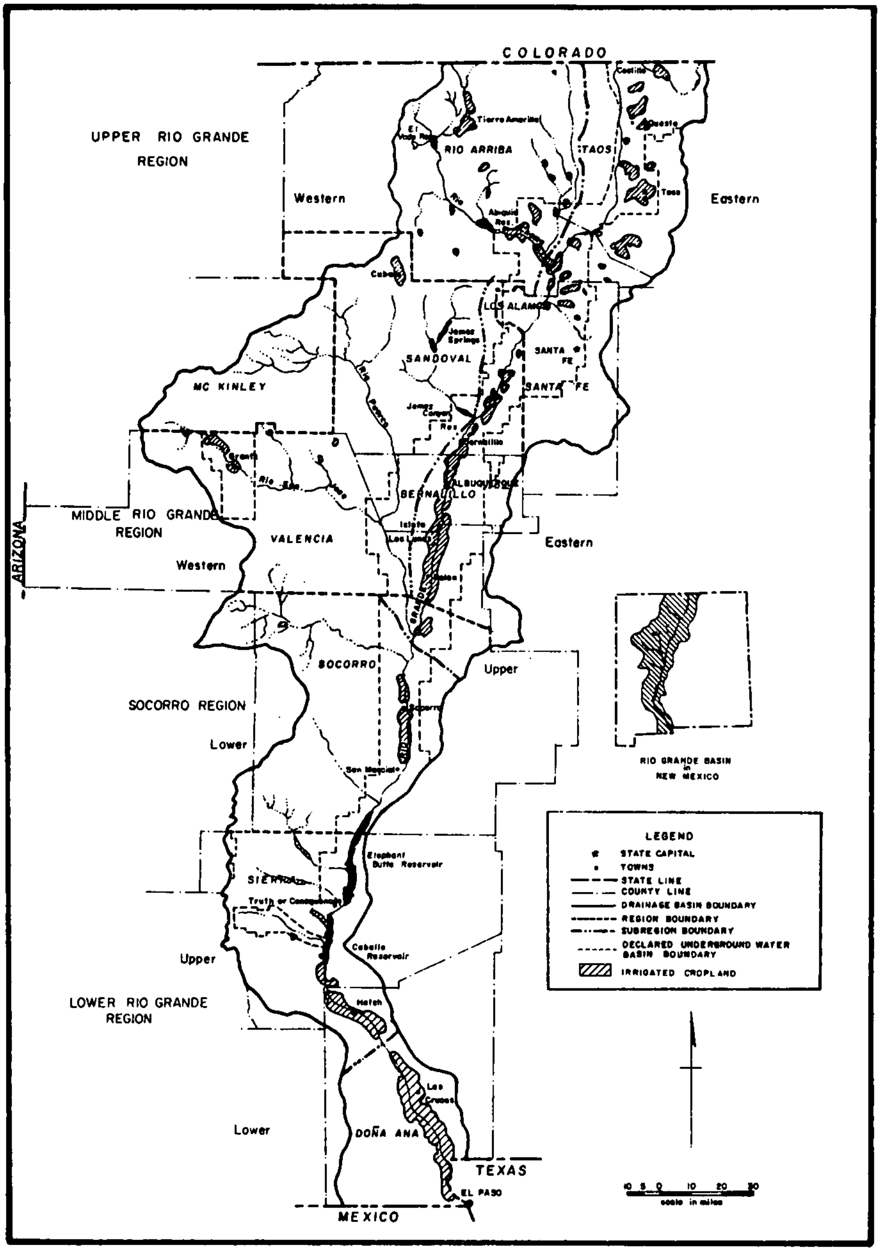

FIGURE 1.
Rio Grande drainage basin in New Mexico.

model developed for this study by utilizing the 1960 New Mexico State Input-Output (I-O) Table[1] which was developed by the New Mexico Bureau of Business Research and updated with 1967 state outputs.[2] The 1960 I-O Table economically classified New Mexico into 50 major sectors. This 50-sector model was aggregated into a 24-sector matrix (Table 1), and regional I-O tables were derived for each of the five subregions. Transactions among the subregions were calculated to derive an interregional input-output table.

An optimal solution of the model for a given set of economic and demographic conditions can be obtained by maximizing the model's objective function. The objective function is constructed to maximize value added within the state subject to several separate cost components. Typically, value added per unit measures the payment to households as wages, payments to governments as taxes, and payments to business as profits. The goal, therefore, is to maximize this net addition to the state. The cost components serve as mechanisms to encourage the system to optimize the use of the resources that these cost components reflect.

Each production sector in each subregion contributes to the total value added according to its level of production, while negative impacts on the environment, such as water pollution, or on the labor force, such as unemployment, impose a cost to the system. The optimal solution should, therefore, provide the optimal mix of production sectors and their geographical distribution which satisfies the state's final demands and resource availabilities while internalizing the environmental and social effects for each subregion.

REGIONAL RESOURCES

A. *Population*

New Mexico's 1960 population was 951,000.[3] Fifty-one percent (434,700) were residents of the Rio Grande Region.[4] Urban dwellers accounted for 352,300, and rural residents accounted for 132,400.[5] In 1970, the population of the region was 572,170: 74.7 percent were urban, and 25.3 percent were rural residents.[6] During the

1. New Mexico Bureau of Business Research, *A Preview of the Input-Output Study,* New Mexico Business, October 1965, at 1.

2. The year 1967 was chosen as the base year for the coefficients in the model because it was the latest year for which output figures on a statewide and county basis could be derived.

3. 1, pt. 33, Bureau of the Census, U.S. Dep't of Commerce, Census of Population: 1960, Table 1, at 33-5 (1963).

4. *See id.,* Table 6, at 33-8.

5. *See id.*

6. *See* 1, PC(1)-A33, Bureau of the Census, U.S. Dep't of Commerce, Census of Population: 1970, Table 9, at 33-17 (April 1971).

TABLE 1
Definition and Classification of Production Sectors

Production Sector	*1960 I-O Study**	*Major SIC Codes***	*Production Sector Description*
Agriculture			
1	1,2		Meat animals, farm dairy products and poultry
2	3		Food grains and feed crops
3	4		Cotton and cottonseed
4	5		Vegetables, fruits and nut trees, miscellaneous food products
5	6	7	Agricultural services
Mining			
6	7,8,11,12	10,12,14	Metals and non-metals
7	9,10	13	Crude petroleum and natural gas, oil and gas field services
Manufacturing			
8	13	201	Meat packing and other meat products
9	14	202	Dairy products
10	15	204,205	Grain mill and bakery products
11	16	remainder of 20	Miscellaneous food products
12	17,21	24,25,32	Lumber and wood products, concrete and stone products
13	19,20	28,29	Chemicals and petroleum refining
14	22,23	19,34,35,36,38, 371-373	Electrical machinery and equipment, scientific instruments, fabricated metal products
15	18,24	22,23,27,31,39	Printing and publishing, miscellaneous manufacturing
Transportation Communications Utilities			
16	25,26	40,41,42,45,47	Railroads and all other transportation
17	27	46,4924	Gas and oil pipelines
18	28,29,30	48,49	Communications, electric and gas utilities
Trade			
19	31,34	50,52,53,54,56,57,59	Wholesale trade and most retail trade
20	32,33	55,58	Retail auto dealers and gas stations, eating and drinking places
Finance, Insurance, and Real Estate			
21	35,36	60,61,62,63,64,65,67	Finance, insurance, and real estate
Services			
22	37,38,39,40	70,72,73,75,76,78,79	Hotels, motels, personal services, business services
23	41,42	80,81,82,88,89,37(p)	Medical and professional services, research and development
Construction			
24	47	15,16,17	Contract construction

*Source: New Mexico Bureau of Business Research, 1965
**Standard Industrial Classification

20-year period between 1950-1970, urban inhabitants of the region increased almost 245 percent while rural population decreased by 5 percent.[7]

B. Employment[8]

Employment data for the Rio Grande Region for the years 1960 and 1970 are summarized as follows: The total civilian work force in the region increased 26.0 percent during the decade compared with 2.4 percent in the rest of the state. The unemployment rate increased from 5.7 percent to 6.0 percent in the region compared with a change from 5.5 percent to 6.7 percent in the rest of the state. In all reported categories except agriculture, the region has increased its portion of the total employment in the state. The largest employment gains for the region were made in contract construction and wholesale and retail trade.

C. Land[9]

Within the Rio Grande Region there are approximately 16.9 million acres. Federal and state ownership account for about 51 percent of the total land area in the Rio Grande Region. Within the region the acreage of forest land controlled by the Forest Service accounts for about 22 percent of the total land area; land administered by the Bureau of Land Management (BLM) accounts for about 18 percent; defense, less than 1 percent; and other federal ownership, about 3 percent. State ownership accounts for about 8 percent; private ownership, about 37 percent; and Indian ownership, about 12 percent of the total land area.

Only 1.7 percent, or 280,785 acres, of the land in the region is irrigated. The irrigated cropland is located in a somewhat narrow strip along the rivers in the Rio Grande region. About 73 percent was cropped acreage and about 81 percent was cultivated acreage. In terms of acres, alfalfa was the most important, accounting for about 22 percent of the total irrigated cropland. The next most important crop was cotton with about 20 percent. Finally, out-of-production and idle acreage accounted for about 19 percent of the total irrigated cropland.

7. *See id.* (changes 1960-70); 1960 Census, *supra* note 3, Table 6, at 33-8 (changes 1950-60).

8. Data in this section are from Employment Security Comm'n of N.M., *New Mexico County Work Force Estimates 1960-68* (July 1970).

9. Data in this section are from R. Lansford, S. Ben-David, T. Gebhard, W. Brutsaert, & B. Creel, *An Analytical Interdisciplinary Evaluation of the Utilization of the Water Resources of the Rio Grande in New Mexico* (Water Resources Research Institute Rep. No. 020, N.M. State U., March 1973) [hereinafter cited as Lansford].

D. Surface Water[10]

Stream flow in the Rio Grande is generated chiefly by the melting snow in Colorado and in the Upper Rio Grande Basin of New Mexico. The perennial streams are located in the northern part of the basin above Albuquerque. Rainfall from summer thundershowers supplements the supply during July, August, and September. Below Otowi Bridge, tributaries flow intermittently during thunderstorms. Flow from the Rio Puerco and Rio Salado is intermittent and heavily laden with silt. Streamflow is consumed in the Albuquerque area and below.

The Rio Grande is not a regulated stream in the usual sense. Only two reservoirs, Elephant Butte and Caballo, exist on the main stem in New Mexico, and they are operated in tandem. Elephant Butte Dam is also the measuring point for the flows received by Texas under the provisions of the Rio Grande Compact. A third reservoir, Cochiti Lake, is presently under construction above Bernalillo on the main stem.

From the Colorado-New Mexico state line south through the Rio Grande Gorge, the stream is declared a Wild and Scenic River. Below Cochiti, most of the water is diverted into the canals of the Middle Rio Grande Conservancy District and the Elephant Butte Irrigation District. Diversion dams, canals, drains, and levees are used to regulate and control the water within the districts. Control of tributary inflow to the Rio Grande is accomplished by reservoirs on the Rio Chama, Jemez River, Rio Santa Cruz, Costilla Creek, and Galisteo Creek.

E. Ground Water

The Rio Grande aquifer consists of a series of structural basins formed chiefly by faulting and other deformation of the older rocks and their subsequent filling with sedimentary and volcanic deposits. This series of basins forms a structural depression generally referred to as the Rio Grande depression, graben, or trough. It is mostly filled with the Santa Fe group sediments, alluvial fans, and valley alluvium. This valley fill of unconsolidated to loosely consolidated sediments is saturated with water and is mostly stream-connected. It generally has high permeability and is extremely thick (in some areas it is over 10,000 feet). High permeability and extreme thickness combine into large values of transmissivity: in some places it is greater than 250,000 gallons per day per foot. Well yields are rather high; for example, an average of 860 gpm is reported for the Albuquerque area.

10. Data in this section are from Lansford.

Because of the lack of data, an estimate of the amount of ground water within the Rio Grande trough is not very reliable. Any estimate of the water supply is tentative because of the unknown saturated thickness of the aquifer and the possibility that the water at greater depths may be of poor chemical quality. Data compiled by Z. Spiegel (1955) indicate that storage coefficients for some areas are approximately 0.2, and that the thickness of the saturated valley fill is between 2,000 and 20,000 feet with an areal extent of about 8,000 square miles. Using a conservative average thickness of fill of 4,000 feet and an average storage coefficient of 0.2, 4 billion acre-feet of water might be stored in the valley fill of the Rio Grande Basin.

An important aspect of this study is the dynamic availability of ground water. In the Rio Grande Basin there exists an intimate relationship between surface water and ground water, and, therefore, ground-water availabilities are not simply related to pumpage but are also controlled by precipitation, amount and frequency of runoff in streams, return of irrigation water, and evapotranspiration. Consequently, the management of such a system should be based on a conjunctive operation of surface and ground water.

For a comprehensive alternative water-use analysis, it is necessary to know both the ground-water availability and the behavior of the aquifer under projected stresses. Since historical records of the hydrologic system in most instances are inadequate to permit direct analysis of basin behavior under projected stresses, it was decided that a ground-water system simulator would be developed. The most efficient and practical simulator for this study appeared to be a mathematical analogue of the hydrologic basin, solved by digital computer.

Ground-water availability in the socio-economic model for the four subregions within the Rio Grande River Basin was assumed to be unlimited in the period of analysis. It was felt that with the tremendous storage in the aquifer, the relatively short time span of analysis (50 years), and the intricate relationship of the ground and surface waters, especially in subregions 1 (Upper), 2 (Middle), and 3 (Socorro), this assumption would not significantly affect the results or inferences of the model. Built into the model was the effect of time and increased pumpage on surface-water flow or availability. Each year the pumpage from ground water will decrease surface flow due to either or both of the following reasons: 1) decreased flow from the aquifer to the river when the water table is above river level, and 2) increased flow from the river to the aquifer when the water table is below river level.

F. Water Quality[11]

The quality of the surface water of the Rio Grande reflects the use of the water upstream. Below Otowi Bridge all ionic constituents increase while flow decreases. The consumption of water by irrigated agriculture tends to concentrate constituents. In addition, exchange of ions between the water and soil can increase certain ionic concentrations.

Large concentrations of sediment in the Rio Grande constitute another major water quality problem. Substantial loads are carried by the Rio Grande to be deposited in Elephant Butte Reservoir. Sediment management and control is a major problem throughout the Middle Rio Grande Conservancy District. Heavy silt loads carried by the Rio Grande below its confluence with the Rio Puerco at Bernardo have settled and caused the river bed to become aggraded. Most of the sediment is produced by the collapse of channel walls where tributaries flow through deep gorges in silty soil and by the surface erosion of lands with sparse vegetation.

There is a possibility that ground water below a certain depth (perhaps 2,000 feet) in the Rio Grande trough may be of lower quality and may not be directly usable. Lack of adequate subsurface data precludes an extensive survey of ground-water quality. The data available come from local (*e.g.*, municipal) studies, mostly of electrical conductivity analyses. Locally increased dissolved solid contents are due to urbanization and agricultural development, and salinity tends to increase from north to south along the basin.

G. Water Utilization

Water in the Rio Grande Basin is supplied from surface sources, underground sources, and combinations of the two. Ground water meets most of the municipal, industrial, commercial, mineral, power production, rural domestic, and stock-watering requirements. Surface sources furnish the primary supply of water for irrigation. In 1970, about 45 percent of all the acreage in the basin was supplied entirely from surface-water sources, about 7 percent was dependent entirely on ground water, and the remaining 48 percent received a combination of both surface water and ground water.[12]

During the period 1969-1970, about 576,000 acre-feet were depleted annually in the Rio Grande region. Irrigation depletions accounted for almost 90 percent of the beneficial depletions.

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11. Data in this section are from Lansford.

12. Lansford & Sorenson, *Trends in Irrigated Agriculture, 1970 and 1971*, in New Mexico Agriculture–1971, at 42-43 (Agricultural Experiment Station Research Rep. No. 235, N.M. State U. 1972).

H. Recreation[13]

The Rio Grande Basin comprises 54 percent of the total miles of trout streams in New Mexico but only 29 percent of the miles of warm water streams. Lakes and reservoirs in the Rio Grande Basin account for 52 percent of the total acreage available in New Mexico. Within the basin, 87 percent of the lakes and reservoirs are located in the lower Rio Grande Region which includes Elephant Butte and Caballo Reservoirs.

COMPARISON OF ALTERNATIVES

The socio-economic model was utilized to simulate long-run production and water utilization patterns in the Rio Grande Basin under alternative assumptions. A basic optimal solution was used to approximate 1970 conditions. Each simulation process starts with this same basic solution to the model and continues with annual changes to satisfy the alternative conditions for a period of 50 years. Differences between the basic optimal solution of the model and the actual production levels in 1970 result from the optimization procedures used. The optimal use of resources in the model allows for social considerations such as recreation demands and unemployment levels. This basic optimal solution of the model was used as a point of departure for the alternative solutions; hence, a description of the basic solution is presented first.

A. The Basic Optimal Solution of the Model

The economy of New Mexico was represented in the model by 24 production sectors (Table 1). All sectors were defined in the model in units of one million dollars of production. Each sector had its own demands for resources such as water, and labor, and its contribution to the total benefits to the state's economy (measured by the value added of each one-million-dollar unit). Tables 2 and 3 present some of the major results of the basic model and relate them to water utilization.

Table 2 presents measures of outputs, inputs, and efficiencies of water use by sector, and detailed levels of production for all 24 sectors measured in value of total output. The value added generated by each sector ranges from 17.7 percent of the total value of output in the meat packing industry (Sector 8) to 71.2 percent in retail auto and eating places (Sector 20). The average value added in the Rio Grande Region was 58 percent of total output. The large coefficients of output per unit of water in the nonagricultural sectors are a result

13. Data in this section are from Lansford.

TABLE 2

Production, Value, Employment and Water Use by Production Sector in the Rio Grande Region, 1970–Basic Optimal Solution

*Sector**		*Total Output*	*Value Added*	*Employment*	*Water Depletions*
		($1 thousand)	*($1 thousand)*		*(acre-feet)*
Agriculture	1	41,839	14,351	2,346	79,888
	2	9,886	6,357	1,424	224,748
	3	8,574	5,264	233	134,180
	4	19,526	15,406	2,739	58,393
	5	4,950	3,024	454	59
Mining, oil & gas	6	81,785	52,342	1,731	2,977
	7	26,277	19,051	189	1,594
Manufacturing	8	20,651	3,655	273	62
	9	25,948	6,798	504	111
	10	14,277	4,183	537	20
	11	13,071	4,902	539	189
	12	56,155	26,730	2,332	854
	13	7,931	1,753	109	297
	14	70,345	29,615	4,017	158
	15	50,456	26,691	2,139	137
Trade & services	16	109,842	72,935	5,004	274
	17	13,501	9,316	151	34
	18	104,925	68,201	4,518	4,484
	19	325,258	214,345	22,071	1,597
	20	98,281	69,976	11,297	579
	21	177,302	131,381	7,230	1,742
	22	151,463	88,303	13,158	1,940
	23	517,957	286,430	17,474	6,371
	24	172,462	71,744	9,559	3,039
	Total	2,122,660**	1,232,753**	110,030	523,722**

*for sector definition see Table 1.
**does not add due to rounding.

of the low water consumption in these sectors. The number of employees in each production sector is presented in the employment column of Table 2.

Table 3 magnifies the differences between the agricultural sectors and all other producing sectors. While the agriculture sectors produced only 4.0 percent of the total output, 3.6 percent of the total value added, and provided only 6.5 percent of the total employment, they consumed 94.9 percent of all the water used in production in the Rio Grande Region. The trade and services sectors played the opposite role, using only 3.9 percent of all water depleted by the production sectors but were responsible for about 79 percent of the total value of output and 82.2 percent of the total value added.

Water recreation demands in the Rio Grande Region in the base year (1970) and the distribution of supply by origin are as follows:

TABLE 3

Production, Water Use, and Employment for Major Sectors in the Rio Grande Region, New Mexico—Basic Optimal Solution

Major Sector	*Total Output* ($1 thousand)	*Total Value Added* ($1 thousand)	*Employment*	*Total Water Depletions* (acre-feet)	*Output per Acre-foot* (dollars)	*Value Added per Acre-foot* (dollars)	*Water Depletions per Employee* (acre-feet)
Agriculture	84,775	44,402	7,196	497,268	170	89	69.10
Mining, Oil & Gas	108,062	71,393	1,920	4,571	23,641	15,618	2.38
Manufacturing	258,834	104,327	10,451	1,826	141,749	57,134	0.17
Trade & Services	1,670,991	1,012,630	90,463	20,059	83,303	50,482	0.92
Total	2,122,660*	1,232,753*	110,030	523,722*	4,053**	2,354**	4.76**
	(percent)	(percent)	(percent)	(percent)			
Agriculture	4.0	3.6	6.5	94.9			
Mining, Oil & Gas	5.1	5.8	1.8	0.9			
Manufacturing	12.2	8.4	3.5	0.3			
Trade & Services	78.7	82.2	82.2	3.9			
Total	100.0	100.0	100.0	100.0			

*does not add due to rounding
**weighted average

The major supply area for water skiing and boating is the Lower Rio Grande. Recreationers from the Middle, Socorro, and Lower Regions, as well as out-of-state visitors utilize the availability in the Lower Region. The Lower Rio Grande Region satisfies about 43 percent of the Middle Rio Grande Region's demand for water skiing, about 23 percent for boating, but none of the Middle Rio Grande Region's demand for fishing. The out-of-state demands far exceed out-of-state supplies for all three water-based recreation activities.

B. Three Water Management Alternatives

The socio-economic model was used to estimate the effects of population growth on the distribution of production and water requirements for the period 1970-2020 in the Rio Grande Region. Regional population projections used in the model were based on the New Mexico Bureau of Business Research county projections.[14] An increase in population affects the final demand for consumer products and the labor force, as well as the direct demand for water for municipal and rural use. An increase in the final demand will affect all 24 sectors according to the interrelationships of the input-output table. Because of these predetermined relationships, any change in the final product mix produced within the region will require a change in the model constraints.

Three alternative solutions of long-run production and water-use patterns, utilizing a population growth at an average rate of 1.19 percent annually or 59.5 percent for the period 1970-2020, are presented below. The three alternatives differ only in water constraints. In the first alternative, water availability was not constrained. The production sectors were permitted to grow as required in order to supply the products demanded. Thus, additional surface water for agricultural use would become available as needed: for example, by water importation or water-saving technological developments. Ground-water sources were assumed to be sufficient to permit the required increases in pumpage but not to substitute for surface sources.

The assumption that surface water can be imported to satisfy all future demands is not a realistic assumption. There are only limited opportunities for water importation to the Rio Grande Basin. It is more likely that no additional surface water will be available in the foreseeable future. The second alternative reflects this assumption and places a constraint on surface-water availability: *i.e.*, the 1970 surface-water supplies plus the San Juan-Chama diversion water. Any

14. R. Edgel, Projections of the Population of New Mexico and Its Counties to the Year 2070 (Bureau of Business Research, U.N.M., July 1968).

increase in water demand is required to be satisfied within the region. In the model, surface and ground water are used in fixed proportions in the agricultural sectors; thus, ground water cannot be substituted for surface water. The effect of limiting surface-water availability to 1970 levels (basic optimal solution) implies that growth in agricultural production can be expected only in areas where the availability of surface water exceeds depletions. No effect should be expected in the nonagricultural sectors because ground-water depletions have not been restricted. Under the legal constraints imposed by the water laws of New Mexico, the mining of ground water may be restricted by the authority of the State Engineer to declare a ground-water basin and to close it to future development. Most of the Rio Grande Region in New Mexico lies within declared basins. To maintain the base flow of the Rio Grande, increased pumping effects on the river must be offset by retiring surface-water rights. This alternative approximates the current administration of water resources in the Rio Grande Region.

The third alternative is much more restrictive than the second alternative of imposing a constraint on the surface water only. This alternative reflects contraints placed on both surface-water and ground-water resources. Total surface-water availability for use in the Rio Grande Region was restricted to the average surface flow in the Rio Grande, including the supplementary flow from the San Juan-Chama project. Ground-water pumpage was initially restricted in this set to the total pumpage in 1970. It was assumed that any future growth will require the transfer of surface-water rights from agriculture to other production sectors and uses (rural, domestic, and municipal). A transfer mechanism was added to the model to allow the transfer of surface-water rights to ground-water rights. Additional pumpage was permitted only to the extent that surface-water depletions were reduced.

Within the alluvial deposits of the Rio Grande the surface water and ground water are connected, and pumpage either diverts water from the river or intercepts water destined for the river. In order to maintain interregional deliveries over time, the total surface-water availability in each region was reduced annually to compensate for the additional effects of pumping upon the flow of the river.

1. Alternative 1: No Water Constraint

The long-run effects of population growth under the above assumptions are summarized in Table 4. Table 4 presents the production levels required to satisfy the increases in local demand and expected increases in nonagricultural out-of-state sales. Total value of

TABLE 4

Summary of Alternative Solutions for the Rio Grande Region, New Mexico, 1970-2020

Alternative	*Sector*	*Value of Production*	*Value Added*	*Employment*	*Water Depletions*
		($1 million)	*($1 million)*		*(acre-feet)*
BASIC OPTIMAL SOLUTION–1970	Agriculture	84.8	44.4	7,197	497,268
	Mining	108.1	71.4	1,920	4,571
	Manufacturing	258.9	104.3	10,451	1,826
	Trade & Services	1,671.0	1,012.6	90,463	20,059
	Mun. & Rural				39,144
	Total	2,122.7*	1,232.7	110,030*	562,866*
NO WATER CONSTRAINT	Agriculture	117.2	61.8	9,997	724,603
	Mining	170.9	112.9	3,027	7,199
	Manufacturing	415.9	167.5	16,781	2,928
	Trade & Services	2,686.2	1,627.4	145,374	32,221
	Mun. & Rural				62,660
	Total	3,390.3*	1,969.5*	175,178	829,611
SURFACE-WATER CONSTRAINT	Agriculture	110.3	57.3	9,213	586,215
	Mining	170.9	112.9	3,027	7,199
	Manufacturing	415.6	167.3	16,767	2,926
	Trade & Services	2,675.3	1,621.3	144,827	32,088
	Mun. & Rural				62,660
	Total	3,372.2*	1,958.9*	173,833*	691,087*
TOTAL WATER CONSTRAINT	Agriculture	107.4	55.5	8,900	528,050
	Mining	173.9	114.8	3,073	7,285
	Manufacturing	415.8	167.4	16,776	2,926
	Trade & Services	2,674.0	1,620.5	144,699	32,070
	Mun. & Rural				62,660
	Total	3,371.1	1,958.2	173,448	632,989*

*Does not add because of rounding.

production in the Rio Grande Region is expected to increase at approximately the same rate as the population. This amounts to an increase of more than $1,267.6 million (59.7 percent) in the total value of production for the period 1970-2020.

Agricultural production is expected to increase only 38.3 percent compared to an increase of 59.7 percent in the total value of production ($32.5 million). This smaller than average increase results from the assumption that additional surface water will not be made available for agricultural exports and will be used only for local increases in demand for agricultural products. The major increases in agricultural products are expected in the Middle Rio Grande Region which also expects the largest population increase. This results from the interregional input-output matrix structure which does not allow for changes in the interregional transfer coefficients.

The total nonagricultural production is expected to increase by $1,235 million. The expected increase in agricultural production represents only 2.6 percent of the total increase in the value of production, while it represents 85.2 percent of the additional water depletions required.

Water depletions in the year 2020 are expected to reach almost 830,000 acre-feet. This increase of 266,743 acre-feet over the depletions in 1970 will be required to meet the projected population needs in 2020. Of this amount the agricultural sectors will require 227,336 acre-feet, the remaining production sectors 15,769 acre-feet, and domestic increases 23,516 acre-feet. The increase in agricultural depletions will be met by utilizing 191,720 acre-feet of surface water and 35,616 acre-feet of ground water. All increases in surface water will be used by agriculture.

2. Alternative 2: Surface-Water Constraint

Table 4 summarizes production levels, employment by sector, and expected water depletions for this alternative. The Rio Grande regional value of production would be $3,390.3 million without a constraint and $3,372.2 million with a surface-water constraint. Thus, the cost of imposing a surface-water constraint is $18.1 million (0.53 percent). Direct agricultural production would decrease $6.9 million, manufacturing production $0.3 million, and trade and services about $10.0 million. Surface-water depletions in the Socorro and Lower Regions in the base year 1970 approached the average annual availability for these regions. The Upper and Middle Regions are expected to benefit from the additional surface water to be supplied by the San Juan-Chama diversion project. Thus, the long-run average annual availability in these two regions exceeds their 1970 depletions. Total surface-water availability is reduced over time because of the increased effect of ground-water pumping over time and the increases in pumpage necessary to satisfy growth requirements. The decrease in ground-water depletions for agricultural use in the same years results from the fixed ground-water-to-surface-water relationship assumed for agricultural production. This assumption was necessary in order to avoid further surface-flow depletions which would take place if ground water were substituted for surface water in agricultural production. The total surface-water usage decreases in the fifty-year period due to the effect on the river of continued pumpage at an increasing rate, even though the total average flow in the Rio Grande is increasing by 110,000 acre-feet (from the San Juan-Chama).

Ground-water depletions for nonagricultural use are expected to increase by 65,599 acre-feet (60 percent). Total water depletions are expected to increase 22.8 percent and reach 691,086 acre-feet in 2020. However, this is 138,524 acre-feet less than the amount required where no water constraint was imposed. Reduced agricultural depletions would account for over 99 percent of the reductions. The demand for agricultural products which could not be satisfied in this case is allowed to be supplemented by agricultural imports or by reduction of exports.

3. Alternative 3: Surface-Water and Ground-Water Constraint

Production, employment, and water depletions for this alternative are also presented in Table 4. The additional constraint on ground-water availability shows its impact mainly in the Socorro Region where agricultural production must be reduced in order to release enough water rights to allow the other sectors to reach their required level. The cost of imposing the additional constraint on ground water is $1.1 million in 2020 compared to a surface-water-only constraint, and $19.2 million compared to the alternative without any constraint on water.

Total value of annual output in the Rio Grande Region is expected to increase by $1,270.4 million between the years 1970-2020. This increase of 58.8 percent is close to the projected population increase in the region.

Average annual surface-water availability in the Rio Grande Region in the base year 1970 was 527,100 acre-feet, 412,151 acre-feet of which were depleted. The total pumpage in the base year reached 300,000 acre-feet, 150,715 of which were depleted.

Total surface availability will be reduced to 443,800 acre-feet by the year 2020 as a result of the increased effect of continued pumpage at an increasing rate. The increased demand for water by the nonagricultural sectors will require a transfer of 47,166 acre-feet from surface rights to ground-water pumpage. Annual agricultural production in 2020 will be $22.6 million more than in 1970. The increase in agricultural production will occur primarily in the Middle Rio Grande Region where water depletions in the base year reached only 55 percent of the average annual availability of 170,000 acre-feet. By the year 2020, total surface availability in that region will decline to 67.5 percent of the 1970 availability. In addition, increased demand for nonagricultural water use will require the retirement of additional surface rights.

4. Summary

Three sets of water management alternatives have been presented for the Rio Grande Region. The first was an analysis of the region's growth without a water constraint. The second was an analysis of growth, with a surface-water constraint. The third was an analysis of growth, with both surface-water and ground-water constraints. The solutions for these alternatives are summarized in Table 4.

Without a water constraint, both regional production and depletions are expected to exhibit the largest increase (59.7 percent and 47.4 percent, respectively) in 2020. When a surface-water constraint is imposed, the value of production is reduced by $18.1 million in 2020 and water depletions are expected to decrease about 17 percent (138,523 acre-feet). With a surface-water and ground-water constraint, the value of production is expected to be reduced to $3,376.1 million in 2020, decreased $1.1 million before the value obtained when only a surface-water constraint is imposed and decreased by $19.2 million below the no-water-constraint alternative.

The level of employment is expected to exhibit the largest increase, about 60 percent from 1970 to 2020 under the no-water-constraint alternative. When a surface-water constraint is imposed, the level of employment is expected to be reduced by 1,345 (0.3 percent) employees in 2020. Agricultural sectors are expected to account for about 60 percent of the reduction, the Trade and Services sector about 40 percent, and manufacturing less than one percent. With a total water constraint, the level of employment is expected to be reduced by an additional 385 employees below the surface-water constraint and 1,730 below the no-water-constraint alternative. Agricultural production sectors are expected to account for over 80 percent of the additional unemployment.

Water depletions are expected to decrease from 829,610 acre-feet without any water constraints to 632,989 acre-feet with a total water constraint, a 24 percent reduction. The impact of this reduction is expected to be felt mainly in the Middle Rio Grande and Socorro Regions where agricultural water depletions must be reduced in 2020 to release enough water rights for other other sectors' growth. The Middle Rio Grande Region is expected to deplete for nonagricultural uses all of the surface-water rights by the year 2075. Without water imports, increased pumpage restrictions will have to be placed on manufacturing, services, and municipal water usage at this time. Any allocation of surface-water rights to agriculture will require these changes at an earlier date. Another alternative might be interregional transfer of water rights. The other regions are expected to have enough surface-water rights to last many years. The Albuquerque metropolitan area has about 90 percent of the expected population increase in the total Rio Grande Region; consequently, the pumpage necessary to sustain its growth increases its effect on the Rio Grande flow by more than 1,000 acre-feet annually.