AN ANALYTICAL INTERDISCIPLINARY EVALUATION OF THE UTILIZATION OF THE WATER RESOURCES OF THE RIO GRANDE IN NEW MEXICO

LOWER RIO GRANDE REGION

Robert R. Lansford,	*Principal Co-Investigator & Project Coordinator, Agricultural Economist*
Shaul Ben-David	*Principal Co-Investigator, Economist*
Thomas G. Gebhard, Jr.,	*Civil Engineer*
Willem Brutsaert,	*Hydrologist*
Bobby J. Creel,	*Agricultural Economist*

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This study was part of an interdisciplinary-interuniversity research project entitled "An Analytical Interdisciplinary Evaluation of the Utilization of the Water Resources of the Rio Grande in New Mexico."

The principal investigators were Robert R. Lansford, Agricultural Economist, New Mexico State University; Shaul Ben-David, Economist, University of New Mexico; Thomas G. Gebhard, Jr., Civil Engineer, New Mexico State University; Willem Brutsaert, Groundwater Hydrologist, New Mexico Institute of Mining and Technology; and Bobby J. Creel, Agricultural Economist, New Mexico State University. Other investigators included John W. Hernandez, Civil Engineer, New Mexico State University; Clyde Eastman, Development Sociologist, New Mexico State University; John Borrego, Landscape Architect, University of New Mexico; William C. Arnwine, Industrial Engineer, New Mexico State University; and Walter Parr, Attorney, Las Cruces, New Mexico.

These consultants were included in the research effort and made contributions both in advice to the study group and in data development. The architectural consultant provided information on landscape architecture and aesthetic functions of the environment as related to alternative settlement patterns. Sociological and population problems in the Rio Grande region were considered by the Development Sociologist and included in the interregional models. The law consultant served on legal phases which developed as the investigations proceeded, and his advice was considered in the final analysis of the study. The Industrial Engineer helped in the development

of industrial water-use coefficients. Robert R. Lansford served as the coordinator for all phases of the project.

Although the research team is solely and totally responsible for statements and conclusions in this report, many people helped in the work: Fred Roach, Graduate Assistant at the University of New Mexico, helped with the development of the socio-economic model. One of the key elements of this study was the use of a Technical Advisory Committee composed of representatives from state and federal agencies. The willingness of this advisory committee to work with the study group was outstanding. Many of the changes in the study reflected the advice offered by members of the Technical Advisory Committee. Membership of the Technical Advisory Committee was:

Mr. Robert F. Stephens	U.S. Bureau of Sport Fisheries and Wildlife
Mr. T. A. Garrity	U.S. Bureau of Indian Affairs
Mr. William E. Hale	U.S. Geological Survey
Mr. W. J. Anderson	U.S. Bureau of Land Management
Mr. James Kirby	U.S. Bureau of Reclamation
Mr. Rowland Fife	U.S. Bureau of Reclamation
Mr. Wayne Cunningham	Elephant Butte Irrigation District
Mr. Ralph Bell	U.S. Soil Conservation Service
Mr. Phil Mutz	New Mexico Interstate Stream Commission
Mr. Pete Metzner	Middle Rio Grande Council of Governments
Mr. Charles F. Youberg	Middle Rio Grande Council of Governments
Mr. Larry Bronaugh	U.S. Bureau of Indian Affairs
Mr. Mike Martinez	U.S. Bureau of Land Management
Mr. Edwin A. Lewis	U.S. Bureau of Reclamation
Mr. Robert Schembera	U.S. Bureau of Reclamation
Mr. Ed Grey	U.S. Soil Conservation Service
Mr. Clyde Wilson	U.S. Geological Survey

Graduate students who participated in the study are as follows:

Student Assistants	Degree Sought	Discipline
Bobby J. Creel	M.S.	Agricultural Economics - NMSU
Fred Roach	Ph.D.	Economics - UNM
Shao-Chih Way	Ph.D.	Hydrology - NMIMT
Gary L. Richardson	M.S.	Civil Engineering - NMSU
Numa Imara	Ph.D.	Civil Engineering - NMSU

Don D. Jones	Ph.D.	Civil Engineering	- NMSU
Jesus Najera	Ph.D.	Hydrology	- NMIMT
William R. Porter	M.S.	Economics	- UNM
David Mishaeli	Ph.D.	Economics	- UNM
C. L. Edwards	Ph.D.	Geophysics	- NMIMT
Mohammed Q. Islam	Ph.D.	Civil Engineering	- NMSU
Abdul Mohammed	Ph.D.	Civil Engineering	- NMSU
Hugh Ryan	M.S.	Industrial Engineering	NMSU
John Uxer	M.S.	Industrial Engineering	NMSU
Wellman Lim	M.S.	Industrial Engineering	NMSU
Mohd Sualeh Qurashi	M.S.	Industrial Engineering	NMSU

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ABSTRACT

An interdisciplinary approach to the solution of the water resource problems of the Lower Rio Grande Region in New Mexico was centered around a socio-economic model, developed to represent the New Mexico economy, with special emphasis placed upon the Rio Grande region. Inputs into the socio-economic model were obtained from separate studies covering the hydrological, agricultural, municipal, and industrial areas.

Three sets of alternatives were considered: 1) growth without a water constraint; 2) growth, with a surface-water constraint; 3) growth, with both surface- and ground-water constraints.

Without a water constraint, in the Rio Grande region, both production and depletions are expected to exhibit the largest increase (59.7 percent and 47.4 percent, respectively). 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 18.1 percent by 2020. When a total water constraint is imposed, the value of production is decreased $4.1 million below that expected when using only a surface-water constraint, and water depletions are reduced about 8.4 percent.

The Lower Rio Grande Region is expected to follow the general trend of the total Rio Grande region but at a slightly higher growth rate. The expected increase in total value of production from 1970 to 2020 is 62.0 percent, employment is about 63.5 percent.

When a surface-water constraint is imposed, the value of production is expected to be reduced $13.6 million in 2020, employment by 929 employees, and water depletions by 61,404 acre-feet. When an additional constraint is imposed on ground water in the LRGR, value of production would be decreased $0.4 million in 2020, employment by an additional 15 employees, and water depletions by 5,764 acre-feet.

*KEYWORDS: *New Mexico, *Rio Grande Basin, *Water resources, *Socio-economic model, Interdisciplinary, Ground water appropriation, Water law, Compacts, Treaties, Litigation, Adjudication of water rights, Water quality, Water utilization, Population, Employment, Industrial, Recreation, Water management, Input-output coefficients, Linear programming model, Surface-ground-water conjunctive-use model, Economic land classification, Irrigation diversions and depletions.*

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INTRODUCTION

This report represents an in-depth look at the water and related resources in the Lower Rio Grande Region (LRGR) of New Mexico (Figure 1). Other reports have been prepared for the Upper Rio Grande Region (WRRI Report No. 021), Middle Rio Grande Region (WRRI Report No. 022), and the Socorro Region (WRRI Report No. 023). These reports are viewed as basic data reports to supplement the overall report (WRRI Report No. 020, *An Analytical Interdisciplinary Evaluation of the Utilization of the Water Resources of the Rio Grande in New Mexico*, March 1973).

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. A distinction 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.

* *Principal contributors to this interdisciplinary research effort: Associate Professor, Agricultural Economics and Agricultural Business, NMSU; Associate Professor, Economics, UNM; Associate Professor, Civil Engineering, NMSU; Assistant Professor, Geoscience, NMIMT; and Research Associate, Agricultural Economics and Agricultural Business, NMSU, respectively.*

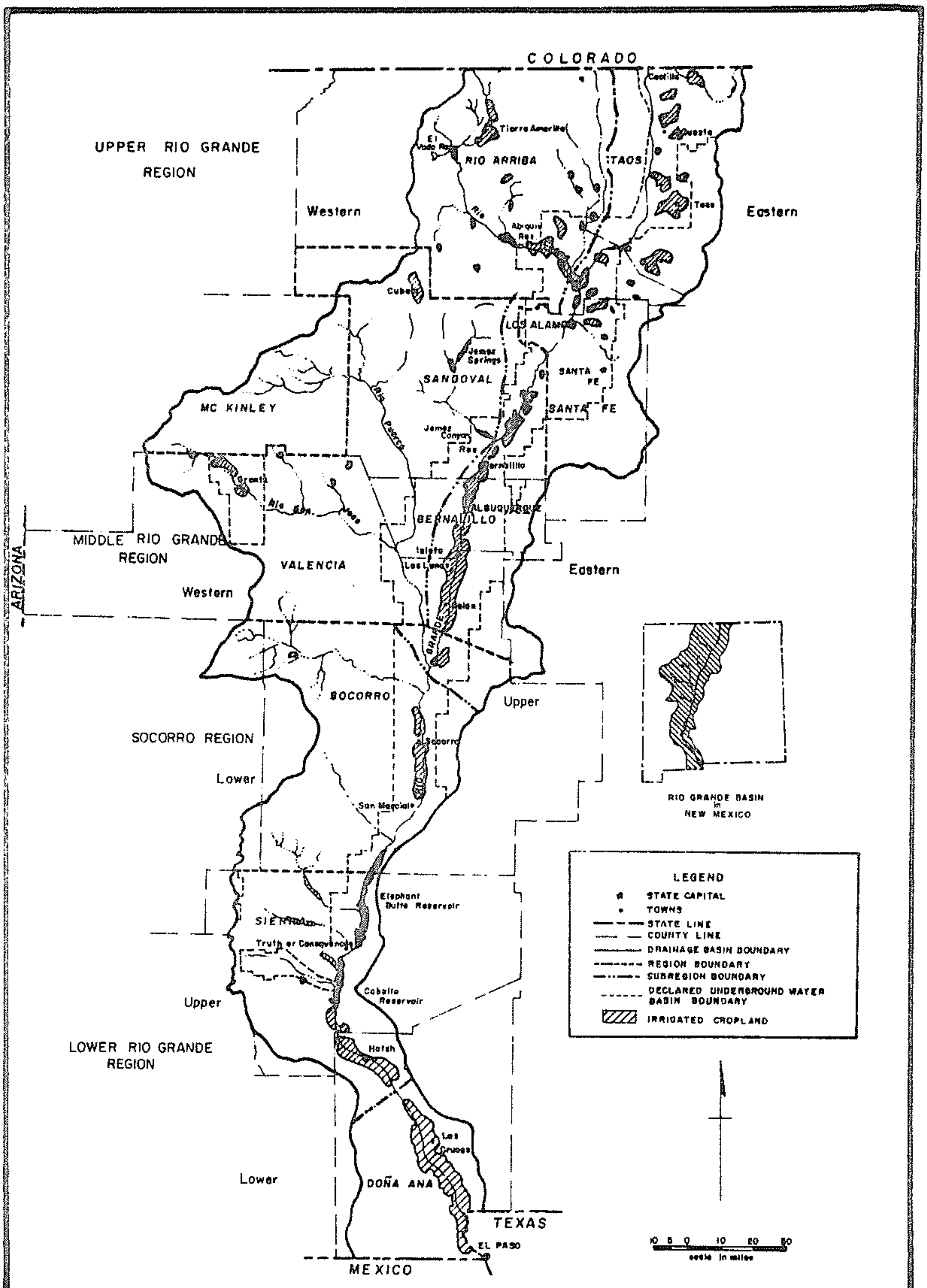

Figure 1. Rio Grande drainage basin in New Mexico, for this study, as of January, 1970.

GENERAL DESCRIPTION

The Lower Rio Grande Region (LRGR) includes Dona Ana and Sierra Counties in the southcentral part of the state. The LRGR was subdivided, for this study, into the Rincon and Mesilla Valleys (Figure 2), which are divided by Selden Canyon. This canyon is about seven miles long and just wide enough to contain the Rio Grande, a railroad, and a highway.

The Rincon Valley is generally regarded as extending from Percha Dam, a diversion dam on the Rio Grande just downstream from the Caballo narrows, to the Selden Canyon constriction; however, for this study, the Rincon Valley included the northward Las Animas, Palomas, and Monticello Valleys, related tributary units, and scattered highland areas in Sierra County. The major population centers are Truth or Consequences and Hatch.

The Mesilla Valley extends approximately 60 miles from Selden Canyon to El Paso Canyon and has an average width of about five miles. It includes the cropland areas in the mesas adjacent to the Valley. For this study the Mesilla Valley includes only the area in New Mexico, and, therefore, does not extend completely to El Paso Canyon. The major population center is Las Cruces.

Topography and Climate

The two Valleys are bounded from north to south on the east side by Fra Cristobal, Sierra Caballo, mesa highlands, and Organ and Franklin mountain ranges; on the west side they are bounded by mesa highlands. The topography of the area varies from fairly level areas in the Valley floors to steep bluffs and mountains. The Valleys have relatively smooth alluvial floors ranging in width from a few hundred feet to about five miles and are bordered by steep bluffs of about 50 to 100 feet high, composed of loosely cemented sand, silt, clay, and gravel. From the bluffs, generally inclined plains extend back to the mountains.

The climate of the LRGR is predominantly semi-arid. It is characterized by clear and sunny days, large diurnal temperature ranges, low humidity, and scant rainfall. The mean annual precipitation averages less than 10 inches, with a maximum of about 18 inches and a minimum of

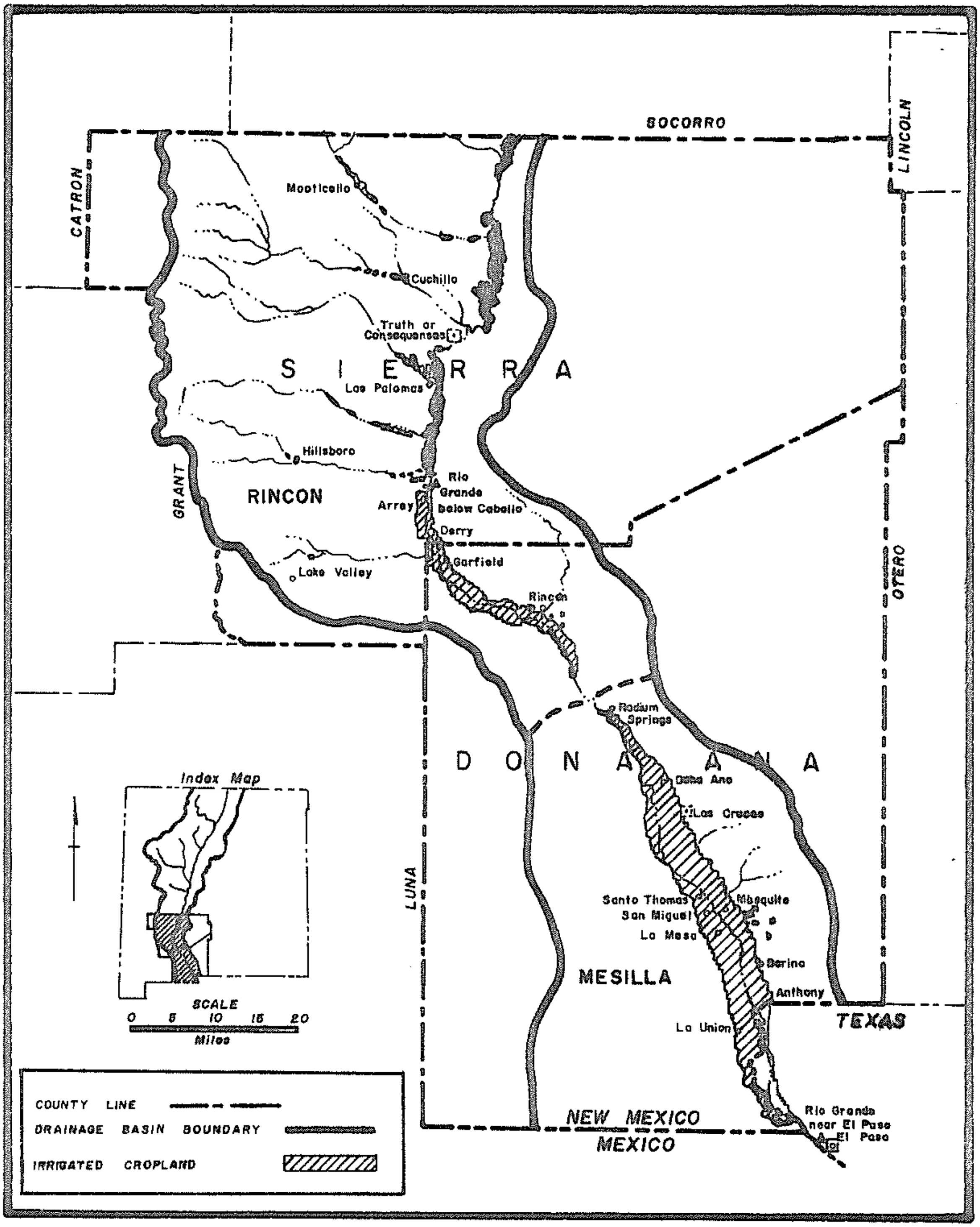

Figure 2. Map of the Lower Rio Grande Region in New Mexico.

about 3 inches (Texas Water Rights Commission, 1970). The summer months are, in general, the wettest ones when tropical air masses from the Gulf of Mexico predominate over the area and cause thundershowers. Occasionally these thundershowers are accompanied by hail which may cause severe damage to crops and property. The high temperatures and low relative humidity result in the rainfall being quickly evaporated or transpired. The mean annual precipitation, mean annual temperature, and average frost-free period for the stations are summarized in Table 1.

Temperatures in the area average about 60 degrees Fahrenheit. Winters are usually mild and dry, and temperatures above 100 degrees Fahrenheit are not uncommon in the summer months. The growing season usually begins in early April and lasts about 200 days until late October (Table 1).

Table 1. Eleven-year average of annual average temperature, total precipitation, and frost-free period for State University, Hatch, and Truth or Consequences, New Mexico, 1960-1970

Weather Bureau Station	Average Temperature	Total Precipitation	Frost-free Period	
			Length	Dates
	degrees F	inches	days	
State University	61.1	8.09	202	Apr. 11 - Oct. 30
Hatch	59.3	8.54	184	Apr. 19 - Oct. 20
Truth or Consequences	59.5	8.87	215	Apr. 4 - Nov. 5
Average	60.0	8.50	200	Apr. 11 - Oct. 28

Source: United States Weather Bureau, Climatological Data, New Mexico (Annual Summaries), Vols. 64-74, 1960-1970.

Drainage Area

The drainage area of the LRGR, because it is the lower basin, consists of the 25,690 square mile total drainage area of the Rio Grande in New Mexico. The runoff reaching the lower basin is derived principally from snow melt, either in New Mexico or Colorado, upstream from Otowi Bridge. Additional runoff is furnished as runoff from flash floods from summer and fall rainstorms that produce ephemeral tributaries below Otowi Bridge.

The production of water in the LRGR is negligible since there are no perennial streams tributary to the Rio Grande in this reach. There are, however, numerous intermittent tributaries, some of which have rather large drainage areas. The principal tributaries, beginning at the northern extreme, are Alamosa River, Cuchillo Negro River, Palomas River, Los Animas Creek, Percha Creek, and a few large arroyos in the vicinity of Las Cruces.

Hydrogeology

The Rio Grande, in its present valley, is probably as old as mid-Pleistocene, born during the late uplift of its headwater mountains (Texas Water Rights Commission, 1970). The main body of sedimentary deposits of the Rio Grande depression, from the north end of the San Luis Valley to beyond El Paso, is considered to be of the same general age and to belong to the Santa Fe formation. Bryan (U. S. National Resources Committee, 1938, p. 205) noted that the basins were presumably formed by faulting and these valleys filled with material carried by the river and its tributaries. The basins appear to have been generally elongated into ovals. The Santa Fe formation is permeable and produces sandy soils that promote good infiltration. This group is a rock-stratigraphic unit consisting of a complex sequence of unconsolidated to moderately consolidated sedimentary deposits with some basalts (King, et al. 1969, p. 30). King et al. (1969) placed the lower limit of the Santa Fe group in the LRG depression above the volcanic and associated sedimentary rocks of middle Tertiary age, and the upper limit at the surface of the youngest basin-fill deposits pre-dating initial entrenchment of the present Rio Grande Valley system in middle Pleistocene time. The Santa Fe group is the major ground-water reservoir in the area.

Postdating the depositions of the Santa Fe group is the valley fill of late Quaternary Age. These channel deposits of the Rio Grande and alluvial fan deposits of tributary arroyos are finer textured flood plain sediments.

Nearly all of the economically exploitable ground water in the area is in unconsolidated to partly consolidated Tertiary and Quaternary sedimentary deposits (King, et al., 1969). In general, the quantity of water production from wells penetrating the shallow valley and basin fill deposits is not a problem. Wells developed in buried channel gravel and sand deposits below the river flood plain are capable of producing 1,000 to 3,000 gallons of water per minute. Specific capacities are usually high, often ranging from 70 to 100 gallons per minute per foot of drawdown, with coefficients of transmissivity commonly in the 100,000 to 150,000 gallons per day per foot range (Conover, 1954; Leggat, et al., 1962).

King et al. (1969) noted that because of the structural, depositional, erosional, and igneous features of the area, the thickness of the prime basin and valley-fill ground-water reservoir is highly variable. The area is extensively faulted and has a history of abundant extrusive and igneous activity. The maximum basin-fill reservoir thickness was estimated to be from zero to over 3,400 feet.

The basins of the Rio Grande drainage area are geologically and hydrologically open. They are surrounded by higher ground and generally gain rather than lose underground water. The only possibility of loss underground is to the next lower basin on the river.

The Rincon Valley is largely enclosed on the east and north. It is open to the west, but this part of the basin is higher and must contribute water to, rather than gain water from, the Rio Grande Valley (RGV). The lower end of the region, at Selden Canyon, is not wholly closed, but it is so narrow that ground-water losses are almost impossible except through the gravel below the river. In the upper area of the Rincon Valley, the Socorro Valley merges to the south into the Jornada del Muerto and basins west of the river. Leakage to these basins is improbable because of their higher altitude. Ground-water movement from the Valley in the vicinity of San Marcial to the area west of the Elephant Butte Reservoir depends on the hydrologic conditions, for when the reservoir is full, the valley fill is saturated with water to an altitude close to that of San Marcial and there is no hydraulic gradient for movement (King, et al., 1969). When the reservoir is low or empty there is a gradient, but whether it is enough to cause significant movement is doubtful. King et al. (1969) noted that ground water in the northern Jornada del Muerto moved in a northwestward direction to an outlet area into the RGV between San Diego Mountain and the Rincon hills. This flow pattern differs from previous interpretations.

The Mesilla Valley is almost closed at both ends but open to the sides. Bryan (U. S. National Resources Committee, 1938, p. 225) noted that the ground-water levels in the La Mesa area seemed somewhat higher than the floor of the valley and that there must be a ground-water gain. A ground-water mound in the La Mesa area, which closely approximates the drainage area of the volcanic explosion craters of Kilbourne's, Hunt's, and Phillip's Holes, may be a combination of the more abundant recharge and the lower permeability at the edge of La Mesa adjacent to the Mesilla Valley (King, et al., 1969).

Ground-water loss into Mexico west of El Paso seems unlikely since the altitudes of the enclosed basins to the south appear to be higher than the valley floor above El Paso. The movement of ground water through the gorge at El Paso is small because of the relatively shallow alluvium (86 feet above bedrock (U. S. National Resources Committee, 1938, p. 225).

The aquifers of the RGV are capable of high yields and represent a precious resource for New Mexico. The southern Palomas area and the Rincon-Fort Selden portions of the Valley have only a shallow alluvial aquifer. The Mesilla Valley has an aquifer which appears to represent unconfined-aquifer conditions (King, et al., 1969, p. 56). This aquifer system, because of the excellent capacity for recharge, transmission, and storage, is capable of supplying ground water in large quantities for agricultural, municipal, and industrial use. Because of the local availability of large quantities of good-quality ground-water in certain parts of the LRGR, the potential exists for further industrial development.

WATER MANAGEMENT

Management of water and related lands involves several federal and state agencies, municipal and county governments, irrigation districts, and innumerable private entities. The New Mexico statutes provide for irrigation districts which are formed in cooperation with the United States. Once a district is formed it is a legally stable institution with broad powers to perform the purposes for which it was organized. Irrigation districts are able to borrow money, tax lands for the indebtness, and charge for the water they deliver.

Surface Water

The quantity of surface water delivered to the project lands depends upon the quantity of water in storage and the anticipated inflow to storage. This is in turn related to the conditions upstream in Colorado and New Mexico: these are the total amount of water and the amount of use.

Under the provisions of the Rio Grande Compact, Colorado must deliver to New Mexico, at the state line, a certain portion of the total quantity of water originating in Colorado; likewise, New Mexico must deliver to Texas a certain portion of the flow. The operation of the Compact and the methods for determining the deliveries each state must make are somewhat involved and are included in this study only to the extent necessary.

New Mexico, for Compact purposes, is that area of the Rio Grande basin lying between the Colorado-New Mexico state line and Elephant Butte Reservoir; Texas, for Compact purposes, includes portions of Sierra and Dona Ana Counties in New Mexico as well as the areas of Texas in the drainage basin above Fort Quitman.

The waters of the Rio Grande are used by Colorado in the San Luis Valley and by New Mexico in the Upper and Middle Rio Grande before being delivered to the LRGR. The water is then stored in Elephant Butte and Caballo reservoirs for release to the LRG project lands. The Rio Grande project was constructed by the Bureau of Reclamation and is operated by the Bureau in cooperation with the Elephant Butte Irrigation District of New Mexico and the El Paso County Water Improvement District No. 1 of Texas. The project furnishes irrigation water to about 159,650 acres of water-right lands, and provides electric power for communities and industry in the area. All of the project lands in New Mexico are within the Elephant Butte Irrigation District, while all lands in Texas are within the El Paso Water Improvement District No. 1. The canals are continuous from one District to the other across the state line.

The Elephant Butte Irrigation District was formed in 1918, and succeeded the Elephant Butte Water Users' Association which was organized and incorporated under the laws of the Territory of Arizona. The primary purpose of the District is to provide water for the irrigation of lands; to achieve this, the District contracted to repay the construction costs of the irrigation and drainage facilities, provide operation and maintenance funds, and pay a storage charge on the water released from storage annually for District lands (Texas Water Rights Commission, 1970). Diversion of the water released is made by a number of diversion dams between Caballo and Fort Quitman. Three diversion dams are within the Rincon and Mesilla Valleys. Percha Dam is at the head of Rincon Valley and diverts water to the Arrey and Percha Canals which serve the Rincon division of the irrigation District; Leasburg Dam is the head of Mesilla Valley and diverts water to the Leasburg Canal; and the Mesilla Dam, southwest of Las Cruces, diverts water to the East Side and West Side Canals.

Most of the water for irrigation in the project is delivered from approximately the first of March through the middle of September (U. S. Department of State, 1968). The distribution system is operated as a semi-demand system and is basically designed for cotton and alfalfa irrigation. An increase in vegetable production has created a problem for the District because of shorter notice of irrigation requirements by the farmers; short notice places a strain on delivering water through the existing distribution system (Texas Water Rights Commission, 1970, p. 260).

Since 1951, an allotment system has been used whereby the quantity of water available for irrigation distribution is divided among the users in the Rio Grande project, including the Mexican deliveries, on a proportional basis. In years of full supply the allotment is about 3 acre-feet per acre for the New Mexico and Texas users, and 60,000 acre-feet for the Mexican users. In years of less than full supply the users, including Mexico, receive a prorated share of the available supply. The annual allotments to the project lands since 1951 are presented in Table 2.

Table 2. Annual allotments of surface water in the Lower Rio Grande project, New Mexico and Texas, 1951-1970

Year	Release Date	Initial Allotment	Total Allotment for the Year
		- - - acre-feet per acre - - -	
1951	March 6	1.00	1.75
1952	March 20	.21	2.50
1953	March 10	1.00	1.90
1954	March 20	.42	.50
1955	March 20	.21	.42
1956	March 18	.33	.39
1957	March 20	.10	1.17
1958	March 1	1.75	4.00
1959	March 2	3.00	3.50
1960	March 2	2.25	3.25
1961	March 10	1.25	2.45
1962	March 5	1.75	3.25
1963	March 5	1.85	2.00
1964	March 15	.25	.33
1965	March 20	.17	1.85
1966	March 5	1.75	2.50
1967	February 27	1.25	1.50
1968	February 27	1.00	2.00
1969	February 27	1.33	3.00
1970	February 23	2.00	3.00
Average	March 9	1.14	2.06

Source: United States Department of Interior, Bureau of Reclamation, El Paso Office, "Annual Allotments - Rio Grande Project" (unpublished data sheet), 1971, 1 p.

Ground Water

The management of the ground water in the LRGR is primarily a private entity function. Three small areas are controlled by the State Engineer Office through declared underground water basins: these include the southern extreme of the Rio Grande underground water basin above Elephant Butte Dam, the Hot Springs Underground Water basin in the vicinity of Truth or Consequences, and the Las Animas Creek Underground Water basin extending along the Las Animas Creek west of Caballo Reservoir (Figure 1).

In the remainder of the LRGR, the pumpage is not limited. Within the Elephant Butte Irrigation District, the pumpage of ground water varies annually and seasonally with the amount of surface water available. Approximately 90 percent of the land in the District receives supplemental ground water. Outside of the Elephant Butte Irrigation District, approximately 8,500 acres are irrigated from only ground-water sources. All municipal and industrial diversions are from ground-water sources.

RESOURCES

Population

Table 3 presents a summary, based on data from the Bureau of the Census, of the population of the LRGR from 1950 to 1970. Urban population refers to that part of the total population which resides in places of over 2,500 in number. Rural population refers to that part of the total which either resides in communities of less than 2,500 or in the "rural" portion of the county.

Sierra County has had a fairly constant population in both make-up and totals over the three periods. There was a definite decline between 1950 and 1960, but the trend reversed itself in the 60's and more than made up for the earlier loss: water-based recreational-type activities appear to be responsible for these fluctuations.

Dona Ana County has experienced a rapid growth in both urban and total populations during all three periods. The urban population almost quadrupled in number from 1950 to 1970, and the percentage increased from 31.2 percent to 66.2 percent of the total. This implies that the rural population has been decreasing both in absolute number as well as percentage of the total. The growth of the LRGR reflects the growth and changing make-up of Dona Ana County.

Only one major city exists within each county. Las Cruces accounts for most of the urban growth in Dona Ana County during the 21-year period. Las Cruces and University Park (a "suburb") account for over 80 percent of Dona Ana's urban population. Sierra County's growth patterns are reflected well by Truth or Consequences (T or C) which at first declined and more recently showed a slight increase. T or C accounts for more than 90 percent of the urban population in Sierra County.

In 1970, the LRGR encompassed approximately 7 percent of the urban population, 8 percent of the rural, and 7 percent of the total population in the state of New Mexico; in 1960, it contained approximately 6 percent

Table 3. Urban and rural population* for the Lower Rio Grande Region, New Mexico, 1950-1970

	Urban	Percent Urban	Rural	Percent Rural	Total	Percent Change from Previous Census
1950						
Dona Ana	12,325	31.2	27,232	68.8	39,557	30.1
Sierra	4,563	63.5	2,623	26.5	7,186	3.2
LRGR	16,888	36.1	29,855	63.9	46,743	25.1
1960						
Dona Ana	33,754	56.3	26,194	43.7	59,948	51.5
Sierra	4,269	66.3	2,140	33.4	6,409	-10.8
LRGR	38,023	57.3	28,334	42.7	66,357	42.0
1970						
Dona Ana	46,189	66.2	23,584	33.8	69,773	16.4
Sierra	4,656	64.8	2,533	35.2	7,189	12.2
LRGR	50,845	66.1	26,117	33.9	76,962	16.0

Major Cities	1950	1960	Percent Change	1970	Percent Change
Truth or Consequences (S)	4,563	4,269	-6.4	4,656	9.1
University Park (D.A.)	--	4,387	--	4,165	-5.1
Las Cruces (D.A.)	12,325	29,367	138.3	37,857	28.9

*County definition.

Source: Developed from census data

of the urban population, 9 percent of the rural, and 7 percent of the total population; and in 1950, the LRGR contained less than 5 percent of the urban population, approximately 9 percent of the rural, and less than 7 percent of the total population.

Industrial Development

While Dona Ana County has grown significantly in manufacturing and trade over the past 20 years, Sierra has remained predominantly agriculturally and recreationally oriented. Neither county has developed any appreciable mining or oil production and, therefore, no industry related to the associated natural resources.

Sierra County's development over the last 10 years has been basically in the recreational field. Elephant Butte Reservoir and Caballo Reservoir have always been used for recreational activity, although recently efforts have been made to develop the potential of the area. With the help of several real estate brokers and investors from other areas (primarily Albuquerque), growth is beginning to return to the area. With this recreational home-site and activity development, plus an increase in retirement, come the service and trade industries needed to supply the increased population and activity level of the region.

Dona Ana County has increased tremendously its trade and service industries over the past 20 years. In the late 50's and early 60's, with the advent of the American space program, and increased emphasis on testing and evaluation at White Sands Missile Range, many facilities were developed near Las Cruces and in adjacent Otero County. With the growth of the space industry in the area, many small manufacturing and tooling industries began to develop. Along with this type of growth in the basic-type industries, the secondary industrial base, trade and services, also began to develop. Recently, efforts to attract light industrial and commercial firms have helped spur industrial growth.

Industrial development within the LRGR has hinged primarily upon the space industry; however, more recently it has been influenced by the increase in recreational activity. With the very recent move to downgrade the space industry as a whole, industrial development has slowed down somewhat, and unless a new base can be developed from the agricultural processing sector or the recreational sector, the growth witnessed over the last 10 years will be affected.

Employment

The Bureau of Census publishes employment numbers for each census year, but the figures are in very generalized classifications and groupings. Instead of such a general structure, the Employment Security Commission's (ESC) reports and estimates are used.

The LRGR's increase in employment from one period to the next can be attributed primarily to Dona Ana County. An increase of approximately 16 percent was recorded from 1960 to 1970 in total employment and in population (Table 4).

The major employer in Dona Ana, and therefore in the LRGR, has been the government. In both Counties, over 40 percent of the labor force was employed by the local, state, or federal government. Manufacturing employment accounted for much less than 10 percent of the employment force. There has been no appreciable change in the manufacturing base during the past 10 years, and agricultural employment has decreased significantly in both Counties.

During the 10-year period 1950-1960, employment increases have been noticeable for several major categories, both in absolute terms and percentage increases in the proportion of total employment. These categories are the services and miscellaneous sectors; the real estate, finance, and insurance sector; and the wholesale and retail trade sector. Public utilities and transportation is another sector that has shown a fairly significant increase from 1950 to 1960.

The unemployment rate, as reported by the ESC, has shown no appreciable change over the 10-year period either in the LRGB or in any individual county.

Table 4. Employment in the Lower Rio Grande Region, New Mexico, 1960-1970

Employment (County Definition) - ESC	Dona Ana County 1960	Dona Ana County 1970	Dona Ana County Percent change	Sierra County 1960	Sierra County 1970	Sierra County Percent change	Lower Rio Grande Region 1960	Lower Rio Grande Region 1970	Lower Rio Grande Region Percent change
Total Civilian Work Force	23,700	27,450	15.8	1,775	2,089	17.7	25,475	29,539	16.0
Unemployment	1,269	1,426		56	59		1,325	1,485	
Rate	5.3%	5.2%		3.2%	2.8%		5.2%	5.0%	
Employment	22,521	26,008	15.5	1,719	2,028	18.0	24,240	28,036	15.7
Non-ag. Wage and Salary	16,604	20,772	25.1	942	1,327	40.9	17,546	22,099	25.9
Manufacturing	938	1,198	27.7	33	16	-51.5	971	1,214	25.0
Contract Construction	907	968	6.7	76	152	100.0	983	1,120	13.9
Mining	*	*		15	33	120.0	(1)	(1)	(1)
Public Utilities and Transportation	812	1,122	38.2	45	60	33.3	857	1,182	37.9
Wholesale & Retail Trade	2,450	3,484	42.2	268	335	25.0	2,718	3,819	40.5
Real Estate, Finance, and Insurance	351	641	82.6	30	44	33.3	381	685	79.8
Services & Miscellaneous	1,302	2,620	101.2	173	197	13.9	1,475	2,817	91.0
Government	9,843	10,739	9.1	301	491	63.1	10,144	11,230	10.7
All Other Non-ag.	2,382	2,134	-10.4	413	416	1.0	2,795	2,550	-8.9
Agriculture	3,535	3,102	-12.3	364	285	-21.7	3,899	3,387	-13.1

Source: Developed from data from the New Mexico Employment Security Commission

Land

Within the Rio Grande region there are approximately 16.9 million acres but only 1.7 percent, or 280,785 acres, are irrigated. The land ownership of the Rio Grande drainage basin is reported in Table 5. Federal and state ownership account for about 43 percent of the total land area in the Rio Grande region (Table 5).

The LRGR accounts for approximately 2.95 million acres (about 17 percent of the total land area within the Rio Grande region) of which 105,660 are irrigated. Within the LRGR federal ownership accounts for about 60 percent of the total land area. Within the region the acreage of forest land controlled by the Forest Service accounts for about 14 percent of the total land area; land administered by the Bureau of Land Management (BLM) accounts for about 46 percent; defense less than 1 percent; and other federal ownership less than 1 percent. State ownership accounts for about 15 percent. Private ownership accounts for about 23 percent. Inland water accounts for about 1 percent.

Irrigated Cropland. The irrigated cropland in the lower drainage basin is located in a somewhat narrow strip along the river (Figure 2). The acreages of the various crops produced are reported in Table 6. In terms of acres, cotton was the most important crop in 1969, accounting for about 52 percent of the total acreage and about 54 percent of the cultivated acreage. Alfalfa was the second most important crop in terms of acreage with about 13 percent of the total acreage and about 14 percent of the cultivated acreage. The remaining acreage was composed of both high income-generating crops such as lettuce, onions, and pecans (14 percent of total acreage) and low income-generating crops such as small grains, irrigated pasture, sorghum, and other forage crops which accounted for about 9 percent of the total acreage. Irrigated farmland not farmed accounted for the remaining 12 percent of the total irrigated cropland.

The Mesilla Valley accounts for about 76 percent of the irrigated cropland but only 68 percent of total cropped acreage.

Soil productivity. The soils in the valley floor of the lower drainage basin consist primarily of highly stratified alluvial deposits of mixed origin.

Table 5. Land ownership, in acres, in the Rio Grande drainage basin, New Mexico, 1971

Region and County[1]	Federal					State[2]	Private	Indian[3]	Total Land Area	Inland Water	Total Area
	Forest	BLM	Defense	Other	Total						
Upper Rio Grande											
Taos	461,200	199,800	--	24,300	685,300	102,700	545,200	110,300[4]	1,443,500	400	1,443,900
Rio Arriba	1,154,200	215,000	--	45,600	1,414,800	181,400	816,500	185,000	2,597,700	10,000	2,607,700
Mora	9,900	--	--	--	9,900	--	--	--	9,900	--	9,900
San Miguel	6,900	300	--	--	7,200	600	1,900	--	9,700	--	9,700
Santa Fe	158,600	61,000	--	35,200	254,800	38,400	409,800	75,700	778,700	300[5]	779,000
Los Alamos	--	--	--	68,300	68,300	--	3,700	--	72,000	--	72,000
Subtotal	1,790,800	476,100	--	173,400	2,440,300	323,100	1,777,100	371,000	4,911,500	10,700	4,922,200
Middle Rio Grande											
Sandoval	418,400	192,580	2,600	177,400	790,980	93,060	903,730	516,740	2,304,510	1,200[6]	2,305,710
Bernalillo	53,100	17,520	45,800	140	116,560	28,500	271,020	268,230	684,310	--	684,310
Torrance	49,140	2,400	--	--	51,540	19,800	53,600	16,400	141,340	--	141,340
Valencia	262,620	211,100	--	--	473,720	102,260	1,008,540	626,380	2,210,900	1,300	2,212,200
McKinley	15,370	149,520	--	35,500	200,390	65,300	398,580	173,800	838,070	480	838,550
Subtotal	798,630	573,120	48,400	213,040	1,633,190	308,920	2,635,470	1,601,550	6,179,130	2,980	6,182,110
Socorro region											
Socorro	598,050	556,000	3,800	80,300	1,238,150	277,780	1,129,570	65,700	2,711,200	13,900[7]	2,725,100
Catron	75,400	15,500	--	--	90,900	14,900	51,000	--	156,800	--	156,800
Subtotal	673,450	571,500	3,800	80,300	1,329,050	292,680	1,180,570	65,700	2,868,000	13,900	2,881,900
Lower Rio Grande											
Sierra	403,500	450,500	--	1,900	855,900	218,700	434,700	--	1,509,300	36,100	1,545,400
Dona Ana	--	915,670	21,640	7,800	945,110	230,120	232,700	--	1,407,930	--	1,407,930
Subtotal	403,500	1,366,170	21,640	9,700	1,801,010	448,820	667,400	--	2,917,230	36,100	2,953,330
Basin Total	3,666,380	2,986,890	73,840	476,440	7,203,550	1,373,520	6,260,540	2,038,250	16,875,860	63,680	16,939,540

[1]Includes only county area lying within the Rio Grande Drainage Region (Figure 2).
[2]Includes state trust and deeded land and lands administered by other state agencies.
[3]Includes both trust and deeded Indian lands.
[4]Includes transfer of 48,000 acres from Forest Service to Taos Indian Pueblo.
[5]Includes 56 acres for proposed Nambe Falls Reservoir.
[6]Includes 1,200 acres for Cochiti Lake under construction.
[7]Includes 1,801 acres for La Joya and Bosque del Apache Lakes.

Source: Estimated from Bureau of Land Management Quadrangle Maps; acreage of lakes and reservoirs from New Mexico State Engineer Office Preliminary Report, "Reservoirs and Lakes in New Mexico with 40 or more surface acres," February 8, 1971.

Table 6. Acres of irrigated cropland by use in the lower Rio Grande drainage basin, New Mexico, 1969

Land Use	Rincon Valley	Mesilla Valley	Total	Percent
	- - - - - - - - - -	- - acres - -	- - - - - - - - - -	
Cotton	9,489	44,948	54,437	51.6
Alfalfa	3,368	10,349	13,717	13.0
Sorghum	1,276	3,350	4,626	4.4
Corn	1,106	894	2,000	1.9
Small grains	355	625	980	0.9
Irrigated pasture	912	1,098	2,010	1.9
Chile	2,416	710	3,126	3.0
Orchards	186	6,087	6,273	5.9
Spring lettuce	(1,300)*	(2,800)*	(4,100)*	(3.9)
Fall lettuce	1,403	2,903	4,306	4.0
Spring onions	(320)*	(1,920)*	(2,240)*	(2.1)
Fall onions	66	400	466	0.4
Miscellaneous vegetables and family gardens	80	810	890	0.8
Subtotal Cropped Acreage[a]	20,657	72,174	92,831	87.8
Diverted and fallow[b]	3,353	5,109	8,462	8.0
Subtotal Cultivated Acreage[c]	24,010	77,283	101,293	95.8
Idle[d]	865	1,624	2,489	2.4
Out of Production[e]	526	1,352	1,878	1.8
Total Irrigated Cropland[f]	25,401	80,259	105,660	100.0

* Double cropped acreage, not included in total.

a. Irrigated cropland on which crops were growing at the time the field survey was conducted, and on which crops had been produced during the current crop year.

b. Acreage of irrigated cropland which was not cropped under provisions of the Agricultural Adjustment Programs or had been tilled in the past two years.

c. Irrigated cropland to which cultural practices were actively applied during the preceding two years, including the year in which this study was conducted. (Includes cropped, fallow, and diverted acreage.)

d. Irrigated cropland not actively farmed for the past two consecutive years but farmed within the past five years. (Includes suspended land which was not serviced by ground water.)

e. Irrigated cropland not actively farmed within the past five years.

f. Irrigated cropland: Land on which water is artificially applied for the production of agricultural products, on which the owner has the physical facilities or right to engage in such practices.

Source: Adjusted from: Lansford, R.R., and E.F. Sorensen, "Planted Cropland Acreage in New Mexico in 1969, 1970," *New Mexico Agriculture--1970*, Agricultural Experiment Station Research Report 195, New Mexico State Univ., Las Cruces, N.Mex., pp. 6-12, Tables 6 and 8; and Lansford, R.R., "Planted Cropland Acreage in New Mexico in 1970 and 1971," *New Mexico Agriculture--1971*, Agricultural Experiment Station Research Report 235, New Mexico State Univ., Las Cruces, N.Mex., pp. 31-37, Tables 17 and 18.

The principal soil types vary in texture from sand to clay, but the medium, moderately fine, and fine are the more common textures. The most extensive soils usually have a surface layer of loam underlain by stratified loams and sandy loams. The soils of the alluvial fans and terraces immediately above the valley flood plain are generally deep and sandy. These soils were formed from alluvial and eolian sediments of mixed origin and have an extremely sandy texture (Dobson, 1941).

A base map was drawn showing the location of the irrigated cropland acreage. Soils with the same characteristics were designated on the map by means of SCS soil survey symbols. A further designation was made according to the SCS capability classification for each of the different soils. It was considered desirable for purposes of this study to group the soils in such a way as to reflect differences in productivity, managerial requirements, and responsiveness to intensive cultural practices. After consulting with SCS personnel and county agents, and interviewing farmers, the soils were assigned to one of three groups depending on the degree of limitation of the above characteristics. A productivity index was used to reflect 100-percent expected yields of eight major crops produced on these different soils. Group I soils were considered to be those with only slight, if any, limitations; Group II, those with moderate limitations; and Group III, those with sever limitations. Such a grouping was considered to reflect the long-run economic potential of different soils in the LRG drainage basin. A detailed description of the soils is given in Appendix A.

About 21 percent of the irrigated cropland in the drainage basin is Group I soil and occurs primarily in the Mesilla Valley (Table 7). These soils are primarily loams, clay loams, silt loams, and fine sandy loams of the Gila series. They are level and deep and are considered to be highly productive. These soils are moderately stratified with thin layers of light and heavy-textured subsoils. They have moderate permeability, moderate to good drainage, and good water-holding capacity. While stratified layers present slight problems with some soils in this group, they are deep enough to allow deep plowing and other corrective measures, and they respond well to the application of improved management practices.

Table 7. Acreage of irrigated cropland by soil productivity groups, lower Rio Grande drainage basin, New Mexico, 1969

Soil Productivity Group*	Rincon Valley (acres)	Mesilla Valley (acres)	Total (acres)	Total (percent)
Group I	5,687	15,859	21,546	20.4
Group II	8,625	40,741	49,366	46.7
Group III	11,089	23,659	34,748	32.9
Total	25,401	80,259	105,660	100.0

*Soils included in each group are described in Appendix A.

Group II consists of almost 47 percent of the soils in the drainage basin which have moderate limitations that restrict maximum production. Most of these soils also occur in the Mesilla Valley (Table 7). These soils are similar to the soils in Group I, but they are characterized by low permeability and are affected by a shallow water table and the accumulation of alkali. They are heavier in texture than the soils in Group I and are moderately stratified. The soils in Group II consist primarily of the heavier textured soils of the Gila and Pima series and the lighter textured soils of the Gila series. These soils are the most extensive in the drainage basin. In general they do not respond as favorably to the use of improved management practices as the soils in Group I. Lower crop yields and incomes can be expected on farms with a large percentage of these soils.

Group III soils account for almost 33 percent of the soils in the drainage basin. They account for 29 percent of the total in the Mesilla Valley. The number of acres of Group III lands in the Rincon Valley was less than in the Mesilla Valley, but the percentage of Group III lands was greater (44 percent). The primary difficulties with these soils are the sandy textures, the extremely heavy textures, and the existence of heavy or impervious layers in the subsoils. Common problems also include moderate slope, shallow depth, high water-tables, and accumulation of alkali. These soils occur primarily along the river in narrow strips throughout the valley floors, along the sides of the valleys, and in the tributary areas. A large percentage of the irrigated cropland which is idle and out of production is included as Group III soil.

HYDROLOGIC DATA

The water supply of the Lower Rio Grande Basin depends primarily on the surface water supplied to the Region. The ground water within the Region is recharged by excess surface waters.

Surface Water.

The surface water resources of Sierra and Dona Ana Counties come from the Rio Grande and its tributary arroyos within these Counties. Elephant Butte Reservoir is a storage facility located within Sierra County. Surface water inflow to the reservoir is used to meet the obligation of New Mexico to deliver water to Texas under the terms of the Rio Grande Compact, 1938. Compact deliveries were measured at the U.S.G.S. gaging station at San Marcial, New Mexico, until 1949 when a change in measuring point was made and deliveries were measured by determining the inflows to Elephant Butte Reservoir. Outflow from Elephant Butte Reservoir is used within the Elephant Butte Irrigation District of New Mexico and the El Paso County Water Improvement District No. 1 of Texas.

Measurements of the flows of the Rio Grande reflect the upstream use of the water and the management practices employed. The Rio Grande is not a wild river, but neither is it a regulated river in the classic sense. The Rio Grande is regulated upstream from Elephant Butte Dam by controlling the tributary inflow to the river and by diverting water for agricultural use within the San Luis Valley of Colorado and within the Middle Rio Grande Conservancy District of New Mexico. Releases from Elephant Butte Dam are used to generate hydroelectric power, and releases to the Elephant Butte Irrigation District are then made from Caballo Dam. Below Caballo Dam the Rio Grande is a fully controlled and regulated stream.

The streamflow records at San Marcial were begun in February, 1895, and have been continuous since February 1896. The records were obtained from a gage located on the Atchison, Topeka and Santa Fe Railway bridge until October, 1964; since that time, the flows of the Rio Grande within the conveyance channel and within the floodway have been reported separately. Users of historical records must aggregate the flows of the floodway and the conveyance channel to obtain comparable records. The drainage area of the Rio Grande at San Marcial is approximately 27,700 square miles, including 2,940 square miles of noncontributing area in the San Luis Valley in Colorado. The historical flows at San Marcial can be seen in the mass curve for the Rio Grande at San Marcial, Figures 3 and 4. The mass curve can be segmented into several lines of different slopes to represent average flows for the different time periods. Table 8 presents the average flows for different time periods.

Table 8. Average monthly flows for the Rio Grande at San Marcial, New Mexico

Period	Average Monthly Flow	Average Monthly Flow for March-October	Average Monthly Flow for November-February
	. . . .	(acre-feet).	
1896-1916	96,614	122,943	37,957
1916-1939	88,384	111,929	41,295
1940-1957	63,985	74,864	42,225
1958-1968	49,032	49,641	47,812
1896-1968	78,145	96,422	41,592
1916-1968	71,930	86,413	42,964
1940-1968	58,313	65,297	44,344

The decrease in average monthly flow with time may be attributed to changes in weather patterns and to changes in upstream uses. The flow at San Marcial is considered to be the outflow from the Socorro Region, but is not the inflow to the Lower Rio Grande Region.

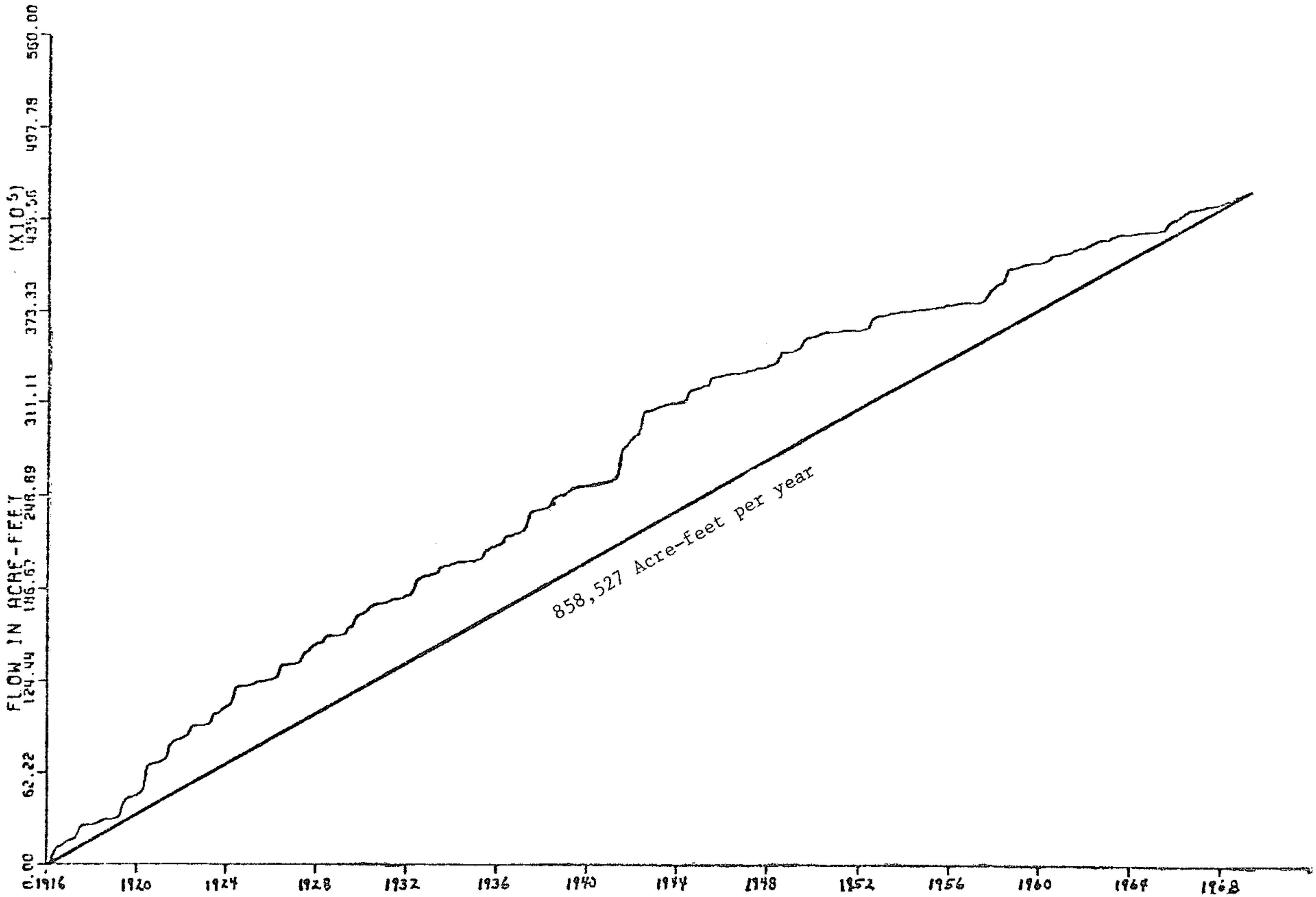

Figure 3. Mass flow curve for the Rio Grande at San Marcial, New Mexico, 1916-1968.

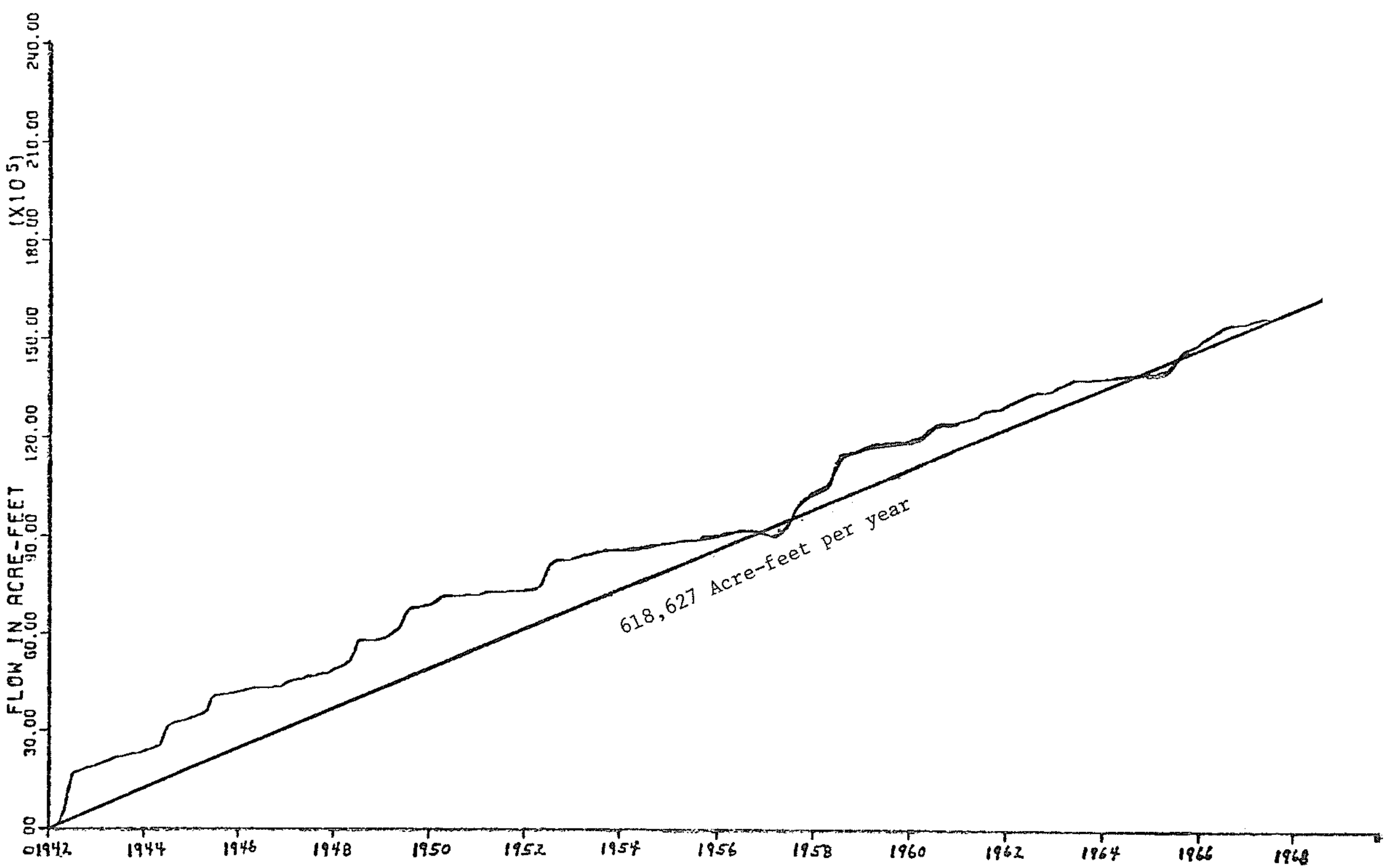

Figure 4. Mass flow curve for the Rio Grande at San Marcial, New Mexico, 1942-1968.

The inflow to the Lower Rio Grande Region is the outflow from Elephant Butte and Caballo Reservoirs. Between 1916 and 1938, the inflow to the region was the release from Elephant Butte Dam. In 1938, Caballo Dam was constructed so that releases from Elephant Butte Dam for generation of hydroelectric power would not have to coincide with the release of agricultural water. The gage, Rio Grande below Caballo Dam, is located 4,200 feet downstream from Caballo Dam, and records have been kept continuously since January, 1938. Figure 5 is the mass curve for the station for its period of record. A comparison of curves of the Rio Grande below Caballo Dam (Figure 5) and the Rio Grande at San Marcial (Figure 4), for a comparable period, illustrates the management effects of the two Dams because the curve below Caballo Dam (1) has more of a seasonal variation and (2) has more uniform slopes, except for drought periods. Table 9 presents the average flows for different time periods. The decrease in average monthly flow follows the same pattern as the data for the San Marcial station and is attributed to the same causes. Beginning in 1950, winter releases from the Dams were halted. No releases from the dams occur during the months of October, November, December, January, and February.

Table 9. Average monthly flows for the Rio Grande below Caballo Dam, New Mexico

Period	Average Monthly Flow	Average Monthly Flow for March-October	Average Monthly Flow for November-February
	. . . .	(acre-feet)	. . . .
1938-1968	53,515	78,437	3,672
1940-1968	52,696	77,450	3,187
1958-1968	46,552	69,693	269

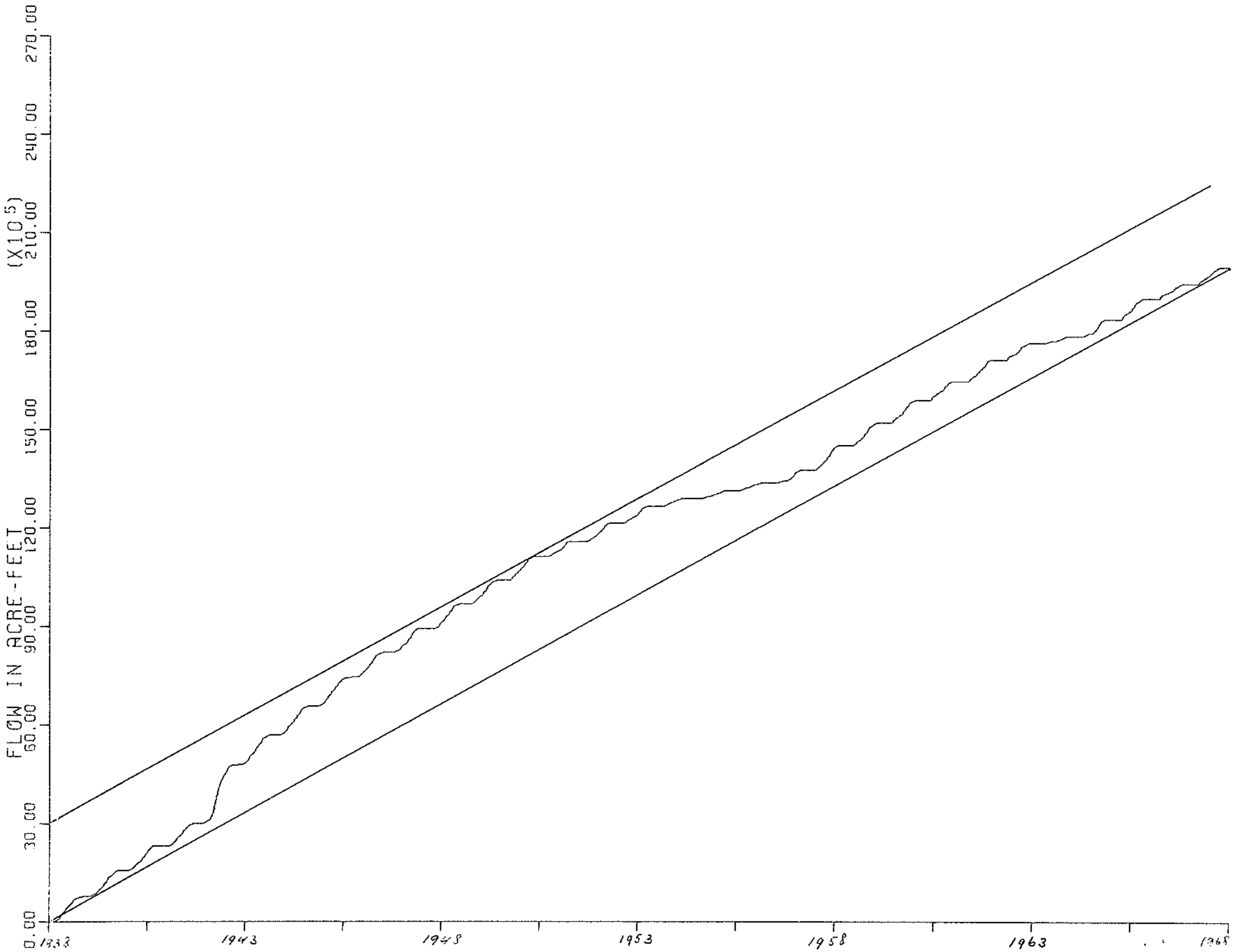

Figure 5. Mass flow curve for the Rio Grande at Caballo Dam, New Mexico, 1938-1968.

The inflow to the Lower Rio Grande Region cannot be completely consumed in Dona Ana and Sierra Counties because the water must be shared with the water users of the El Paso County Water Improvement District No. 1. Approximately 53 percent of the land irrigated with water released from Caballo Dam is located within New Mexico; assuming that 53 percent of the consumptive use occurs within New Mexico, a rough estimate of water availability can be made. The average yearly flow below Caballo Dam for 1958 through 1968 is 559,505 acre-feet and 53 percent of that total is 296,484 acre-feet (Table 9). This value can be checked against historical data for inflow and outflow. Table 10 presents the average monthly flows as measured at Rio Grande below Caballo Dam, New Mexico, and Rio Grande at El Paso, Texas, and also the net consumption of water between Caballo Dam and El Paso. The mass diagrams for flow past the El Paso Station, and out of the region, are shown in Figure 6 (1897-1968) and Figure 7 (1942-1968). Comparison of the El Paso and San Miguel mass flow curves shows that the flow patterns are the same. The flow measured at the El Paso station includes from 2,500 acre-feet to 4,000 acre-feet per year which is transferred from the Canutillo shallow field to El Paso's water treatment plant. It is reasonable to assume that 297,000 acre-feet of surface water are consumed within the Lower Rio Grande Region.

The original purpose of Elephant Butte and Caballo Dam was to minimize yearly flux and control monthly flows. It is difficult to measure the efficiency of the operations of the two Reservoirs because of high surface-evaporation from the reservoirs and other gains and losses. Table 11 presents the inflow to Elephant Butte and the outflow from Caballo for 1961 through 1970. The net change in storage from 1961 through 1970 was a decrease of 91,830 acre-feet. Because releases from Caballo Dam are made when requested by the irrigators, operational patterns of the Reservoirs are difficult to analyze.

Groundwater.

The groundwater resources of the Lower Rio Grande Region are used (1) to supplement the surface waters for agricultural use, (2) as the municipal supply for towns within the Region, (3) as an industrial supply water, and (4) for rural domestic use. Most of the water use

Table 10. Average monthly flows for the Rio Grande below Caballo Dam and for the Rio Grande at El Paso, 1958-1968

Month	Caballo	El Paso	Gain	Loss
	. . . . (acre-feet)			
January	83	3,502	3,419	--
February	826	2,477	1,651	--
March	101,220	38,883	--	64,337
April	58,942	30,062	--	28,880
May	55,578	26,733	--	28,845
June	98,621	42,428	--	56,193
July	109,230	50,592	--	58,638
August	95,853	48,004	--	47,849
September	38,005	30,023	--	7,982
October	97	7,881	7,784	--
November	83	4,843	4,760	--
December	85	4,772	4,657	--
Total	558,623	288,200	22,301	292,724
Net Consumption between Caballo and El Paso			270,423	

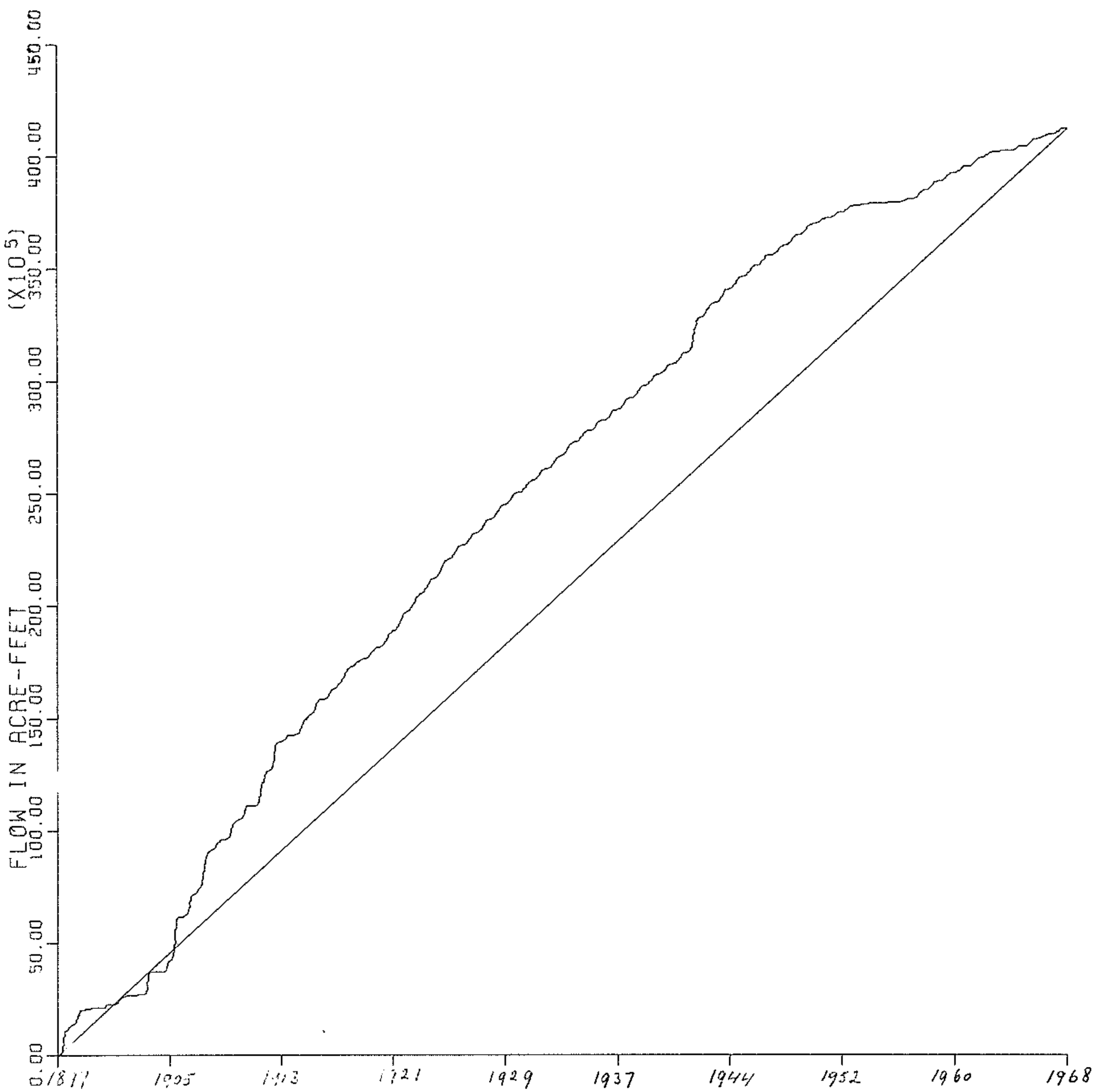

Figure 6. Mass flow curve for the Rio Grande at El Paso, Texas, 1897-1968

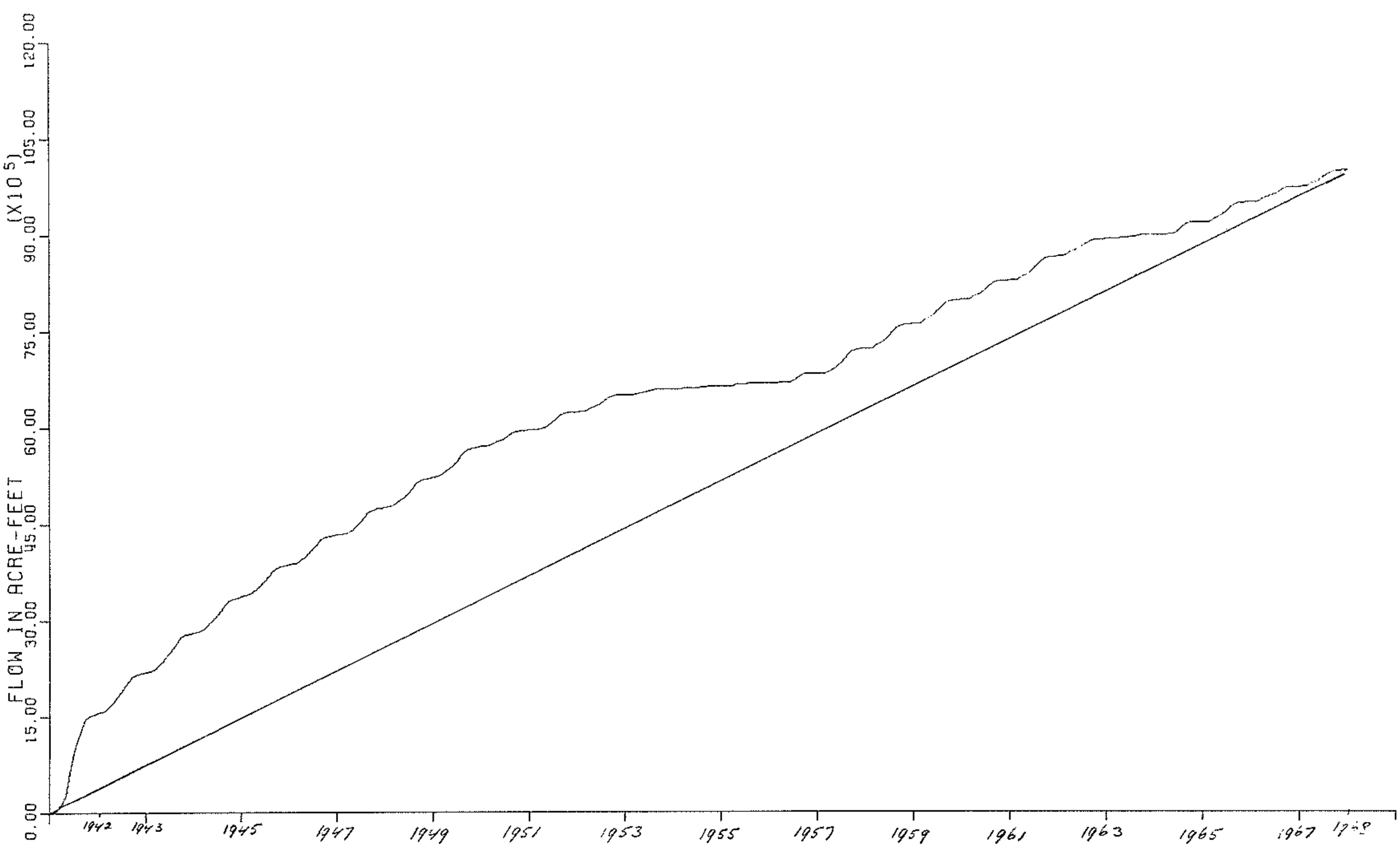

Figure 7. Mass flow curve for the Rio Grande at El Paso, Texas, 1942-1968.

Table 11. Hydrologic budget for Elephant Butte and Caballo Reservoirs, 1958-1968

Year	Deliveries to Elephant Butte Reservoir	Outflow from Caballo Reservoir
	. . . . (acre-feet)	. . . .
1961	544,070	561,697
1962	746,730	651,941
1963	268,687	517,172
1964	169,042	206,085
1965	1,038,470	505,598
1966	565,520	610,341
1967	386,740	456,517
1968	647,430	505,691
1969	983,760	667,669
1970	618,089	661,125

Source: United States Department of Interior, Bureau of Reclamation, El Paso Office (unpublished data), 1971.

is within the Mesilla and Rincon Valleys, and, therefore, this ground-water study concentrates on only these two sections.

The lower Rincon Valley from Hatch to Selden Canyon has a recent valley fill less than 200 feet thick which is underlain by clay (King, et al., 1969). The Mesilla Valley also has the recent valley fill less than 200 feet thick, but it is underlain by the Santa Fe formation, a mixture of sand and gravel interspersed by numerous clay lenses. The valley fill in both Valleys is a relatively fast backfill of an earlier river cut. The backfill and valley floors were completed about 10,000 years ago. The upper fill is fine grained sands and silts, while the lower part of the fill is mainly gravel (King, et al., 1969). All ground-water development within the Valleys is within this valley fill, and it is assumed that the basic aquifer constants within the two Valleys are identical. Therefore, most information will be used interchangeably between the Rincon and Mesilla Valleys.

Most known aquifer data for the Mesilla Valley was evaluated in a subproject study by Richardson (1972) and later published as a report by Richardson, Gebhard, and Brutsaert (1972). The study covered only the Mesilla Valley and encompassed all of the irrigated acreage within the Valley. The study area is shown in Figure 8. Richardson (1971) evaluated the aquifer constants and developed a crude water-budget by using the ground- surface-water simulator developed by Brutsaert (Lansford, et al., WRRI Report 020).

The water-budget for the Mesilla Valley is difficult to generalize because of the interaction of the surface-water flow and the elevation of the ground-water table. This is clearly demonstrated in the water-table contour map of Richardson (Figure 9). The ground-water system is recharged by deep percolation from excess irrigation waters, seepage from canals, and some leakage from the Rio Grande. The flow in the Rio Grande at the lower end of the Mesilla Valley depends upon the flow in the drains which is controlled by the elevation of the water table. The inflows and outflows for the water budget of the ground-water basin are summarized in Figure 10.

Data from known pumping tests are summarized in Table 12. Most of the transmissivities were gathered in the shallow water aquifer of the City of El Paso's Canutillo well field in the Texas portion of the Mesilla Valley. Conover (1954) concluded that the average transmissivity of the valley fill in the Mesilla Valley was 75,000 gpd per foot. Richardson (1971) programmed a 75,000 gpd per foot transmissivity into the groundwater simulator and then doubled the transmissivity in the down-valley direction. Figure 11 shows that doubling the transmissivity does not appreciably affect the water levels, and also shows that the water levels in the Valley are not sensitive to changes in transmissivity.

Storativity is a very important hydraulic parameter for an aquifer because it describes the effect of volumetric changes on water levels. Many estimates for storativity exist; they range from 25 percent by Conover (1954) to 15 percent by others. Richardson (1971) used different values for storativity in order to calibrate the groundwater simulator for 1962 and 1964 historical water-level data. Richardson found that a storativity

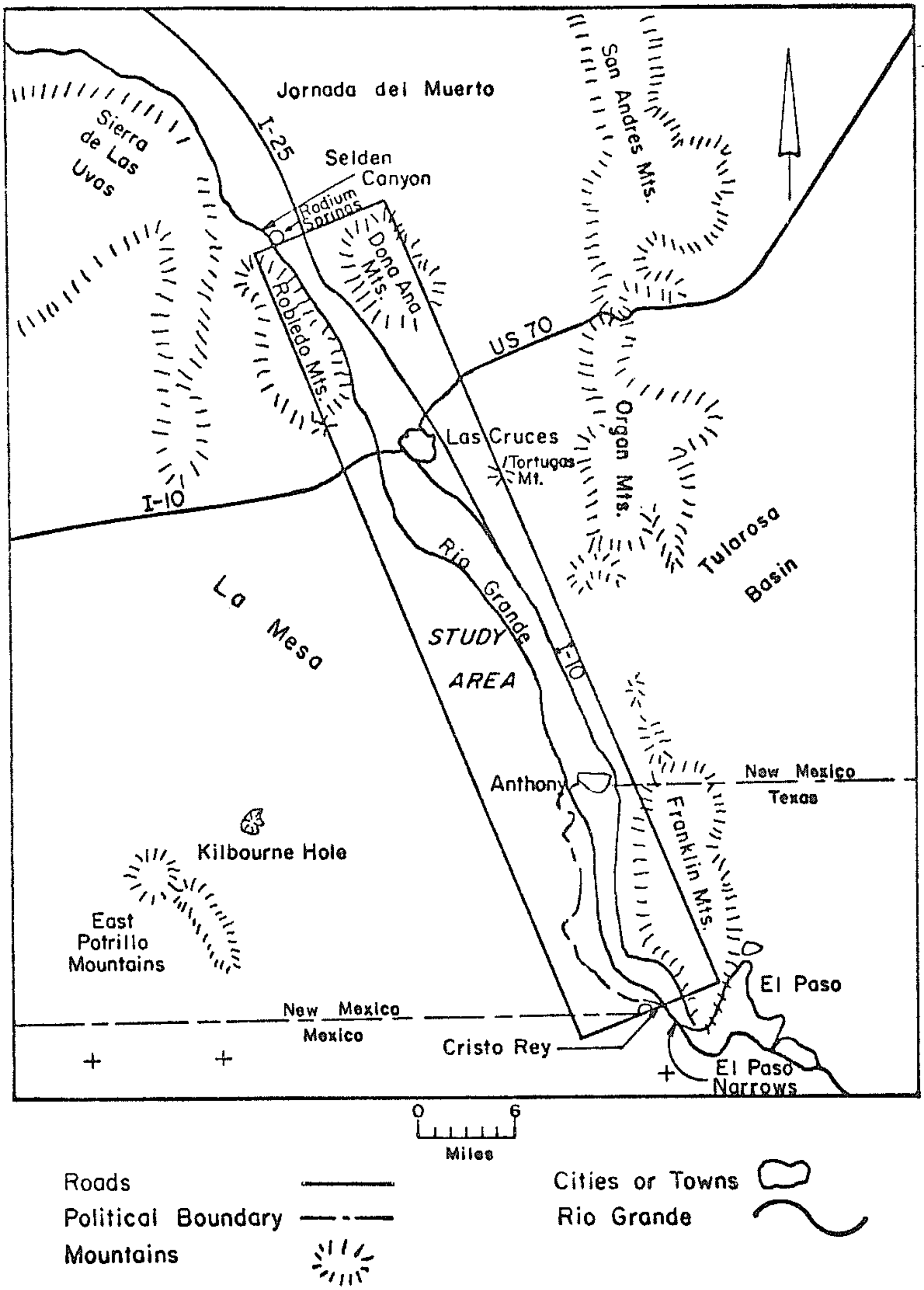

Figure 8. Index map of Mesilla Valley, New Mexico.

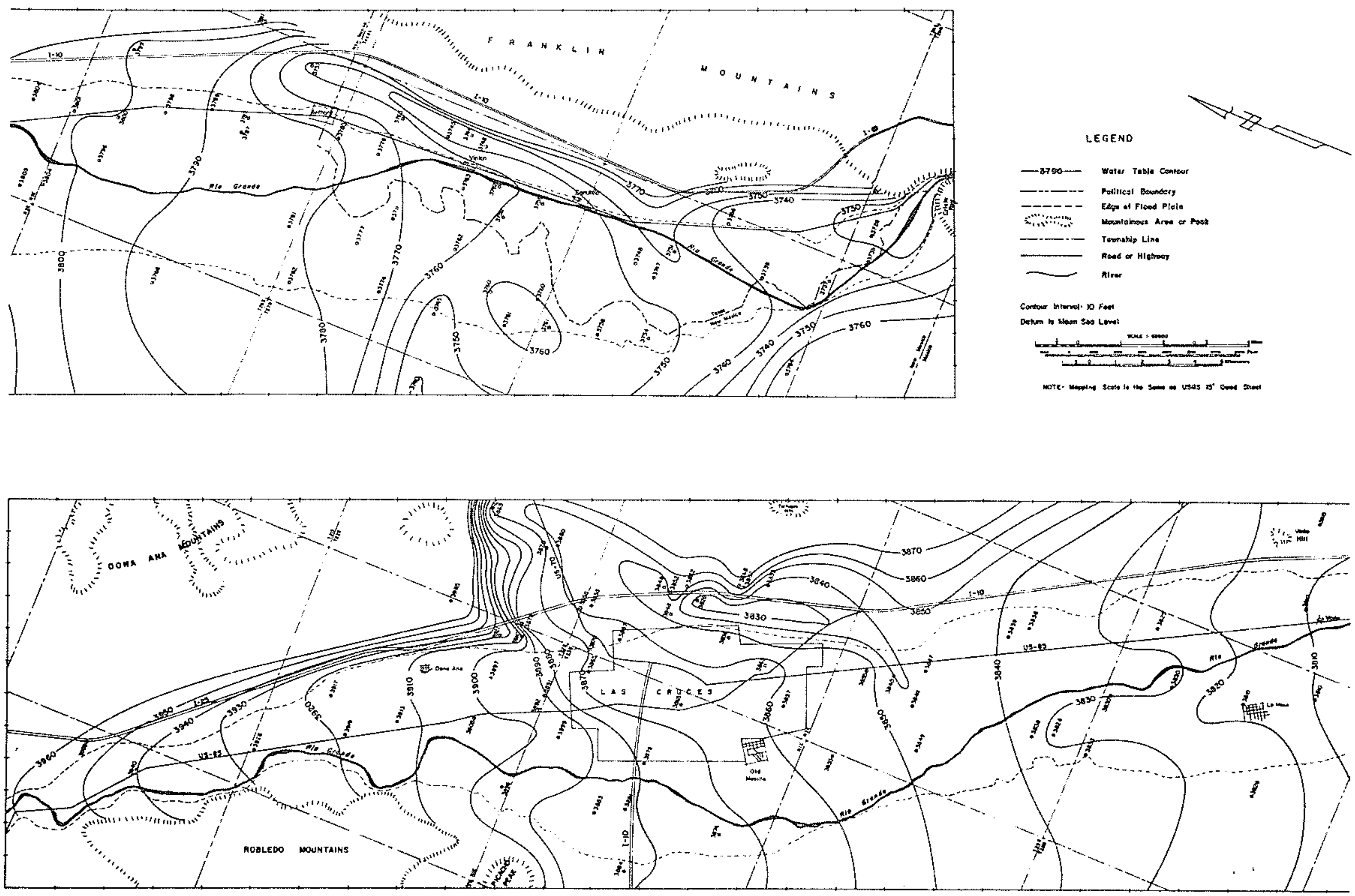

Figure 9. The Lower Rio Grande Region (Mesilla Valley) water-table contour map for January, 1967.

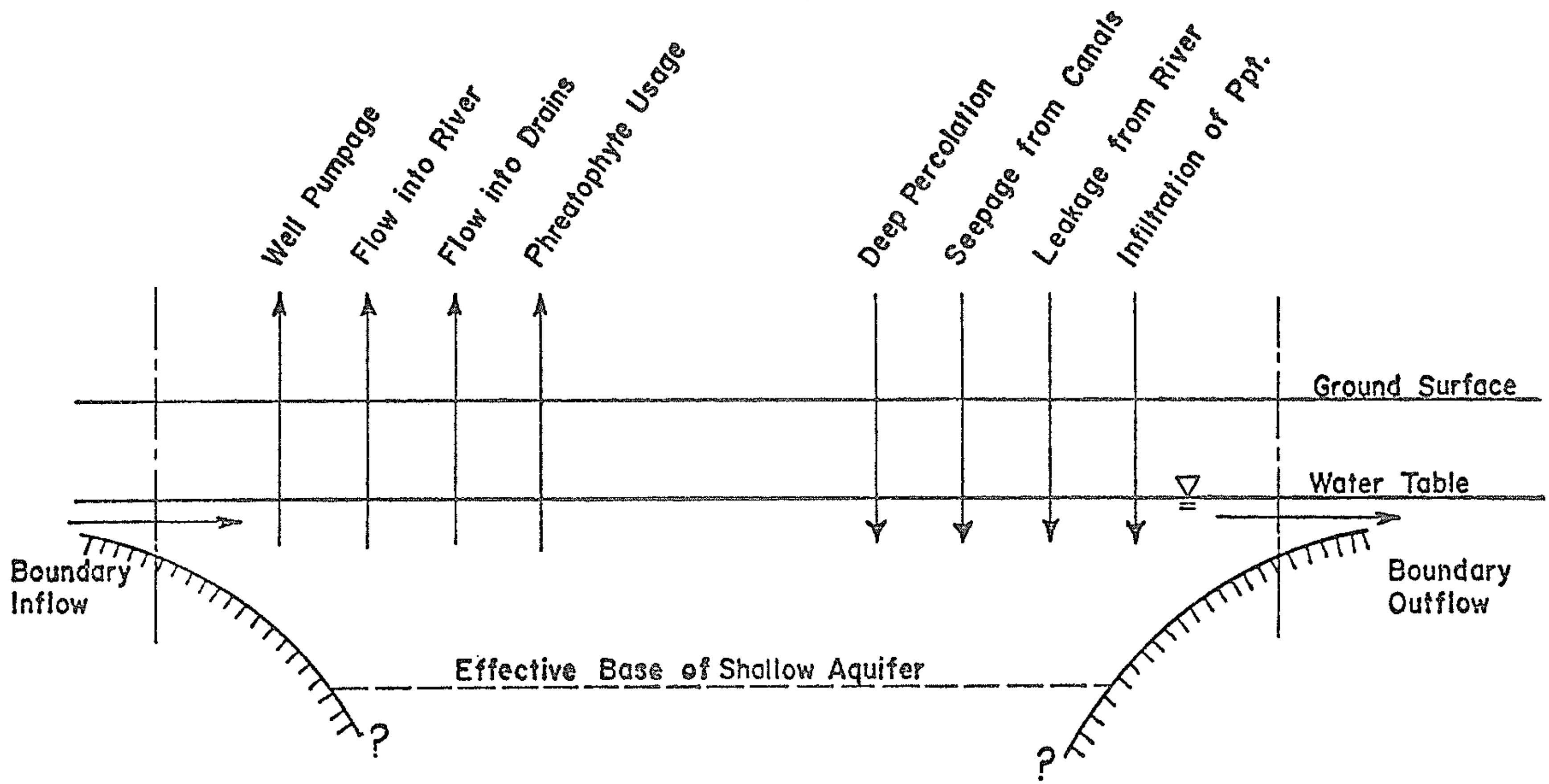

Figure 10. Water budget for the Mesilla Valley ground-water basin.

Well Location	Transmissivity (gpd/ft.)	Pumping Rate (gpm)	Specific Capacity (gpm/ft.)	Depth to SWL (ft.)	Depth of Well (ft.)	Source of Data	Approximate Date of Test	Remarks
23.1E.13.244	91,000	64	16	15	83	Con.	1946	A.T. & S.F. Ry.
23.2E.08.434	73,000	250	21	186	300	Con.	1946	L.C. #5
23.2E.29.143	116,000	1270	98	13	50	Con.	1946	N.M.S.U.
27.3E.14.433	---	600	6.6	17.3	200	E.P.	1964	E.P. Well No. 115
27.3E.14.433	---	700	5.25	17.3	200	E.P.	1964	E.P. Well No. 115
27.3E.23.114	---	1200	13.0	12.6	218	E.P.	1964	E.P. Well No. 117
27.3E.23.213	---	825	6.3	16.8	220	E.P.	1964	E.P. Well No. 116
27.3E.23.433	158,000	---	---	5.5	152	LL&H	1956	Q-82
27.3E.26.112	121,000	---	---	4.9	170	LL&H	1956	Q-165
27.3E.26.132	104,000	---	---	6.0	194	LL&H	1956	Q-166
27.3E.26.231	145,000	---	---	5.0	160	LL&H	1956	Q-83
27.3E.26.414	110,000	---	---	4.3	122	LL&H	1952	Q-84
27.3E.26.432	155,000	---	---	---	---	LL&H	1956	Q-86
27.3E.27.222	140,000	---	---	5.2	160	LL&H	1956	Q-90
27.3E.27.242	150,000	---	---	6.2	202	LL&H	1956	Q-91
27.3E.35.212	---	1065	10.7	17.7	209	E.P.	1964	E.P. Well No. 118

Table 12. Available pumping test results for the Mesilla Valley.

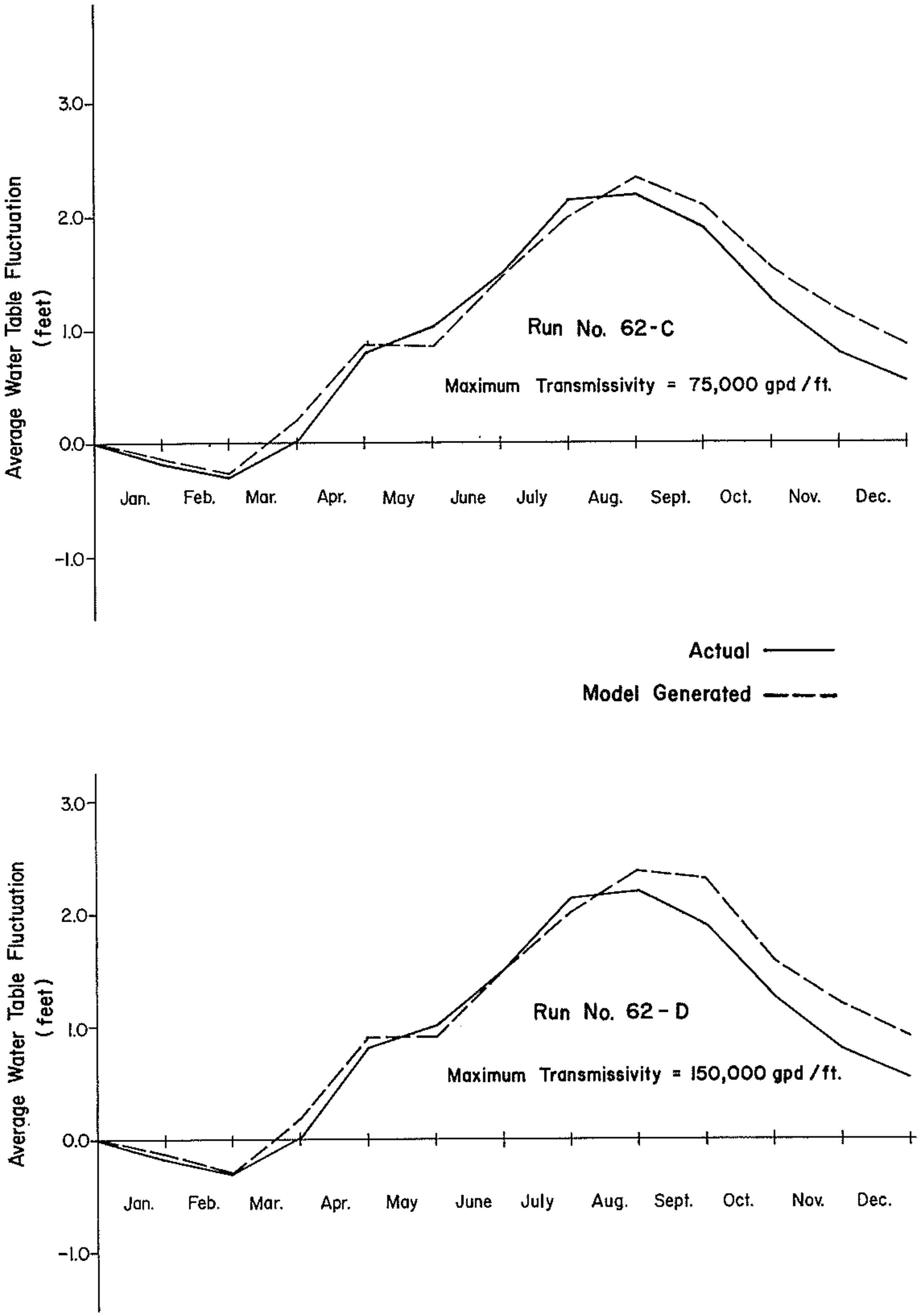

Figure 11. Sensitvity of model to changes in transmissivity.

of 20 percent created the best simulation of historical data. Figure 12 presents the actual and simulated water-table levels for 1962 and 1964 when a storativity of 20 percent was used in the simulator. Although storativity varies with location and depth throughout the Mesilla and Rincon Valleys, an average storativity of 20 percent for the entire valley system is reasonable.

The relationship developed for the Lower Rio Grande Region is

$$\Delta d = -237.15 - 2.8 \, \mathrm{EXP}(d_n/100) + 37.77 \log_{10}(L + 2 \times 10^6)$$

in which $$\Delta d = f(d_n, L)$$

where Δd = change in water-table elevation for the time period (year) considered, d_n = water elevation at the end of previous time period (year), and L = a lump factor combining surface water inflow and outflow, precipitation, and beneficial and nonbeneficial water uses.

The significance of this relationship is demonstrated by Figures 13 and 14. In Figure 13, depth to the water table, d_n, is plotted as a function of time. Starting at present with an average d_n, such as -3 feet, and using present projection rates for the area, water levels are expected to drop approximately another seven feet during the next 40 years with a tendency to level off thereafter. Figure 14 allows calculation of the drop (-) or rise (+) of the water table, Δd, given the depth of the water table at any time and the L-value.

Water Quality.

The surface water is generally of better quality than the groundwater used in the basin and is usually preferred by the farmers for irrigation supplies.

Surface water. The quality of the surface water in the Rincon Division is usually considered to be good. Chemical analyses of the surface water released from Caballo Dam were conducted on a monthly basis from February, 1966, to December, 1967. Records of these analyses indicated that the quality of the surface water varied with the quantity of the surface water released, becoming lower with smaller releases and better with larger releases. This was true both seasonally and annually. During 1966, which was an above average year for releases, the quality of the water averaged about 650 micromhos of specific conductance and

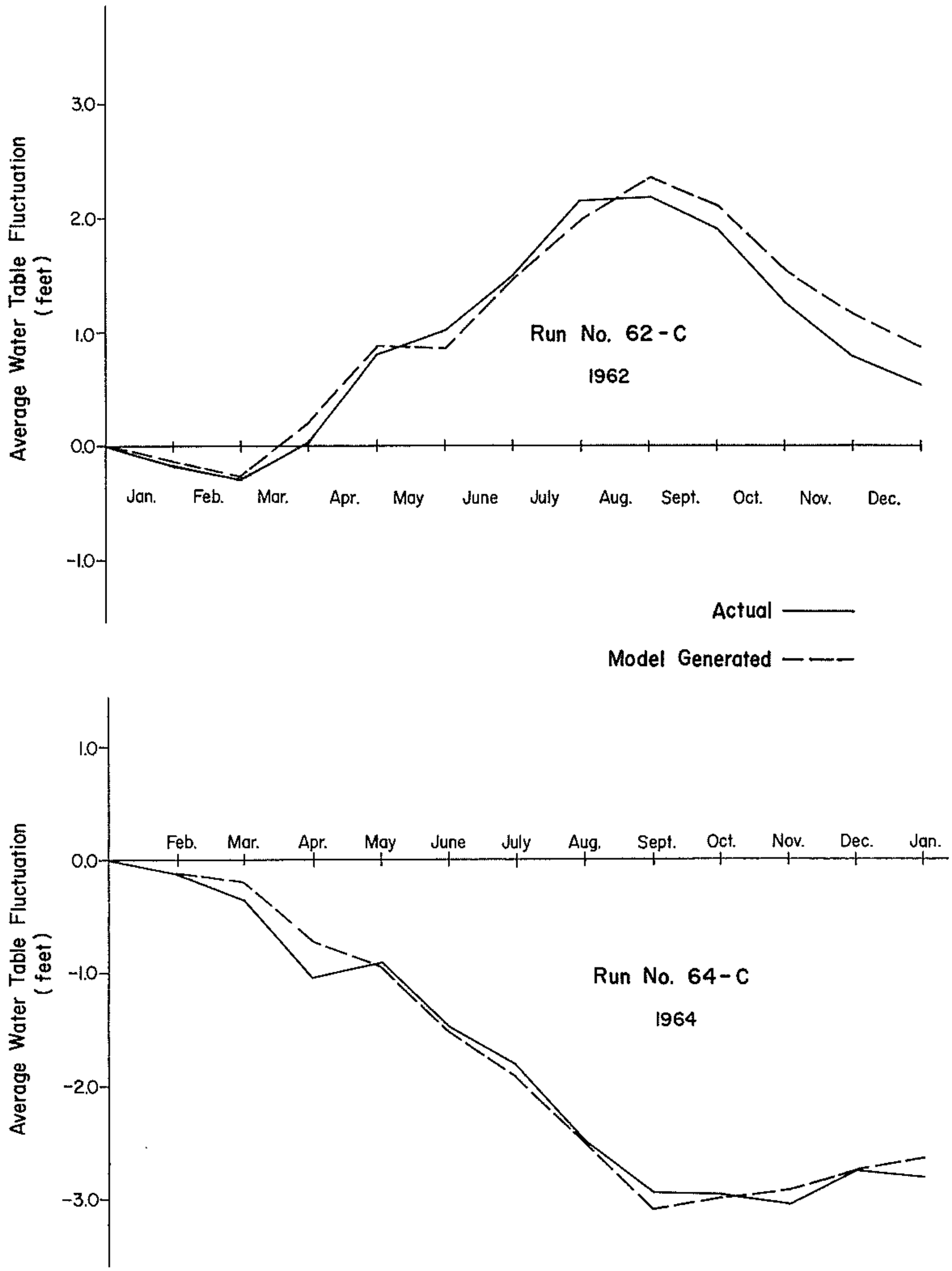

Figure 12. Actual and simulated water-table levels for 1962 and 1964, assuming .20 storativity.

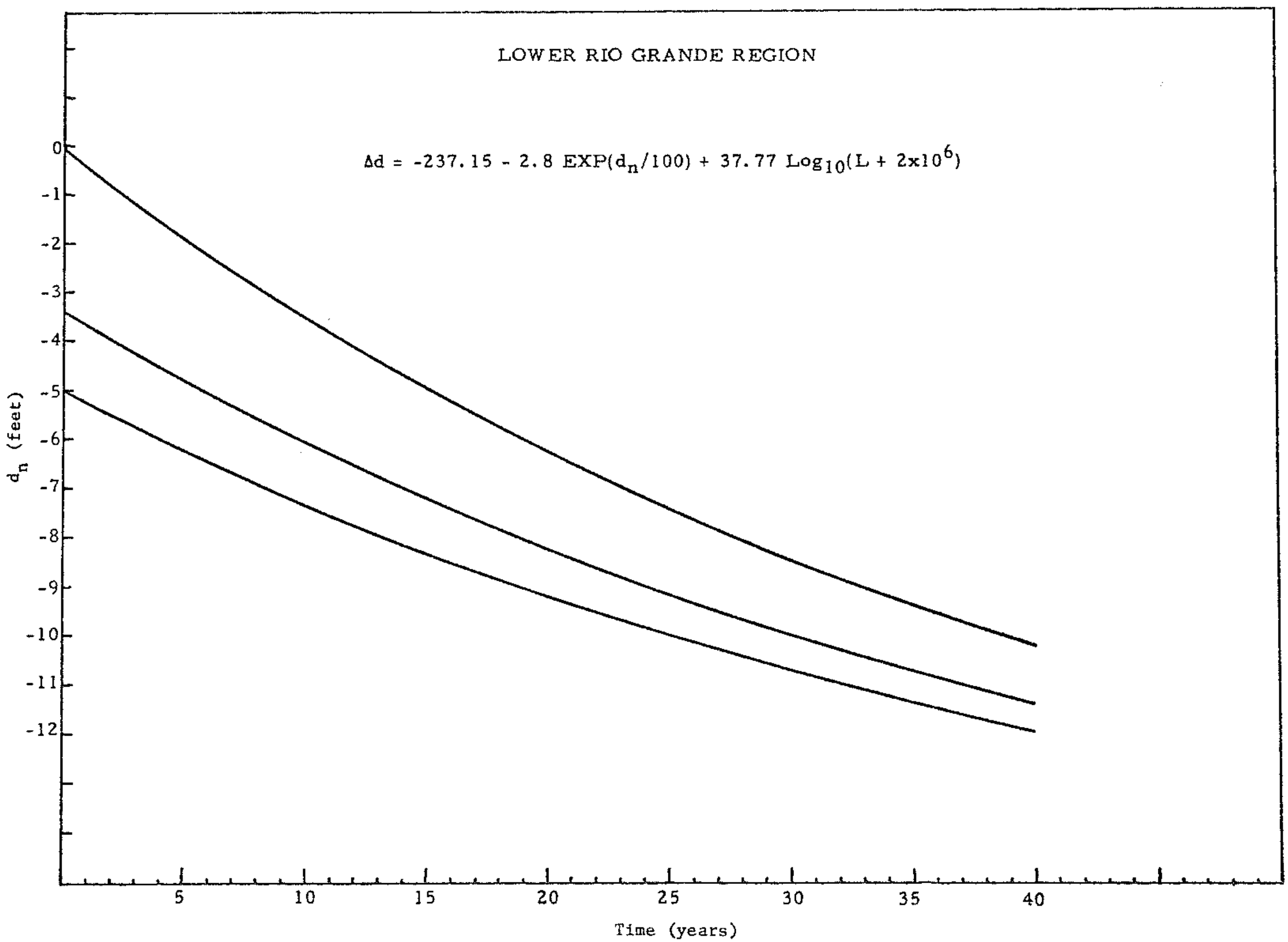

Figure 13. Depth (feet) to the water table [d_n] with respect to time for the Mesilla Valley section, Lower Rio Grande Region, New Mexico.

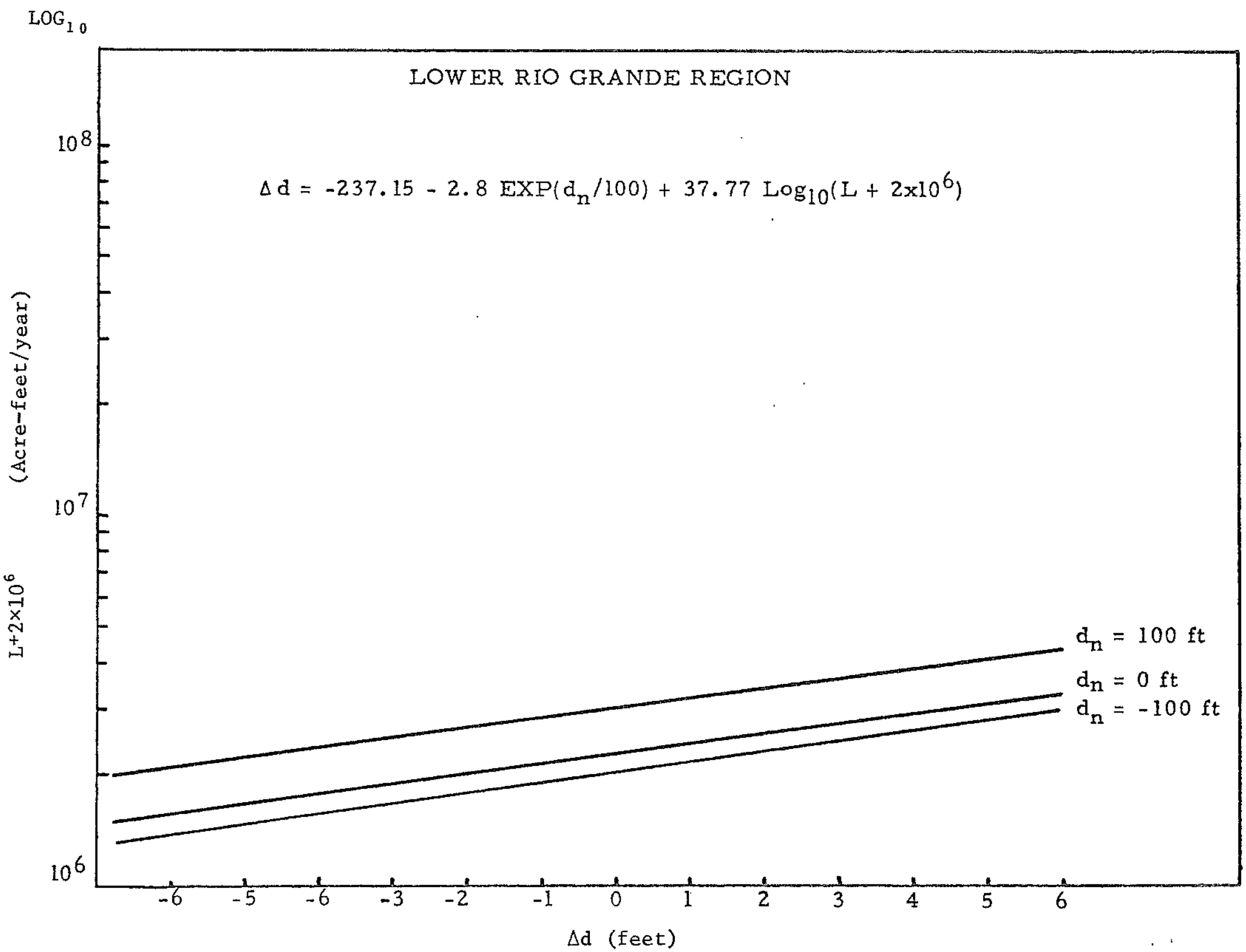

Figure 14. Expected declines in the water-table level in the Mesilla Valley section utilizing varying depths to water, Lower Rio Grande Region, New Mexico.

had a sodium adsorption ratio of about 1.8 for the March through September period (U.S. Department of the Interior, 1966). During 1967, however, when releases were below average, the specific conductance averaged about 800 micromhos and the sodium adsorption ratio about 2.3. Since irrigation return flows are not returned to the delivery system within the Rincon Division, the water was not considered to become lower in quality with use throughout the division. This indicated that the surface water-quality was not a limitation as long as releases were above average.

The quality of the surface water in the Mesilla Valley was not considered a limitation except in the southern portion below Anthony. In this area the problem of lower quality surface-water is compounded by the existence of poorer quality ground-water. Records of the chemical analyses of the river at El Paso in 1966 and 1967 indicated that the quality of the surface water varied generally with the quantity of water flowing in the river, becoming poorer with smaller flows and better with larger flows. During 1966, for the March through September period, the quality of the river averaged about 1,010 micromhos of specific conductance and the river flow averaged 20,969 second-feet (U.S. Department of State, 1966). During 1967, for the March through September period, the specific conductance averaged about 1,170 micromhos and the river flow averaged 15,571 second-feet (U.S. Department of State, 1967). In a study of the lower Mesilla Valley in 1962, Leggat, et al. (1962) noted that the chemical quality of the water of the Rio Grande increased in dissolved solids content by nearly 45 percent between Leasburg, New Mexico, and El Paso, Texas. Conover (1954, p. 84) found that the quality of the surface water of the area was generally best at the upper end of the project and became progressively poorer toward the lower end. The surface water of the Rio Grande increased in concentration of dissolved salts downstream from Elephant Butte to El Paso, but there was little change in the relative concentrations of the dissolved mineral constituents except sodium which increased slightly (Conover, 1954).

Since some surface water used in the Rincon Division is returned to the system through drains and is reused by the Leasburg Division and returned through drains, this indicates that the water in the southern portion of the Mesilla Division is of lower quality. Records of the chemical quality of the surface water diverted by the two sections of the Mesilla Valley were not available, but the surface-water quality was considered to be lower than when released from Caballo Dam and better than at El Paso.

Ground water. Ground-water quality was considered a moderate limitation in some areas of the Rincon Valley. These areas were primarily along the river in the lower end of the Valley. Chemical analyses of wells in the area were limited in number, but those available indicated that the ground-water was of moderate quality. In the ground-water areas outside of the Valley, water quality was not considered a major limitation. The water is generally of better quality near the edges of the Valley and on the highlands because of the direction of ground-water movement.

The quality of the ground water in the Mesilla Valley varies both with location and with depth. The quality generally decreases with movement down the Valley. Samples of water collected from wells in the southern end of the Valley are higher in dissolved solids content than in the northern area. The quality of the water is usually better with increased depth. Fresh water exists in the Santa Fe group to a depth of about 1,200 feet, extending from near the northern end generally south to near Canutillo (King, et al., 1969). South of Canutillo, the water from the Santa Fe group increases in mineral content until it becomes unfit for most uses. This southward increase in mineral content of the water in the Santa Fe group is thought to be due to incomplete flushing of ancient playa lake sediments and to the increased mineral concentration of the ground-water in the alluvium by evapotranspiration (Leggat, et al., 1962).

The shallow ground-water, usually considered to be less than 200 feet in depth, supplies most of the ground water used for irrigation in the Mesilla Valley. The water is relatively fresh throughout most of the area, but contains more dissolved solids than the water in the Santa Fe group. South of Canutillo, the alluvium contains water rather high in dissolved solids but still of better quality than the water in the underlying Santa Fe group (Leggat, et al., 1962) The quality varies laterally in this area and also at different periods of time, due partially to the infiltration of water from the Rio Grande and the infiltration of surface water applied to the land for irrigation. The greatest increase in the chloride content has been in the center of the heavily irrigated areas, and the increases have been at a rate similar to the increases in the river. Leggat et al. (1962) pointed out that increases in ground-water withdrawals in the lower Valley were likely to result in increases in the dissolved solids content of the ground water. Thus, if the shallow aquifer is to remain a source of supplemental supply for irrigation, withdrawals of water must not be so great that an unfavorable salt balance results. Ground-water quality was considered a moderate limitation to about one-third of the irrigated cropland in the Valley, and a severe limitation to about one-sixth, primarily in the southern portion. The potential for further deterioration of the ground water in this portion is regarded as a major limitation.

WATER DIVERSIONS AND DEPLETIONS

Irrigation

Irrigation water in the Lower Rio Grande Region comes from surface and ground sources. The surface water is supplied primarily by the Elephant Butte Irrigation District through the facilities of Elephant Butte and Caballo Reservoirs. Small quantities, however, are diverted from the tributaries in the northwestern area of the region. Ground water is used as a supplemental source in most cases, but is the primary source of irrigation water for over 8,500 acres in the LRGR. Of this, about 3,400 acres are in Sierra County and the remainder in Dona Ana County.

The Elephant Butte Irrigation District can be divided into two sections, the Rincon Division and the Mesilla Division. This division was made because of the separate structures for each unit.

Surface-water quantity. The quantity of surface water released to the project lands has varied widely from year to year, depending upon the amount of water in storage in Elephant Butte and Caballo Reservoirs. Caballo Dam was built in 1938 about 28 miles below Elephant Butte Dam. Prior to this, water releases were gaged at the station below Elephant Butte Dam: since 1938, the water released to the project lands has been gaged at a station 0.8 mile below Caballo Dam and about 1.5 miles above Percha Dam.

For the Rincon Division, the water released from Caballo Reservoir is diverted at Percha Dam into two canals, Arrey and Percha, and by the Bonito ditch which receives water through a diversion at Caballo Dam.

For the Mesilla Division, the water is diverted by the Leasburg Dam into the Leasburg Canal, and by the Mesilla Dam into the East Side and West Side Canals. The Leasburg Dam is located at the head of the Mesilla Valley, and the Mesilla Dam is located southwest of Las Cruces. The project irrigation system serving the Mesilla Valley is more complex than that of the Rincon Valley since water diverted by the Leasburg Dam and used in the upper section of the Valley may be returned to the system by drains and wasteways before being diverted by the Mesilla Dam. In addition, water diverted by the Leasburg Dam may be added to the diversions of the Mesilla Dam in the East Side Canal.

A portion of the water diverted by the Rincon Division is returned to the river by drains and wasteways before entering the Mesilla Division. Likewise, a portion of the water diverted by the Mesilla Division is also returned to the system to be diverted by the El Paso Division.

The diversion of Bonito ditch is not included in the monthly distribution of releases from Caballo Reservoir. The annual diversions of water for the Elephant Butte Irrigation District are reported in Table 13 (Rincon Division and Mesilla Division). The average total diversion for the 33-year period for both Divisions was 456,925 acre-feet. The minimum diversion was in 1955 and the maximum in 1944 and 1945.

These diversions reported are the gross diversions in the LRGR, a portion of which is wasted back into the river or the drainage ditches and is again diverted, along with the return drain water, by the next lower unit. Conover (1954) estimated this wastage for the period 1930 to 1946 to average about 24 percent of the gross annual diversions. This canal

Table 13. Gross annual diversions of irrigation water from the Rio Grande in the Rincon and Mesilla Valleys, Lower Rio Grande Region. New Mexico, 1938-1970

Year	Rincon Valley			Mesilla Valley			Total
	Arrey Canal[1]	Percha Canal[2]	Bonito Ditch[3]	Leasburg Canal[4]	East side Canal[5]	West side Canal[6]	
	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)	(ac-ft)
1938	79,230	--	1,428	150,960	78,880	202,630	513,128
1939	84,210	--	1,653	164,810	90,640	222,433	563,746
1940	80,890	--	1,159	154,790	81,386	199,680	517,905
1941	72,770	--	625	139,130	73,097	182,460	468,082
1942	100,990	--	1,167	192,450	95,060	237,650	627,137
1943	105,180	--	1,522	219,940	90,810	226,350	643,802
1944	108,190	--	1,597	204,340	88,390	215,050	617,567
1945	103,780	--	1,591	218,140	97,890	231,900	653,301
1946	99,650	--	2,175	205,700	86,750	211,100	605,375
1947	86,780	--	1,716	192,680	78,730	200,110	560,016
1948	85,780	--	1,831	183,800	83,370	201,880	556,661
1949	91,996	--	1,015	188,720	88,440	205,200	575,371
1950	89,340	--	1,784	194,010	83,008	196,264	564,406
1951	55,110	--	1,426	100,350	50,860	126,470	334,216
1952	64,800	--	2,288	100,943	56,250	132,690	356,921
1953	63,200	482	2,445	100,664	55,600	139,590	361,981
1954	27,212	141	1,324	50,509	37,391	90,010	206,587
1955	19,861	64	1,176	35,497	23,551	80,778	160,927
1956	24,147	44	1,298	35,340	28,002	84,270	173,101
1957	35,474	188	907	121,847	35,459	124,036	317,911
1958	99,110	424	920	162,954	69,788	179,560	512,756
1959	96,100	446	1,217	162,450	76,228	165,530	501,971
1960	98,740	472	1,166	155,772	77,640	173,490	507,280
1961	71,710	477	1,043	124,973	66,615	161,080	425,898
1962	90,900	620	965	147,965	77,422	171,496	489,368
1963	74,550	436	914	136,562	64,756	160,430	437,648
1964	26,080	74	1,006	78,194	19,242	81,150	205,746
1965	59,528	286	1,048	79,884	42,710	109,280	292,736
1966	84,020	994	1,062	124,145	56,770	140,948	407,939
1967	66,250	565	918	122,902	59,088	132,653	382,376
1968	88,630	609	634	149,711	68,416	166,170	474,170
1969	90,620	869	568	169,205	71,650	202,160	535,072
1970	98,436	993	959	164,650	72,056	190,110	527,204
Average	76,463	455	1,289	143,454	67,453	168,018	456,925

1 Diversion at Percha Dam to the west side of the Rio Grande.
2 Diversion at Percha Dam to the east side of the Rio Grande.
3 Diversion at Caballo Dam to the west side; privately owned structure and releases are not included in records of releases of Rio Grande below Caballo Dam.
4 Diversion at Leasburg Dam to the east side of the Rio Grande.
5 Diversion at Mesilla Dam to the east side of the Rio Grande.
6 Diversion at Mesilla Dam to the west side of the Rio Grande.

Source: United States Department of Interior, Bureau of Reclamation, El Paso Office (unpublished data sheets), 1938-1970, 66 pp.

waste, or return, is of an operational nature and results because of extra diversions for irrigation head and cancellation of water orders after water has already been released. Other specific losses from the canals include seepage losses, evaporation from the water surface in the canals, and transpiration by plants along the banks of the canals. Conover (1954) estimated the canal seepage and other unaccounted for losses in a normal year to average about 20 percent of the gross headgate diversions. Water delivered to the land is the remainder of the gross annual diversions after subtracting canal wastage and seepage losses.

Monthly surface-water deliveries to the lands in the Elephant Butte Irrigation District are reported in Table 14. These deliveries were calculated from information available from the Bureau of Reclamation (1960-1969) and are the net deliveries to the farm headgates (canal wastage, canal seepage, and other unaccounted for losses have been deducted). The average annual delivery to the lands was 176,695 acre-feet. Based on the 1969 acreage, the Rincon Division of the Elephant Butte Irrigation District averaged about 1.51 acre-feet per cropped acre and 1.39 acre-feet per cultivated acre: the Mesilla Division averaged about 1.93 acre-feet per cropped acre and 1.81 acre-feet per cultivated acre.

Although the surface water is generally of better quality than the ground water used in the region and is usually preferred by the farmers, surface water is supplemented with ground water to supply the irrigation requirements of the crops produced.

Ground-water quantity. The ground water in the valley fill is derived from a number of sources, and the quantity from each is generally undeterminable. The water results from seepage from the river, canals, and laterals, irrigation water applied to the lands, precipitation, runoff in arroyos from the mesas to the Valley, and ground-water flow from the bordering mesa lands.

Consumptive irrigation requirements calculated by the Blaney-Criddle formula (1962) on the basis of the 1969 cropping pattern for the lands within the boundaries of the Elephant Butte Irrigation District are reported in Table 15. About 170,025 acre-feet of irrigation water were necessary for crop consumption during the full season. Requirements for the summer season (March through November) were about 168,072 acre-feet, and for the

Table 14. Monthly deliveries* of surface water to the lands in the Rincon and Mesilla Divisions, Elephant Butte Irrigation District, Lower Rio Grande Region, New Mexico, 1960-1969

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
						(acre-feet)							
						RINCON DIVISION							
1960	-	-	4,935	6,296	3,744	5,956	6,126	8,168	5,785	-	-	-	41,010
1961	-	-	2,195	4,390	2,533	3,377	4,728	5,910	3,715	-	-	-	26,848
1962	-	-	2,675	7,523	3,344	6,854	6,186	6,520	5,350	-	-	-	38,452
1963	-	-	5,513	4,344	2,673	3,676	5,012	3,843	2,840	-	-	-	27,901
1964	-	-	495	1,651	0	330	661	826	1,320	-	-	-	5,283
1965	-	-	167	1,669	0	3,003	6,674	7,008	3,838	-	-	-	22,359
1966	-	-	2,785	5,879	2,321	4,487	5,415	5,879	5,415	-	-	-	32,181
1967	-	-	6,098	2,380	1,636	1,041	2,677	3,718	3,272	-	-	-	20,822
1968	-	-	4,938	2,798	2,304	3,786	3,950	7,407	4,115	-	-	-	29,298
1969	-	-	7,220	3,190	2,518	5,877	5,541	10,242	2,518	-	-	-	37,106
Average			3,702	4,012	2,107	3,839	4,697	5,952	3,817				28,126
						MESILLA DIVISION							
1960	-	-	26,049	26,815	16,089	28,347	29,113	43,670	31,412	766	-	-	202,261
1961	-	-	16,864	26,062	12,265	19,930	32,195	32,195	21,463	767	-	-	161,741
1962	-	-	23,426	34,357	14,055	35,919	41,385	42,166	21,864	1,562	-	-	214,734
1963	-	-	30,717	25,991	9,451	18,115	31,505	29,142	14,965	0	-	-	159,886
1964	-	-	2,313	6,940	0	2,313	4,627	6,169	7,711	0	-	-	30,073
1965	-	-	0	8,985	0	16,472	32,945	35,940	25,457	749	-	-	120,548
1966	-	-	10,908	31,269	13,817	18,907	26,179	34,178	22,543	1,454	-	-	159,255
1967	-	-	33,121	8,457	5,638	8,457	16,913	20,437	19,732	705	-	-	113,460
1968	-	-	21,567	13,387	7,437	19,336	22,311	31,235	17,105	744	-	-	133,122
1969	-	-	34,035	15,883	11,345	27,985	37,061	49,162	14,370	756	-	-	190,597
Average			19,900	19,815	9,010	19,578	27,423	32,429	19,662	750			148,567

* Amount of water delivered to the farm headgates; excludes canal wastage, seepage, and other unaccounted for losses (calculated from monthly per acre deliveries and annual irrigated acreage).

Source: United States Department of Interior, Bureau of Reclamation, El Paso Office (unpublished data sheets), 1960-1969, 20 pp.

Table 15. Seasonal and total consumptive irrigation requirements and irrigation requirements by crop for lands within the boundaries of the Elephant Butte Irrigation District for the Rincon and Mesilla Valleys, Lower Rio Grande Region, New Mexico, 1969

Crop	Consumptive Irrigation Requirements [a]			Irrigation Requirements [b]		
	Summer [c] (ac-ft)	Winter [d] (ac-ft)	Total (ac-ft)	Summer [c] (ac-ft)	Winter [d] (ac-ft)	Total (ac-ft)
RINCON VALLEY						
Cotton	15,657	0	15,657	26,095	0	26,095
Alfalfa	6,960	0	6,960	11,600	0	11,600
Sorghum	1,642	0	1,642	2,737	0	2,737
Corn	1,474	0	1,474	2,457	0	2,457
Small grains	426	39	465	710	65	775
Irrigated pasture	634	0	634	1,057	0	1,057
Chile	3,998	0	3,998	6,663	0	6,663
Orchards	306	0	306	510	0	510
Spring lettuce	760	256	1,016	1,267	427	1,694
Fall lettuce	956	0	956	1,593	0	1,593
Spring onions	0	0	0	0	0	0
Fall onions	0	0	0	0	0	0
Misc. veg., and gardens [e]	594	0	594	990	0	990
Total	33,407	295	33,702	55,679	492	56,171
Weighted average	1.80	0.02	1.81 [f]	3.00	0.03	3.02 [f]
MESILLA VALLEY						
Cotton	78,536	655	79,191	130,893	1,092	131,985
Alfalfa	25,896	0	25,896	43,160	0	43,160
Sorghum	4,720	0	4,720	7,867	0	7,867
Corn	1,397	0	1,397	2,328	0	2,328
Small grains	723	110	833	1,205	183	1,388
Irrigated pasture	1,947	39	1,986	3,245	65	3,310
Chile	1,362	0	1,362	2,270	0	2,270
Orchards	13,115	0	13,115	21,858	0	21,858
Spring lettuce	1,582	460	2,042	2,637	767	3,404
Fall lettuce	1,813	0	1,813	3,022	0	3,022
Spring onions	2,027	357	2,384	3,378	595	3,973
Fall onions	512	37	549	853	62	915
Misc. veg., and gardens [e]	1,035	0	1,035	1,725	0	1,725
Total	134,665	1,658	136,323	224,441	2,764	227,205
Weighted average	1.83	0.02	1.85	3.05	0.04	3.08 [f]

a. The quantity of irrigation water, exclusive of precipitation, stored soil moisture, or ground water, that is required consumptively for crop production (Blaney and Hanson, 1965, p. 5).

b. The quantity of water, exclusive of precipitation, that is required for crop production, or the consumptive irrigation requirement divided by the irrigation efficiency (60 percent), (Blaney and Hanson, 1965, p. 5).

c. Months of March through November.

d. Months of December through February.

e. Also includes crops for which consumptive-use values were not available.

f. Does not add because of rounding.

winter season (December through February) were about 1,953 acre-feet. These requirements are the quantities of irrigation water, exclusive of precipitation, stored soil moisture, or ground water, required consumptively for crop production. They do not include surface evaporation or other economically unavoidable wastes normally associated with irrigation. The surface-water deliveries were estimated at the farm headgate and, to be comparable, the irrigation requirements were calculated using a farm irrigation-efficiency of 60 percent. The selection of the 60 percent efficiency was made in consultation with personnel of the Agricultural Engineering Department of New Mexico State University and through observations made during the field survey. The calculated irrigation requirements for the lands within the Elephant Butte Irrigation District are also reported in Table 15. The total irrigation requirement for the summer season was 280,120 acre-feet, or about 3.00 acre-feet per cropped acre. Surface-water deliveries for the same season averaged about 176,693 acre-feet, indicating that about 103,427 acre-feet were pumped from wells during the summer season; about 3,256 acre-feet were pumped to meet the winter season requirement. This gave a total of 106,683 acre-feet for the year.

Outside of the Elephant Butte Irrigation District, but within the Rincon and Mesilla Valleys, and in the tributary units of the Rincon Division, about 15 percent of the acreage relies on surface water only, and about 13 percent on a combination of surface and ground water. The actual quantity of surface water delivered or diverted to the lands in these tributary units was not available, but was estimated to be less than 2.0 acre-feet per acre. The land outside of the District in the Mesilla Valley relies completely on ground water for irrigation.

The total consumptive irrigation requirement for the area outside the boundaries of the Irrigation District in the Rincon Valley was calculated to be 6,978 acre-feet, or 1.89 acre-feet per cropped acre, based on the 1969 cropping pattern (Table 16). The total irrigation requirement, based on a farm irrigation-efficiency of 60 percent, was 11,631 acre-feet, or 3.14 acre-feet per cropped acre (Table 16). On the lands receiving a combination of surface and ground water, the pumpage was

Table 16. Seasonal and total consumptive irrigation requirements and irrigation requirements by crop for lands outside the boundaries of the Elephant Butte Irrigation District for the Rincon and Mesilla Valleys, Lower Rio Grande Region, New Mexico, 1969

Crop	Consumptive Irrigation Requirements[a]			Irrigation Requirements[b]		
	Summer[c] (ac-ft)	Winter[d] (ac-ft)	Total (ac-ft)	Summer[c] (ac-ft)	Winter[d] (ac-ft)	Total (ac-ft)
			RINCON VALLEY			
Cotton	1,675	0	1,675	2,792	0	2,792
Alfalfa	2,529	0	2,529	4,215	0	4,215
Sorghum	322	0	322	537	0	537
Corn	242	0	242	403	0	403
Small grains	67	6	73	112	10	122
Irrigated pasture	1,429	0	1,429	2,382	0	2,382
Chile	0	0	0	0	0	0
Orchards	0	0	0	0	0	0
Spring lettuce	0	0	0	0	0	0
Fall lettuce	0	0	0	0	0	0
Spring onions	0	0	0	0	0	0
Fall onions	0	0	0	0	0	0
Misc. veg., and gardens[e]	708	0	708	1,180	0	1,180
Total	6,972	6	6,978	11,621	10	11,631
Weighted average	1.89	0.00	1.89	3.14	0.00	3.14
			MESILLA VALLEY			
Cotton	2,332	19	2,351	3,887	32	3,919
Alfalfa	2,900	0	2,900	4,834	0	4,834
Sorghum	170	0	170	283	0	283
Corn	33	0	33	55	0	55
Small grain	0	0	0	0	0	0
Irrigated pasture	866	17	883	1,444	28	1,472
Chile	30	0	30	50	0	50
Orchards	709	0	709	1,182	0	1,182
Spring lettuce	0	0	0	0	0	0
Fall lettuce	8	0	8	13	0	13
Spring onions	0	0	0	0	0	0
Fall onions	19	1	20	32	2	34
Misc. veg., and gardens[e]	83	0	83	138	0	138
Total	7,150	38	7,188	11,918	62	11,980
Weighted average	2.21	0.01	2.23[f]	3.69	0.02	3.71

a. The quantity of irrigation water, exclusive of precipitation, stored soil moisture, or ground water, that is required consumptively for crop production (Blaney and Hanson, 1965, p. 5).
b. The quantity of water, exclusive of precipitation, that is required for crop production, or the consumptive irrigation requirement divided by the irrigation efficiency (60 percent), (Blaney and Hanson, 1965, p. 5).
c. Months of March through November.
d. Months of December through February.
e. Also includes crops for which consumptive-use values were not available.
f. Does not add because of rounding.

estimated to be 114 acre-feet. On about 72 percent of the lands, ground water is the only source of irrigation water and pumpage was calculated to be about 8,371 acre-feet. The total pumpage of ground water for irrigation outside of the Irrigation District boundaries was estimated to be 8,485 acre-feet.

Total pumpage of ground water for irrigation in the Rincon Valley was estimated to be 36,530 acre-feet, based on the 1969 cropping pattern and the assumed irrigation efficiency. This is about 1.64 acre-feet per cropped acre.

The total consumptive irrigation requirement for the land outside of the District in the Mesilla Valley was calculated to be 7,188 acre-feet, or about 2.23 acre-feet per cropped acre, based on the 1969 cropping pattern (Table 16). The irrigation requirement was estimated to be 11,980 acre-feet, or about 3.71 acre-feet per cropped acre, using a farm irrigation-efficiency of 60 percent (Table 16).

The total pumpage of irrigation water in the Mesilla Valley was estimated to be 90,618 acre-feet. This included 78,638 acre-feet, or about 1.02 acre-feet per cropped acre, for the supplemental irrigation of the lands inside of the Irrigation District boundary, and 11,980 acre-feet, or about 3.71 acre-feet per cropped acre, for full-service irrigation of the lands outside the District boundaries.

The total quantity of irrigation water required for crop production in the region is reported in Table 17 along with the surface water deliveries and the estimated pumpage. Total requirement of irrigation water, based on the 1969 cropping pattern, was 306,987 acre-feet, and the 10-year average annual surface-water deliveries were calculated to be 176,693 acre-feet, indicating that about 130,294 acre-feet, or about 1.3 acre-feet per cropped acre and about 1.7 acre-feet per cultivated acre, were pumped from the ground-water source.

Table 17. Total irrigation requirements for crop consumption, average annual surface-water deliveries, and estimated ground-water pumpage in the Lower Rio Grande Region, New Mexico

Area	Irrigation Requirements[a]	Surface Water Deliveries[b]	Ground Water Pumpage[c]
	. . . .	. acre-feet	. . . .
Rincon Valley	67,802	28,126	39,676
Mesilla Valley	239,185	148,567	90,618
Total Basin	306,987	176,693	130,294

[a]The quantity of water, exclusive of precipitation, that is required for crop production.

[b]Ten-year average annual surface-water deliveries.

[c]Irrigation requirements minus surface-water deliveries.

Municipal and Industrial

Municipal water use depends primarily upon two factors: the number of urban water users, and the per capita use of water. Industrial water use depends partially on the number of employees and the per employee use of water in the production of goods and services. Using figures from the State Engineer Office, an estimate was made of water use for the urban population in 1960 and 1970. Municipal use includes more than urban population: light industrial as well as commercial activities within a region are dependent upon the municipal water supply. An estimate was made separately for this type of user, which includes the public sector composed of government and associated enterprises. Due to the lack of reliable primary data, these estimates should serve only as crude approximations to the actual water use within the LRGR. The amounts in Table 18 represent a probable approximate maximum during the years 1969 and 1970.

Over 90 percent of the municipal and industrial water users obtained their supplies from ground-water systems. Very little surface water is diverted or depleted by any user other than agriculture.

Rural Domestic

Rural use of water is dependent upon the same two factors, population size (rural only) and the per capita use of water, as the urban population use. All the water diverted or consumed by the rural domestic population was assumed to be derived from ground water

Livestock

Livestock use of water depends upon both use per animal within the region, and the number of, and evaporation from, stock ponds located in the region. To obtain an estimate of the use of water by livestock, an inventory by Capener and Sorensen (1971) for both the number of livestock and the number of stock ponds was used.

Stock ponds are primarily supplied from surface water, but some livestock water comes from the ground supply. However, the most significant portion of water used can be assumed to be from surface supplies.

Between 1960 and 1970, there was no appreciable change in water consumption by livestock, but since 1960 the number of stock ponds increased. Consequently, only an estimate of livestock use was made for 1970.

The actual consumption by livestock was estimated to be 800 acre-feet in 1970 for the LRGR: stock-pond evaporation was estimated to be 600 acre-feet. Irrigated pasture, for which no sale of commodity is involved, must be added to these figures. Approximately 4,900 acre-feet of water was used to irrigate pasture land for grazing by livestock. Therefore, in the LRGR approximately 7,500 acre-feet was consumed each year in the late 60's by the livestock sector.

Recreation

There are no reservoirs in the LRGR maintained solely for recreational use. Elephant Butte and Caballo Reservoirs do have recreational use and activity but they were constructed for irrigation, power, flood control, and sediment abatement. Therefore, the evaporation losses should be charged to these purposes and not to recreation.

Non-beneficial

Each year a large portion of the water supply of the LRGR is lost through non-beneficial depletions. These losses are primarily in the form of evaporation from the surface-water areas and from evapotranspiration by phreatophytes.

Phreatophytes. The phreatophyte classification describes a distinct ecological group of desert plants that have adapted their root systems to survive in arid areas where the water table is between 5 and 30 feet below ground. The phreatophytes, which include salt cedar, saltgrass, cottonwood trees, and willow are found in areas such as the lower flood plain of arid river basins where it is difficult to account for the sources and interaction of surface and ground-water flow.

Phreatophytes, as defined by Blaney and Hanson (1965), are plants that habitually grow where they can send their roots down to the water table or to the capillary fringe immediately overlying the water table. Saltgrass and salt cedar are the two most common phreatophytes in the LRGR. Blaney and Hanson (1965) listed consumptive use of ground water by saltgrass as 29.3 inches per year, and for salt cedar 57.2 inches per year. The area between the levees of the Rio Grande which is not used by the channel is generally covered with saltgrass, and areas of salt cedar concentration are generally scattered along the river within the region. Richardson (1971) reported phreatophyte consumptive use in the Mesilla Valley at over 22,500 acre-feet annually. The total area of phreatophytes in the LRG was estimated (Richardson, et al, 1972) at 8,311 acres of saltgrass and 1,888 acres of salt cedar. The consumptive use would thus exceed 29,000 acre-feet annually in the region. This excludes the phreatophyte area between Caballo Reservoir and Elephant Butte Dam.

Evaporation. Losses due to evaporation from reservoirs and lakes affect the net water supply available. Studies of evaporation from storage reservoirs indicate that during long periods of deficient streamflow, reservoirs may yield, for useful purposes, as little as 50 percent of the total water supply: the balance is lost by evaporation through years of carry-over storage (Blaney and Criddle, 1950).

Elephant Butte and Caballo Reservoirs, both within the LRGR, have a maximum water surface-area of about 48,200 acres. The associated irrigation district has miles of open canals and drains which also contribute to the water surface-area and the evaporation. The evaporation losses from Elephant Butte and Caballo Reservoirs for the period 1961-1970 are reported in Table 18, and were estimated to be about 83,000 acre-feet annually based on information received from the U.S. Department of Interior, Bureau of Reclamation, El Paso Office.

ECONOMIC LAND CLASSIFICATION

An economic land classification of the 104,000 acres of irrigated cropland in the LRGR was based on an adaptation of the Cornell system using soil productivity and irrigation water quality and quantity as the primary variables.

About 8 percent of the irrigated cropland in the LRGR was considered to have only minor income expectancy limitations and was classified as Economic Class I (Table 19). Over two-thirds of the Class I lands are in the Mesilla Valley. Most of it is used for full-time commercial farming. Inputs are high per acre, buildings are well maintained and in good condition, machinery and irrigation systems are modern and in good condition, and fields are large and well situated for the most efficient use of modern machinery and irrigation practices. In the Rincon Valley all of the Class I land is located in the valley floor (Figure 15). In the Mesilla Valley most of the Class I land is located in the northern portion primarily above Las Cruces (Figure 16).

Economic Class II includes 53 percent of the irrigated cropland in the LRGR. Soil productivity, irrigation water quality, and farm size are the primary limiting factors associated with these lands. The Economic Class II lands are distributed throughout the drainage basin, but over three-fourths of the Class II lands are located in the Mesilla Valley.

Table 18. Estimated evaporation losses from Elephant Butte and Caballo Reservoirs, 1961-1970

Year	Elephant Butte	Caballo	Total
	. . . .	acre-feet	
1961	64,310	24,080	87,390
1962	65,879	30,006	95,885
1963	51,253	23,514	74,767
1964	36,026	13,348	49,374
1965	58,080	15,459	73,539
1966	66,802	33,411	100,213
1967	52,893	28,295	81,188
1968	49,894	33,107	33,001
1969	69,197	23,784	92,981
1970	68,708	22,931	91,639
Total	583,042	247,935	829,977
Mean	58,304	24,794	82,998

Source: United States Department of Interior, Bureau of Reclamation, El Paso Office, 1961-1970, 20 sheets.

Table 19. Acreage of irrigated cropland by economic land classes, lower Rio Grande drainage basin, New Mexico

Economic Land Classification	Rincon Valley	Mesilla Valley	Total	
	acres	acres	acres	percent
Class I	2,550	6,105	8,655	8.3
Class II	11,860	43,200	55,060	53.0
Class III	9,600	27,973	37,575	36.1
Unreported and out of production	1,140	1,583	2,723	2.6
Total	25,150	78,863	104,013	100.0

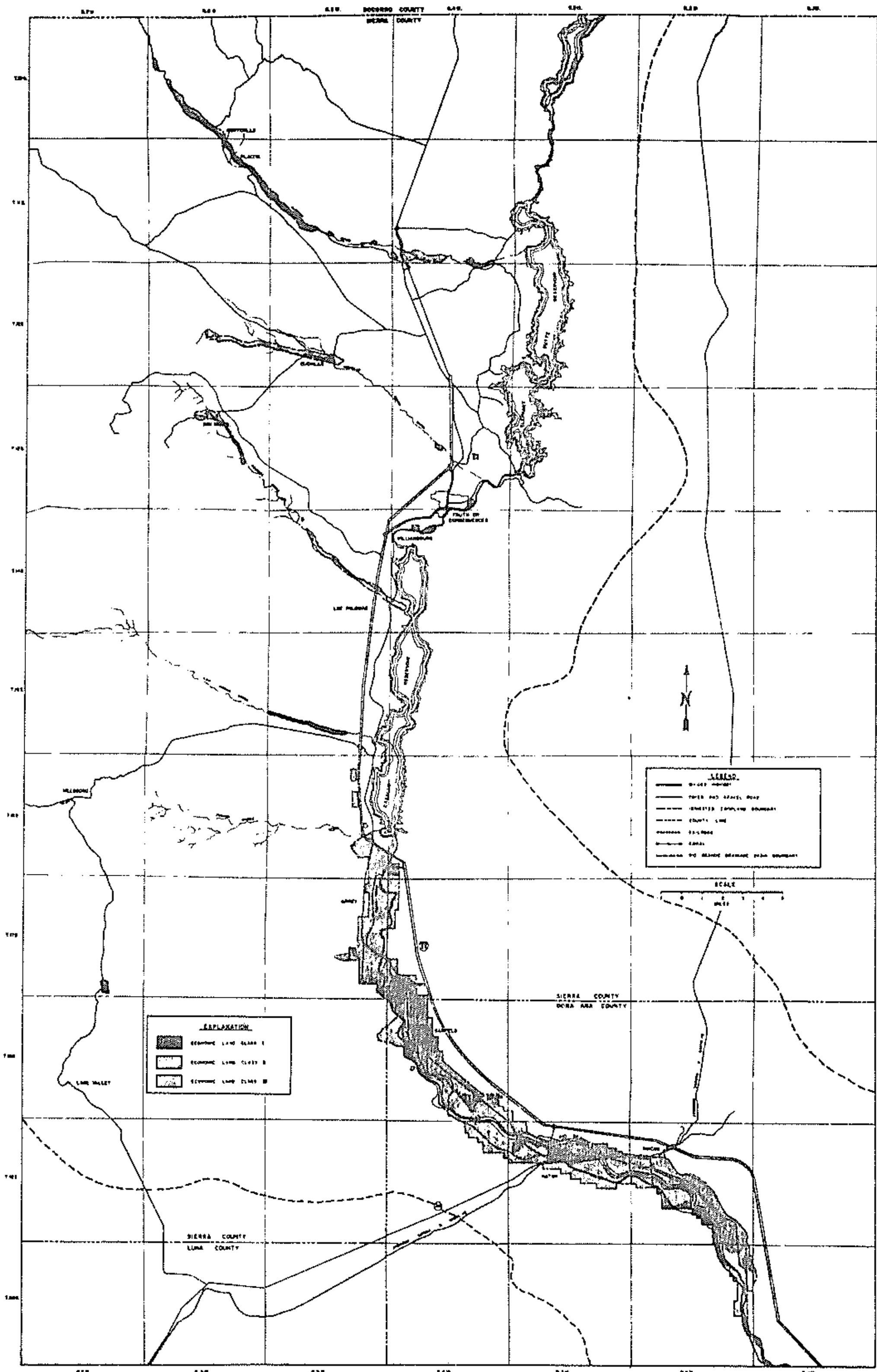

Figure 15. Economic land classification map, Rincon Valley, Lower Rio Grande Region, New Mexico

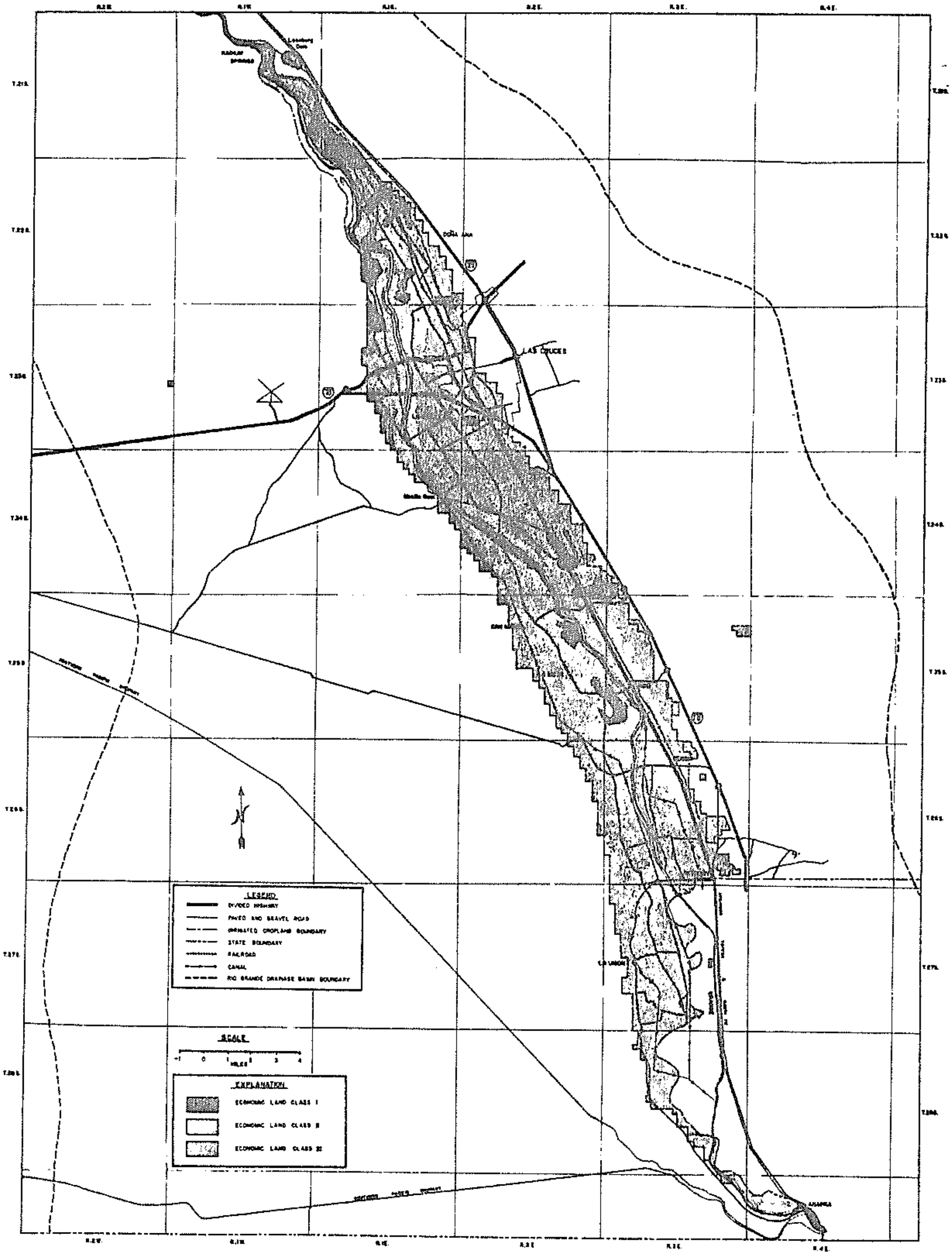

Figure 16. Economic land classification map, Mesilla Valley, Lower Rio Grande Region, New Mexico

In the Rincon Valley about 47 percent of the irrigated cropland was classified as Class II, primarily because of low soil productivity, small farm size, and irregular field shape. In the Mesilla Valley about 55 percent of the irrigated cropland was classified as Class II, primarily because of low soil productivity, lower water quality, small farm size, and irregular field shape. In general, farm buildings were being maintained at levels suitable for commercial farming but seldom at levels comparable to Class I farms. The type of irrigation systems used, age and condition of machinery and equipment, and other economic indicators often pointed to lower expenditures of time and money than in Class I, but higher than in Class III.

Slightly more than 36 percent of the land in the LRGR had severe limitations and was classified as Economic Class III. Many of the farms are small and are operated on a part-time basis, and fields are irregular in shape, divided by canals and drains or limited by terrain. Farmsteads, buildings, machinery, and equipment are generally in poor condition and some are obsolete. Deficiencies in soil, water quality and quantity, unfavorable topography, small farm-size, and likelihood of urban encroachment were the primary limitations imposed on these lands. Economic Class III accounted for about 38 percent of the irrigated cropland in the Rincon Valley and about 35 percent of the irrigated cropland in the Mesilla Valley. The Class III lands are located primarily along the river, in the tributary areas, along the sides and in narrow strips throughout the valleys.

Many of the farms in the LRGR in Class III are small part-time farms, a number of which are operated or leased by larger commercial units. Frequently these arrangements result in farm businesses that have one set of buildings at the headquarters in good condition and two or three other farmsteads with buildings in deteriorating condition. This can result in the area being rated as poorer than it actually is.

The potential of continued declines in ground-water levels, reduced surface-flows, and water quality deterioration in the region may result in the lowering of the economic productivity and profitability of the land. This will lower the economic land classification of these Class III areas.

Income expectancies measured in terms of the crop yields and net returns to land and management for selected crops in the region were estimated from enterprise budgets developed for selected farms on the different land classes. Extreme differences in the yields between the economic land classes were not found in all cases because of the limited number of farms interviewed and differences in managerial ability of the farmers (Table 20). Between land classes wide differences in yields and net returns existed for some crops but not for others. For cotton, yields and net returns were much higher for Class I land than Classes II or III, which were only slightly different. For alfalfa, yields and net returns were only slightly different for Classes I and II, but were much higher than for Class III. This was considered to be due to differences in management and the low productivity of the sandy soils of the Class III lands. Grain sorghum yields and net returns were spread evenly among the land classes. Lettuce yields and net returns, however, were slightly higher for Class III than Class II, but lower than for Class I. This was because of management and marketing aspects. The yield or quantity of lettuce harvested depends to a large degree on the time of harvest and the prevailing price at the time. When the lettuce price is low, a large portion of the production may not be harvested.

Table 20. Expected yields for selected crops on different economic land classes, Lower Rio Grande Region, New Mexico

Economic Land Class	Crop Yield Per Acre: Cotton	Alfalfa	Grain Sorghum	Lettuce
	pounds lint	tons	pounds	cartons
Class I	750	7.2	5,500	600
Class II	520	7.0	4,000	470
Class III	490	5.3	3,000	480

Overall there were differences in the income expectancies measured in terms of net returns to land and management for the different economic land classes in the LRGR. It is generally thought that the better managers farm the better land and the poor managers farm the poor land: this situation was not found to be true in the LRGR. A number of large commercial units operated by what was considered a high level of management farmed some of the lower productive land in the region and some of the land classified as Economic Class I was included in small part-time operations.

THE SOCIO-ECONOMIC MODEL

The socio-economic model was used to simulate long-run production and water utilization patterns in the Rio Grande Basin under alternative assumptions. Because of the difficulty of obtaining population, industrial activity, and employment data by drainage basin they were incorporated into the socio-economic model on a county basis. Therefore, the results from the socio-economic model reflect economic activity and water depletions for all of Dona Ana and Sierra counties: portions of Dona Ana and Sierra counties outside of the Rio Grande drainage basin are also included (Figure 2).

The LRGR and the other three Regions constitute the total socio-economic simulation model. Direct interpretations of the results for only the LRGR do not take into account the interactions with the other Regions; therefore, the LRGR will be highlighted as a part of the total Rio Grande region analysis.

Each simulation process starts with the same basic optimal solution to the model, and continues with annual changes to satisfy the alternative conditions for a period of 50 years. The basic solution used 1970 conditions and closely approximates the actual production levels attained and resources used in the base year 1970. Differences between the basic 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 will be presented first.

Basic Optimal Solution of the Model

The economy of New Mexico was represented in the model by twenty-four production sectors (Table 21). 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, labor, etc., and its contribution to the total benefits to the state's economy, measured by the value added of each one-million-dollar unit. Tables 22 and 23 present some of the major results of

Table 21. 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

the basic model and relate them to water utilization for both the total Rio Grande region and for the LRGR. Table 22 presents levels of production for all 24 sectors measured in terms of output. *Medical and professional services* and *research and development* (sector 23) generated the largest value of production at $517.96 million, and *agricultural services* (sector 5) generated the smallest value of production at $4.95 million. Within the agricultural sector, *meat animals*, *dairy products*, *and poultry* (sector 1) accounted for about 49 percent of the agricultural value of production; *fruits and vegetables* (sector 4) about 23 percent; *cotton* sector 3) about 10 percent; *food grains and feed crops* about 12 percent; and *agricultural services* about 6 percent. The *metals* sector (sector 6) accounted for about 76 percent of the total value of production for the mining industry, and *oil and gas* (sector 7) accounted for the remaining 24 percent. In the manufacturing sectors, *electrical, scientific instruments, and fabricated metal products* (sector 14) accounted for 27 percent of the value of production ($70.345 million); *lumber and wood products*, *concrete and stone products* (sector 12) 22 percent; *printing and publishing*, *miscellaneous manufacturing* (sector 15) 20 percent; *meat packing* and *dairy products* (sectors 8 and 9) 18 percent; and the remaining 13 percent included *grain mill and bakery products* (sector 10) 5 percent, *miscellaneous food* (sector 11) 5 percent, and *chemicals and petroleum refining* (sector 13) 3 percent. The *Services* sectors (sectors 22 and 23) accounted for about 40 percent of the total value of production; *Trade* (sectors 19 and 20) about 25 percent; *Transportation, communications, and utilities* (sectors 16, 17, and 18) about 14 percent; *Finance, insurance, and real estate* (sector 21) about 10 percent; and *Construction* (sector 24) about 10 percent.

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, gas stations, and eating places* (sector 20). The weighted 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 of the low water consumption in these sectors.

The *Trades* and *Services* sectors represent about 82 percent of the employment within the Rio Grande region. *Wholesale trade, retail trade,*

Table 22. Production, value added, employment, and water use by production sector in the Rio Grande region, and in the Lower Rio Grande Region 1970--basic optimal solution

Sector		Total Rio Grande Region: Value of Production ($1 million)	Total Rio Grande Region: Value Added ($1 million)	Total Rio Grande Region: Employment	Total Rio Grande Region: Water Depletions (acre-feet)	Lower Region: Value of Production ($1 million)	Lower Region: Value Added ($1 million)	Lower Region: Employment	Lower Region: Water Depletions (acre-feet)
Agriculture	1	41.839	14.351	2,346	79,888	7.422	2.546	63	4,439
	2	9.886	6.357	1,424	224,748	2.333	1.500	300	43,501
	3	8.574	5.264	233	134,180	8.337	5.119	215	130,581
	4	19.526	15.406	2,739	58,393	17.974	14.181	2,508	43,797
	5	4.950	3.024	454	59	0.852	0.521	140	10
Mining, Oil & Gas	6	81.785	52.342	1,731	2,977	4.739	3.033	136	111
	7	26.277	19.051	189	1,594	0.000	0.000	0	0
Manufacturing	8	20.651	3.655	273	62	0.000	0.000	0	0
	9	25.948	6.798	504	111	1.400	0.367	22	6
	10	14.277	4.183	537	20	0.181	0.053	49	1
	11	13.071	4.902	539	189	2.094	0.785	69	23
	12	56.155	26.730	2,332	854	4.360	2.075	109	28
	13	7.931	1.753	109	297	0.000	0.000	0	0
	14	70.345	29.615	4,018	157	4.243	1.786	262	8
	15	50.456	26.691	2,139	137	7.840	4.147	333	22
Trade & Services	16	109.842	72.935	5,004	274	23.308	15.477	559	58
	17	13.501	9.316	152	34	0.320	0.221	12	1
	18	104.925	68.201	4,518	4,484	12.575	8.174	497	740
	19	325.258	214.345	22,071	1,597	25.340	16.699	1,959	124
	20	98.281	69.976	11,298	579	12.579	8,956	1,404	114
	21	177.302	131.381	7,230	1,742	14.638	10.847	638	144
	22	151.463	88.303	13,158	1,940	23.674	13.802	2,750	286
	23	517.957	286.430	17,474	6,371	12.919	7.144	628	159
	24	172.462	71.744	9,559	3,039	18.358	7.637	1,152	323
	Total	2,122.660	1,232.753	110,030	523,722	205.486	125.070	13,803	224,475

Table 23. Production, employment, and water use for major sectors in the Rio Grande region, and in the Lower Rio Grande Region, New Mexico--basic optimal solution

Major Sector	Total Rio Grande Region: Total Output ($1 million)	Total Rio Grande Region: Total Value Added ($1 million)	Total Rio Grande Region: Employment	Total Rio Grande Region: Total Water Depletions (acre-feet)	Lower Rio Grande Region: Total Output ($1 million)	Lower Rio Grande Region: Total Value Added ($1 million)	Lower Rio Grande Region: Employment	Lower Rio Grande Region: Total Water Depletions (acre-feet)
1. Agriculture	84.775	44.402	7,196	497,268	36.92	23.87	3,226	222,328
2. Mining, Oil & Gas	108.062	71.393	1,920	4,571	4.74	3.03	136	111
3. Manufacturing	258.834	104.327	10,451	1,826	20.12	9.12	843	87
4. Trade & Services	1,670.991	1,012.630	90,463	20,059	143.71	88.96	9,598	1,950
Total	2,122.660*	1,232.753*	110,030	523,722*	205.49	125.07*	13,803	224,475*
	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)	(Percent)
1. Agriculture	4.0	3.6	6.5	94.9	18.0	19.1	23.4	99.0
2. Mining, Oil & Gas	5.1	5.8	1.8	0.9	2.3	2.4	1.0	0.00**
3. Manufacturing	12.2	8.5	9.5	0.4	9.8	7.3	6.1	0.00**
4. Trade & Services	78.7	82.1	82.2	3.8	69.9	71.2	69.5	0.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0*

* Does not add due to Rounding

gas stations, restaurants, and *Services* (sectors 19, 20, 22, and 23) represent almost 60 percent of the total employment. Employment in *Manufacturing* accounts for about 10 percent of those employed in the RGR, primarily in *lumber and wood products*, and *concrete and stone products* (sector 12), *electrical machinery and equipment, scientific instruments, fabricated metal products* (sector 14), and *printing and publishing* and *miscellaneous manufacturing* (sector 15). These three sectors account for over 80 percent of the employment within the *Manufacturing* sectors. *Agriculture* represents about 7 percent of the RGR employment force, with about 38 percent employed in *vegetables and fruits* (sector 4), and about 33 percent in *meat animal and dairy production*.

Agricultural production accounted for 95 percent of the water depleted in the RGR with *food grains and feed crops* (sector 2) accounting for about 45 percent of the total depletions, and *cotton* (sector 3) accounting for another 27 percent. *Mining* sectors accounted for less than 1 percent, *Manufacturing* sectors only 0.3 percent, and *Trade and Services* 3.8 percent.

Table 23 magnifies the differences between the *Agriculture* sectors and all other producing sectors. While the *Agriculture* sectors produced only 4.1 percent of the total output, 3.9 percent of the total value added, and provided only 6.7 percent of the total employment, they consumed 95 percent of all the water used in production in the Rio Grande region. The *Trade and Services* sectors played the opposite role, using only 3.8 percent of all water depleted by the production sectors, but producing 78 percent of the total value of output and accounting for 81.9 percent of the total value added.

In the LRGR the agricultural sectors produced the second largest portion of the subregion's total output (18 percent) and total value added (19 percent), and also provided for the second largest employment rate (2.3 percent). *Agriculture* consumed the largest portion of the water used in production (99 percent of the LRGR total). *Mining* (sectors 6 and 7) is less important in the LRGR than in the total Rio Grande region, producing 2.3 percent of the total output, 2.4 percent of the total value added, and providing for 1.0 percent of the employment. The *Manufacturing* sectors are less important in the LRGR than in the total Rio Grande region. The *Trade* *and Services* sectors in the LRGR were similar to the total Rio Grande region, and the general relationships that exist for the total Rio Grande region are also expressed in the Lower Region; i.e., *Trade and Services* sectors were responsible for the largest portion of the total value of output (70 percent), but used only 0.9 percent of the water depleted. The single most important industry is *wholesale* and most *retail trade* (sector 19) accounting for about 12 percent of the total value of production in the LRGR, followed closely by *Services* (sector 22) accounting for 11.5 percent of total value of production.

In the agricultural sectors, *vegetables, fruit and nut trees* (sector 4) accounted for 49 percent of the value of production, 59 percent of the value added by *Agriculture*, provided 78 percent of the agricultural employment, but consumed only about 20 percent of the agricultural water. *Cotton and cottonseed* (sector 3) accounted for about 23 percent of agricultural value of production, 21 percent of value added, 7 percent of employment, and 59 percent of agricultural depletions. *Meat animals and dairy products* (sector 1) accounted for about 20 percent of the value of agricultural production, 11 percent of value added, 2 percent of agricultural employment, and 2 percent of the agricultural water consumed.

The single most important manufacturing sector in the LRGR is *printing and publishing* (sector 15), followed by *lumber and wood products* and *concrete and stone products* (sector 12), followed by *electrical machinery and equipment, scientific instruments, and fabricated metal products* (sector 14). These three manufacturing sectors account for 82 percent of the manufacturing value of production, 87 percent of value added, 84 percent of manufacturing employment, and 67 percent of the manufacturing depletions.

The single most important *Trade and Services* sector is *wholesale* and most *retail trade* (sector 19) comprising about 18 percent of the value of production of *Trade and Services*, 19 percent of value added, 20 percent of the employment, and 6 percent of the water depletions used in *Trade and Services*. The next closest sector in value of production is *motel, personal services, business services* (sector 22), and contributes about 16 percent of the *Trade and Services* value of production followed closely by *railroad and other transportation* (sector 16) at 16 percent, and *contract construction* (sector 24) at about 13 percent. These four *Trade and Services* sectors account for about 63 percent of the *Trade and Services* total value of production, 60 percent of the value added, 67 percent of the employment, and combined they account for 41 percent of the *Trade and Services* water depletions.

The regional distribution of water depletions by major production sectors and municipal and rural uses is presented in Table 24. The significance of the agricultural sectors as major water users was maintained in all Regions, although their share is reduced in the Middle Rio Grande Region to 74.0 percent, where 16.5 percent of the total water use was for domestic purposes. The Lower Region was responsible for the highest water depletions in the Rio Grande region, utilizing 41 percent of the total water available.

Water recreation demands in the Rio Grande region in the base year (1970) and the distribution of supply by origin are presented in Table 25. 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.

In the concentrated population centers of the Middle Rio Grande Region, demands exceed supply of water-based recreation by 453,235 (551,654-98,419) activity-occasion days (AOD) in water skiing, 146,210 activity-occasion days in boating, and 807,318 activity-occasion days in fishing. The Lower Region supplies 589,672 activity-occasion days of water skiing but demands only 67,719, resulting in a difference of 521,953 AOD (Table 25); in boating there is a net supply of 293,943 AOD (Table 25); and in fishing there is a net supply of 382,904 AOD (Table 25). The LRGR supplies all of the Lower Region's demand for water skiing and boating, and over 90 percent for fishing. In addition, the LRGR supplies 521,953 AOD's for water skiing, 293,943 AOD's of boating, and 408,909 AOD's of fishing.

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 in the Rio Grande region for the period 1970-2020. Regional population projections used in the model were based on the New Mexico Bureau of Business Research county projections (BEA Projections) (Table 26). An increase in population affects

Table 24. Summary of depletions by major sector in the Rio Grande region (acre-feet)--basic optimal solution

Major Sector	Region				Total Rio Grande Region
	Upper	Middle	Socorro	Lower	
	. . . .	acre-feet	. . . .	. . . .	. . . .
Agriculture	111,084	125,795	38,061	222,328	497,268
Mining, Oil & Gas	2,852	1,500	108	111	4,571
Manufacturing	225	1,486	29	87	1,826*
Commercial Trade & Services	4,199	13,708	202	1,950	20,059
Municipal	3,862	25,568	407	4,362	34,199
Rural	2,042	2,527	203	1,051	5,823
Total	124,264	170,581	39,010	229,889	563,746*
	. . . .	percent	. . . .	. . . .	. . . .
Agriculture	89.39	73.74	97.57	96.71	88.21
Mining, Oil & Gas	2.30	0.88	0.28	0.05	0.81
Manufacturing	0.18	0.87	0.07	0.04	0.32
Commercial Trade & Services	3.38	8.04	0.52	0.85	3.56
Municipal	3.11	14.99	1.04	1.90	6.07
Rural	1.64	1.48	0.52	0.46	1.03
	100.00	100.00	100.00	100.00*	100.00

*Does not add due to rounding.

Table 25. Water-based recreation by Region, Rio Grande region--basic optimal solution

Supplying Region	Demanding Region: Upper	Middle	Socorro	Lower	Out of State	Total Supply
	. . . . (activity-occasion days)					
		WATER SKIING				
Upper	121,402				8,281	129,683
Middle		98,419				98,419
Socorro						
Lower		255,459	13,897	67,719	252,597	589,672
Total Rio Grande region	121,402	353,878	13,897	67,719	260,878	817,714
Rest of State	18,643	154,768				173,411
Out of State		43,008	1,544			44,552
Total Demand	140,045	551,654	15,441	67,719	260,878	1,035,737
		BOATING				
Upper	64,012				15,673	79,685
Middle		78,616				78,616
Socorro						
Lower		74,923	5,639	28,145	213,381	322,088
Total Rio Grande region	64,012	153,539	5,639	28,145	229,054	480,389
Rest of State		74,923				74,923
Out of State		16,364	1,023			17,387
Total Demand	64,012	244,826	6,662	28,145	229,054	572,699
		FISHING				
Upper	380,437	250,258			162,706	793,401
Middle		365,600				365,600
Socorro			30,760		9,371	40,131
Lower				264,910	408,909	673,819
Total Rio Grande region	380,437	615,858	30,760	264,910	580,986	1,872,951
Rest of State		549,268	3,230	26,005		578,503
Out of State		7,792				7,792
Total Demand	380,437	1,117,918	33,990	290,915	580,986	2,459,246

the final demand for consumer projects, the labor force, as well as the direct demand for water for municipal and rural use. The model assumes government employment to be a function of population; therefore, it was determined but not reported in the following analyses.

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 linear 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, i.e., the San Juan-Chama diversion. 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 increase in water demands 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

Table 26 Population projections by Region, Rio Grande region, New Mexico, 1970-2020

	Region								
	Upper		Middle		Socorro		Lower		Total Rio Grande Region
Year	Total Population	% of Total	Total Population	% of Total	Total Population	% of Total	Total Population	% of Total	
1970	111,610	19.5	373,355	65.3	9,763	1.7	76,962	13.5	571,690
1980	123,372	19.3	4.9,897	65.6	10,870	1.7	85,630	13.4	639,769
1990	135,133	19.1	466,440	65.9	11,978	1.7	94,297	13.3	707,848
2000	146,895	18.9	512,982	66.1	13,085	1.7	102,965	13.3	775,927
2010	158,656	18.8	559,525	66.3	14,193	1.7	111,632	13.2	844,006
2020	170,418	18.7	606,067	66.4	15,300	1.7	120,300	13.2	912,085
Average Annual Percent Growth	1.054		1.247		1.134		1.126		1.191

Source: Based on county projections by the New Mexico Bureau of Business Research (BEA Projections).

constraints imposed by the water laws of New Mexico, the mining of ground water may be restricted by authority of the State Engineer to declare a ground-water basin and 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 only on the surface water. This alternative reflects constraints placed on both surface 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, rural, domestic, and municipal uses. A transfer mechanism was added to the model to allow the transfer of surface rights to ground-water rights. Additional pumpage was permitted only to the extent that surface-water depletions were reduced.

Additional diversions refer to the effect of pumpage upon the flows of the river. 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.

<u>Alternative 1: No water constraint</u>. The long-run effects of population growth under the above assumptions are presented in Table 27 for the RGR and for the LRGR. Table 27 presents the production levels, value added, employment, and water depletions required to satisfy the increases in local demand and expected increases in nonagricultural out-of-state sales. Total value of output 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

Table 27. Production, value added, employment, and water use by production sector in the Rio Grande region, and in the Lower Rio Grande Region 2020--no water constraint

Sector		Total Rio Grande Region				Lower Rio Grande Region			
		Value of Production ($1 million)	Value Added ($1 million)	Employment	Water Depletions (acre-feet)	Value of Production ($1 million)	Value Added ($1 million)	Employment	Water Depletions (acre-feet)
Agriculture	1	55.812	19.144	3,302	102,831	9.306	3.192	79	5,566
	2	14.502	9.325	2,004	332,144	3.141	2.020	404	58,567
	3	13.530	8.307	368	211,735	13.147	8.072	309	205,920
	4	25.812	20.366	3,629	77,802	23.685	18.687	3,305	57,713
	5	7.588	4.636	693	91	1.277	0.780	210	15
Mining, Oil & Gas	6	129.705	83.011	2,731	4,699	7.407	4.740	212	173
	7	41.219	29.884	296	2,499	0.000	0.000	0	0
Manufacturing	8	33.501	5.930	442	101	0.000	0.000	0	0
	9	41.866	10.969	814	179	2.188	0.573	34	9
	10	22.792	6.678	854	32	0.276	0.081	74	2
	11	20.971	7.864	864	303	3.269	1.226	108	36
	12	89.420	42.564	3,721	1,360	6.802	3.238	170	43
	13	12.868	2.844	177	482	0.000	0.000	0	0
	14	113.719	47.876	6,485	254	6.632	2.792	409	12
	15	80.783	42.734	3,424	219	12.251	6.481	520	34
Trade & Services	16	175.304	116.402	8,068	437	36.423	24.185	873	91
	17	21.588	14.896	245	54	0.500	0.345	19	1
	18	168.080	109.252	7,250	7,164	19.622	12.754	775	1,155
	19	522.722	344.473	35,423	2,567	39.511	26.038	3,054	194
	20	157.470	112.119	18,097	925	19.617	13.967	2,190	177
	21	284.080	210.503	11,577	2,791	22.780	16.880	993	225
	22	242.044	141.112	20,955	3,099	36.917	21.523	4,288	446
	23	838.294	463.576	28,442	10,311	30.193	16.697	1,469	371
	24	276.625	115.076	15,316	4,874	28.693	11.936	1,800	506
Total		3,390.292	1,969.539	175,178	766,950	323.636	196.207	21,324	331,255

$1,267.6 million (59.7 percent) in the total value of output for the period 1970-2020.

Agricultural production is expected to increase only 38.3 percent ($32.5 million) in the Rio Grande region compared to an increase of 59.7 percent in total value of output. This smaller 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 expected increase varies from 58 percent for *cotton* (sector 3) to 32 percent for *vegetables and fruits* (sector 4), with *agricultural services* up 53 percent (sector 5), 47 percent for *food grains and feed crops* (sector 2), and *meat animals, dairy, and poultry* up only 33 percent (sector 1).

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. The value of production for the *Mining* sectors is expected to increase about 58 percent from 1970 to 2020, *Manufacturing* about 61 percent, and *Trade and Services* are expected to increase about 60 percent (Table 28).

Water depletions in the year 2020 for the Rio Grande region 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. However, by 2020 an additional 83,000 acre-feet of surface water will be required to maintain the base flow of the river out of the region to Texas. Of the 266,743 acre-feet, the agricultural sectors will require 227,336 acre-feet, the remaining production sectors 15,769 acre-feet, and domestic needs 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.

Table 28. Production, value added, employment and water use for major sectors in the Rio Grande region, and in the Lower Rio Grande Region, New Mexico, 1970-2020--no water constraint

		Total Rio Grande Region						Lower Rio Grande Region					
		Value of Production				Water Depletions		Value of Production				Water Depletions	
Year	Sector		Change from 1970	Value Added	Employment		Change from 1970		Change from 1970	Value Added	Employment		Change from 1970
		($1 million)	(percent)	($1 million)		(acre-feet)	(percent)	($1 million)	(percent)	($1 million)		(acre-feet)	(percent)
1970 (basic optimal solution)	Agriculture	84.775		44.402	7,195	497,268		36.918		23.867	3,226	222,328	
	Mining	108.062		71.393	1,920	4,571		4.793		3.033	136	111	
	Manufacturing	258.834		104.327	10,451	1,826		20.118		9.214	843	87	
	Trade & Services	1,670.991		1,012.630	90,463	20,059		143.711		88.956	9,598	1,950	
	Municipal & Rural	--		--	--	39,144		--		--	--	5,222	
	Total	2,122.660*		1,232.753*	110,030*	562,866*		205.486		125.070	13,803	229.697	
2020	Agriculture	117.244	38.3	61.778	9,997	724,603	45.7	50.556	36.9	32.752	4,336	327,780	47.4
	Mining	170.924	58.2	112.895	3,027	7,199	57.5	7.407	56.2	4.740	212	173	55.8
	Manufacturing	415.920	60.7	167.459	16,781	2,928	60.3	31.418	56.1	14.391	1,315	136	56.3
	Trade & Services	2,686.207	60.8	1,627.409	145,374	32,221	60.6	234.636	63.2	144.325	15,460	3,166	62.3
	Municipal & Rural	--	--	--	--	62,660	60.1	--	--	--	--	8,163	56.3
	Total	3,390.292*	59.7	1,969.539*	175,178*	829,610*	47.4	323.636*	57.4	196.207	21,324	339,417	47.7

*Does not add because of rounding.

In 1970, the Lower Rio Grande Region accounted for slightly under 10 percent of the total Rio Grande region's value of production and is estimated to remain fairly constant at slightly under 10 percent in 2020. *Trade and Services* accounted for about 70 percent of the value of production in 1970, *Agriculture* 18 percent, *Manufacturing* 10 percent, and *Mining* approximately 2 percent of the value of production in the Lower Rio Grande Region (Table 28). In the year 2020, *Trade and Services* are expected to remain fairly constant at 72 percent, *Agriculture* reduced slightly to about 16 percent, *Manufacturing* constant at about 10 percent, and *Mining* to remain constant at about 2 percent of the value of production.

The economy of the LRGR is expected to grow at a higher rate than that of the total Rio Grande region. The expected increase in total value of production from 1970 to 2020 is 63.5 percent compared to 59.7 percent for the total RGR. *Agriculture* is expected to increase at a lower percentage rate of growth, 36.9 percent for the LRGR and 38.3 percent for the RGR, *Trade and Services* at a higher rate of growth, 63 percent for the LRGR and 61 percent for the RGR, and the remaining sectors at a rate of about 56 percent for the LRGR.

Employment in the LRGR is expected to increase 54 percent from 1970 to 2020, with agricultural employment increasing 34 percent and the other sectors increasing about 61 percent.

Water depletions in the Lower Rio Grande Region in 1970 accounted for about 41 percent of the total Rio Grande region's water depletions and are expected to remain constant at 41 percent in 2020. *Agriculture* is the largest water user, accounting for 99 percent of total depletion in the Lower Rio Grande Region in 1970 and about 97 percent in 2020 (Table 28).

<u>Alternative 2: Surface-water constraint</u>. Table 29 presents production levels, value added, employment, and expected water depletions by sector under the surface-water constraints for the Rio Grande region and for the MRGR, and is summarized by major sector in Table 30. The Rio Grande regional value of production with a constraint would be $3,390.3 million, and $3,372.2 million without a surface-water constraint; thus the cost of imposing a surface-water constraint is $18.1 million (0.53 percent reduction). Direct

Table 29. Production, value added, employment, and water use by production sector in the Rio Grande region, and in the Lower Rio Grande Region 2020--surface-water constraint

Sector		Total Rio Grande Region				Lower Rio Grande Region			
		Value of Production ($1 million)	Value Added ($1 million)	Employment	Water Depletions (acre-feet)	Value of Production ($1 million)	Value Added ($1 million)	Employment	Water Depletions (acre-feet)
Agriculture	1	55.813	19.144	3,303	102,835	9.306	3.192	79	5,566
	2	8.127	5.226	1,261	196,466	0.000	0.000	0	0
	3	13.357	8.201	364	209,026	12.606	7.740	325	197,446
	4	25.812	20.366	3,629	77,802	23.685	18.687	3,305	57,713
	5	7.196	4.397	657	86	1.180	0.721	194	14
Mining, Oil & Gas	6	129.704	83.011	2,731	4,699	7.407	4.740	212	173
	7	41.218	29.883	296	2,499	0.000	0.000	0	0
Manufacturing	8	33.500	5.929	442	101	0.000	0.000	0	0
	9	41.866	10.969	814	179	2.188	0.573	34	9
	10	22.788	6.677	854	32	0.276	0.081	74	2
	11	20.971	7.864	864	303	3.269	1.226	108	36
	12	89.368	42.539	3,719	1,359	6.792	3.233	169	43
	13	12.849	2,840	177	481	0.000	0.000	0	0
	14	113.515	47.790	6,474	253	6.631	2.792	409	12
	15	80.772	42.728	3,423	219	12.248	6.479	520	34
Trade & Services	16	175.294	116.395	8,067	437	36.403	24.172	872	.91
	17	21.582	14.892	245	54	0.499	0.344	18	1
	18	168.010	109.206	7,247	7,161	19.599	12.739	774	1,154
	19	522.539	344.353	35,411	2,566	39.468	26.009	3,051	194
	20	157.350	112.033	18,083	925	19.573	13.936	2,185	177
	21	283.816	210.308	11,566	2,788	22.701	16.821	989	224
	22	241.851	140.999	20,936	3,096	36.831	21.472	4,278	445
	23	828.282	458.040	27,955	10,188	20.192	11.166	982	248
	24	276.618	115.073	15,316	4,874	28.691	11.935	1,800	506
	Total	3,372.196	1,958.862	173,833	628,426	309.545	188.061	20.380	264,086

Table 30. Production, value added, employment, and water use for major sectors in the Rio Grande region, and in the Lower Rio Grande Region, New Mexico, 1970-2020--surface-water constraint

		Total Rio Grande Region						Lower Rio Grande Region					
		Value of Production				Water Depletions		Value of Production				Water Depletions	
Year	Sector		Change from 1970	Value Added	Employment		Change from 1970		Change from 1970	Value Added	Employment		Change from 1970
		($1 million)	(percent)	($1 million)		(acre-feet)	(percent)	($1 million)	(percent)	($1 million)		(acre-feet)	(percent)
1970 (basic optimal solution)	Agriculture	84.775		44.402	7,196	497,268		36.918		23.867	3,226	222,328	
	Mining	108.062		71.393	1,920	4,571		4.793		3.033	136	111	
	Manufacturing	258.834		104.327	10,451	1,826		20.118		9.214	843	87	
	Trade & Services	1,670.991		1,012.630	90,463	20,059		143.711		88.956	9,598	1,950	
	Municipal & Rural	--		--	--	39,144		--		--	--	5,222	
	Total	2,122.660*		1,232.753*	110,030	562,866*		205.486		125.070	13,803	229,697	
2020	Agriculture	110.305	30.1	57.334	9,213	586,215	17.9	47.167	27.7	30.580	3,916	266,502	19.8
	Mining	170.922	58.2	112.894	3,027	7,199	57.5	7.407	56.2	4.740	212	173	55.8
	Manufacturing	415.629	60.6	167.336	16,767	2,926	60.2	31.304	56.0	14.384	1,314	136	56.3
	Trade & Services	2,675.342	60.1	1,621.299	144,827	32,088	60.0	223.996	55.8	138.622	14,953	3,039	55.8
	Municipal & Rural	--	--	--	--	62,660	60.1	--	--	--	--	8,163	56.3
	Total	3,372.196*	58.9	1,958.862*	173,833*	691,086	22.8	309.974	50.8	188.326	20,395	278,013	21.0

*Does not add because of rounding.

Agriculture production would decrease $6.9 million, *Manufacturing* production would decrease $0.3 million, and *Trade and Services* are expected to decrease $10.9 million. The *meat animal, dairy, and poultry* sector (sector 1) would not be affected by a surface-water constraint, but the value of production for *food grains and feed crops* (sector 2) would be decreased $6.4 million, *cotton* (sector 3) reduced $0.2 million, *fruits and vegetables* (sector 4) would be unchanged, and *agricultural services* (sector 5) down about $0.4 million. In the *Services* sectors, *medical and professional*, and *research and development* (sector 23) is expected to decrease about $10 million.

The level of employment in the Rio Grande region is expected to decrease by 1,344 employees in 2020 when a surface-water constraint is imposed. *Agriculture* production sectors (sectors 2, 3, and 5) are expected to account for 784 of these employees, with *food grains and feed crops* accounting for 88 percent of the decrease. *Services* production sectors are expected to account for 546 employees with sector 23 accounting for all employees.

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, and it is expected that 83,000 acre-feet of surface rights will be retired by 2020. Because of the additional San Juan-Chama diversion water, surface-water depletions are expected to increase until about the year 2000 and then decrease. However, the Socorro and Lower Regions are expected to have reductions in surface-water depletions well before the Upper and Middle Regions because they do not benefit from the San Juan-Chama project. The surface-water usage decreases in the 50-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 increased by 111,000 acre-feet (from the San Juan-Chama).

The decrease in ground-water depletions for agricultural use in the same years results from the fixed ground-water: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.

Total water depletions are expected to increase only 22.8 percent and reach 691,086 acre-feet in 2020. This is 138,524 acre-feet less than the amount required where no water constraint was imposed. *Agriculture* accounts for 136,388 acre-feet of this reduction. The remaining 136 acre-feet reduction includes 2 acre-feet in *Manufacturing* and 134 acre-feet in *Trade and Services*.

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.

The value of production in the Lower Rio Grande Region in 2020 would be $323.6 million without a water constraint and $310.0 million when a surface-water constraint is imposed (Table 29). Direct agricultural production would decrease $3.4 million, *Trade and Services* production would decrease $10 million, and the indirect effects of agricultural production would account for about $0.2 million decrease in services associated with agriculture. *Food grains and feed crops* (sector 2) account for 92 percent of the decrease in agricultural production and *cotton* (sector 3) the remaining 8 percent.

Employment in the LRGR would decrease from 21,324 with no water constraint to 20,395 with a surface-water constraint. *Agriculture* would account for 45 percent of the reduction in employment and *Trade and Services* the remaining 55 percent. The reduction in *food grains and feed crops* is expected to account for 43 percent of the total reduction in employment and *motels, personal services, and business services* (sector 22) about 52 percent.

Surface-water depletions in the Lower Rio Grande Region in the base year 1970 approached the average annual availability. The average annual depletions in 2020 with a surface-water constraint would be 61,404 acre-feet less than under the condition of no water constraint. Reduced agricultural depletions account for nearly all (61,278 acre-feet) of the reduced depletions.

<u>Alternative 3: Surface and ground-water constraint</u>. Production, value added, employment, and water depletions in this alternative for the Rio Grande region and the LRGR are presented in Table 31 and summarized by major sector in Table 32. The cost of imposing the additional constraint on ground water is $4.1 million in 2020 compared with a surface-water only constraint, and $22.2 million compared with the alternative without any constraint on water. Direct *Agriculture* production would decrease $2.9 million as a result of imposing the additional ground-water constraint, but *Mining* (sector 6) is expected to remain constant, and the indirect effects of reduced *Agriculture* production would account for the other $1.2 million in *Manufacturing, Trade,* and *Services* associated with agriculture. The affected *Agriculture* sectors are expected to be *food grains and feed crops*, $2.14 million; *cotton*, $0.37 million; and *agricultural services*, $0.38 million. However, annual agricultural production in 2020 is expected to be $22.6 million more than in 1970, and nonagricultural production is expected to be $1,225.8 million above the 1970 level.

The level of employment is expected to decrease by 481 employees when the additional constraint is placed on ground water. *Agriculture* production sectors (sectors 2, 3, and 5) are expected to account for 314 of these employees, with *food grains and feed crops* production accounting for 71 percent of the total decrease.

The increased demand for water by the nonagricultural sectors required a transfer of 47,166 acre-feet from surface rights to ground-water pumpage. The average annual depletion with a total water constraint is expected to be 58,182 acre-feet less than under the condition of a surface-water constraint only, and 196,706 acre-feet less than the alternative of no water constraint. *Agriculture* depletions are expected to decrease 58,165 acre-feet, and *Trade and Services* water depletions are expected to decrease 18 acre-feet when the additional ground-water constraint is added.

The cost of imposing the additional constraint on ground water in the Lower Rio Grande Region would be $0.4 million in 2020 compared with a surface-water constraint only, and $14.1 million compared with the alternative of no constraint on water. *Agriculture* production would be reduced $0.6 million and *Trade and Services* production would increase $0.2 million in 2020. *Cotton* (sector 3) accounts for all reduction in production.

Table 31. Production, value added, employment, and water use by production sector in the Rio Grande region, and in the Lower Rio Grande Region, 2020--total water constraint

Sector		Total Rio Grande Region: Value of Production ($1 million)	Total Rio Grande Region: Value Added ($1 million)	Total Rio Grande Region: Employment	Total Rio Grande Region: Water Depletions (acre-feet)	Lower Rio Grande Region: Value of Production ($1 million)	Lower Rio Grande Region: Value Added ($1 million)	Lower Rio Grande Region: Employment	Lower Rio Grande Region: Water Depletions (acre-feet)
Agriculture	1	55.813	19.144	3,303	102,835	9.306	3.192	79	5,566
	2	5.990	3.852	989	144,070	0.000	0.000	0	0
	3	12.989	7.975	354	203,262	12.606	7.740	325	197,446
	4	25.812	20.366	3,629	77,802	23.685	18.687	3,305	57,713
	5	6.812	4.162	625	82	1.180	0.721	194	14
Mining, Oil & Gas	6	129.704	83.011	2,731	4,699	7.407	4.740	212	173
	7	41.217	29.882	296	2,499	0.000	0.000	0	0
Manufacturing	8	33.500	5.929	442	101	0.000	0.000	0	0
	9	41.866	10.969	814	179	2.188	0.573	34	9
	10	22.786	6.676	854	32	0.276	0.081	74	2
	11	20.971	7.864	864	303	3.269	1.226	108	36
	12	89.353	42.532	3,718	1,359	6.792	3.233	169	43
	13	12.836	2.837	176	480	0.000	0.000	0	0
	14	113.713	47.873	6,484	254	6.631	2.792	409	12
	15	80.769	42.727	3,423	219	12.248	6.479	520	34
Trade & Services	16	175.279	116.385	8,067	437	36.403	24.172	872	91
	17	21.578	14.889	245	54	0.499	0.344	18	1
	18	167.978	109.186	7,246	7,159	19.599	12.739	774	1,154
	19	522.462	344.302	35,406	2,565	39.468	26.009	3,051	194
	20	157.299	111.997	18,077	924	19.573	13.936	2,185	177
	21	283.706	210.226	11,562	2,787	22.701	16.821	989	224
	22	240.775	140.372	20,826	3,082	36.831	21.472	4,278	445
	23	828.277	458.036	27,955	10,188	20.192	11.166	982	248
	24	276.613	115.071	15,316	4,874	28.691	11.935	1,800	806
	Total	3,368.097	1,956.264	173,402	570,242	309.545	188.061	20,380	264,086

Table 32. Production, value added, employment and water use for major sectors in the Rio Grande region, and in the Lower Rio Grande Region, New Mexico, 1970-2020--total water constraint

		Total Rio Grande Region						Lower Rio Grande Region					
		Value of Production				Water Depletions		Value of Production				Water Depletions	
Year	Sector		Change from 1970	Value Added	Employment		Change from 1970		Change from 1970	Value Added	Employment		Change from 1970
		($1 million)	(percent)	($1 million)		(acre-feet)	(percent)	($1 million)	(percent)	($1 million)		(acre-feet)	(percent)
1970 (basic optimal solution)	Agriculture	84.775		44.402	7,196	497,268		36.918		23.867	3,226	222,328	
	Mining	108.062		71.393	1,920	4,571		4.793		3.033	136	111	
	Manufacturing	258.834		104.327	10,451	1,826		20.118		9.214	843	87	
	Trade & Services	1,670.991		1,012.630	90,463	20,059		143.711		88.956	9,598	1,950	
	Municipal & Rural	--		--	--	39,144		--		--	--	5,222	
	Total	2,122.660*		1,232.753*	110,030	562,866*		205.486		125.070	13,803	229,697	
2020	Agriculture	107.416	26.7	55.499	8,900	528,050	6.2	46.777	26.7	30.340	3,903	260,738	17.2
	Mining	170.921	58.2	112.894	3,027	7,199	57.2	7.407	56.2	4.740	212	173	55.8
	Manufacturing	415.794	60.6	167.407	16,776	2,926	60.2	31.404	56.0	14.384	1,314	136	56.3
	Trade & Services	2,673.967	60.0	1,620.464	144,699	32,070	59.9	223.957	55.8	138.596	14,951	3,039	55.8
	Municipal & Rural	--	--	--	--	62,660	60.1	--	--	--	--	8,163	56.3
	Total	3,368.097*	58.7	1,956.264	173,402	632,904*	12.4	309.545	50.6	188.061	20,380	272,249	18.5

*Does not add because of rounding.

Employment in the LRGR would decrease an additional 15 employees when the additional ground-water constraint is added. *Agriculture* employment would account for 13 of these employees, all in the *cotton* sector.

Total depletions in 2020 in the LRGR are expected to decrease 5,764 acre-feet below that of a surface-water constraint only, and 67,168 acre-feet when compared with the alternative of no constraint on water. *Agriculture* depletions would account for all of the reduction in 2020.

Summary. In the previous discussion, three sets of water management alternatives were 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- and ground-water constraints. A summary of the solutions for these alternatives is presented in Table 33 for the total Rio Grande region and for the Lower Rio Grande Region.

Without a water constraint, value of production, employment, and water depletions in the Rio Grande region are expected to exhibit the largest increase (59.7 percent, 59.2 percent, and 47.4 percent, respectively.) The expected increase in value of production varies from 38.3 percent for *Agriculture* to 60.8 percent for *Trade and Services*. Water depletions are expected to increase 45.7 percent for *Agriculture*, 57.5 percent for *Mining*, 60.3 percent for *Manufacturing*, 60.6 percent for *Trade and Services*, and 60.1 percent for *Municipal and Rural* domestic purposes.

When a surface-water constraint is imposed, the expected value of production would be reduced by $18.1 million in 2020, employment by 1,344 employees, and water depletions by 138,523 acre-feet (16.7 percent) below the alternative of no water constraint (Table 33). Reduced *Agriculture* production would account for about 38 percent ($6.9 million) of the reduced value of production, and *Trade and Services* about 60 percent ($10.9 million). The level of employment in the RGR is expected to decrease by 1,344 employees in 2020. *Agriculture* production sectors are expected to account for about 58 percent and *Trade and Services* sectors about 41 percent. *Agriculture* water depletions are expected to represent about 85 percent of the total water depletion reduction when a surface-water constraint is imposed.

Table 33. Summary of alternative solutions by major sectors in the Rio Grande region, and in the Lower Rio Grande Region, New Mexico, 1970-2020

			Total Rio Grande Region							Lower Rio Grande Region					
			Value of Production				Water Depletions		Value of Production				Water Depletions	
Alternative	Year	Major Sector		Change from 1970	Value Added	Employment		Change from 1970		Change from 1970	Value Added	Employment		Change from 1970
			($1 million)	(percent)	($1 million)		(acre-feet)	(percent)	($1 million)	(percent)	($1 million)		(acre-feet)	(percent)
BASIC OPTIMAL SOLUTION	1970	Agriculture	84.775		44.402	7,196	497,268		36.918		23.867	3,226	222,328	
		Mining	108.062		71.393	1,920	4,571		4.739		3.003	136	111	
		Manufacturing	258.834		104.327	10,451	1.826		20.118		9.214	843	87	
		Trade & Services	1,670.001		1,012.630	90,463	20,059		143.711		88.956	9,598	1,950	
		Municipal & Rural	--		--	--	39,144		--		--	--	5,222	
		Total	2,122.660*		1,232.753*	110,030	562,866*		205.486		125.070*	13,803	229,697*	
NO WATER CONSTRAINT	2020	Agriculture	117.244	38.3	61.778	9,997	724,603	45.7	50.556	36.9	32.752	4,336	327,780	47.4
		Mining	170.924	58.2	112.895	3,027	7,199	57.5	7.407	54.5	4.740	212	173	55.8
		Manufacturing	415.920	60.7	167.459	16,781	2,928	60.3	31,418	56.1	14.391	1,315	136	56.3
		Trade & Services	2,686.207	60.8	1,627.409	145,374	32,221	60.6	234.636	63.2	144.325	15,460	3,166	62.3
		Municipal & Rural	--	--	--	--	62,660	60.1	--	--	--	--	8,163	56.3
		Total	3,390.292*	59.7	1,969.539*	175,178*	829,610*	47.4	323.636*	57.4	196.207*	21,324*	329,417*	47.7
SURFACE WATER CONSTRAINT	2020	Agriculture	110.305	30.1	57.334	9,213	586,215	17.9	47.167	27.7	30.380	3,916	266,502	19.8
		Mining	170.922	58.2	112.894	3,027	7,199	57.5	7.407	56.2	4.740	212	173	55.8
		Manufacturing	415.629	60.7	167.336	16,767	2,926	60.2	31.404	56.0	14.384	1,314	136	56.3
		Trade & Services	2,675.342	60.1	1,621.299	144,827	32,088	60.0	223.996	55.8	138.662	14,953	3,039	55.8
		Municipal & Rural	--	--	--	--	62,660	60.1	--	--	--	--	8,163	56.3
		Total	3,372.196*	58.9	1,958.862*	173,833*	691,086	22.8	309.974	50.8	188.325	20,395	278,013	21.0
TOTAL WATER CONSTRAINT	2020	Agriculture	107.416	26.7	55.499	8,900	528,050	6.2	46.777	26.7	30.340	3,903	260,738	17.2
		Mining	170.921	58.2	112.894	3,027	7,199	57.2	7.407	56.2	4.740	212	173	55.8
		Manufacturing	415.794	60.6	167.407	16,776	2,926	60.2	31.404	56.0	14.384	1,314	136	56.3
		Trade & Services	2,673.967	60.0	1,620.464	144,699	32,070	59.9	223.957	55.8	138.596	14,951	3,039	55.8
		Municipal & Rural	--	--	--	--	62,660	60.1	--	--	--	--	8,163	56.3
		Total	3,368.097*	58.7	1,956.264	173,402	632,904*	12.4	309.345	50.6	188.061*	20,380	272,249	18.5

*Does not add because of rounding

In 2020, when a total water constraint is imposed, value of production in the RGR is expected to be reduced to $3,368.1 million, decreased $4.1 million below the value obtained when only a surface-water constraint is imposed, and decreased by $22.2 million below the no-water-constraint alternative (Table 33). The level of employment is expected to decrease by 481 employees when a constraint is imposed on ground water. Again, *Agriculture* sectors account for 82 percent of the reduced employment.

Water depletions in the RGR are expected to decrease from 829,610 acre-feet without any water constraints to 632,904 acre-feet with a total water constraint, a 24 percent reduction. 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*, *Trade and 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 for many years. The Albuquerque metropolitan area has about 90 percent of the expected population increase in the total Rio Grande region, and the pumpage necessary to sustain its growth increases its effect on the Rio Grande flow by more than 1,000 acre-feet annually.

The Lower Rio Grande Region is expected to follow the general trend of the total Rio Grande region but at a slightly higher growth rate. The expected increase in total value of production from 1970 to 2020 is 62.0 percent. Employment is expected to increase 63.5 percent. Water depletions are expected to increase about 48 percent in 2020, with *Agriculture* accounting for 97 percent of total depletions in the LRGR at that time.

When a surface-water constraint is imposed, the value of production is expected to be reduced $13.6 million in 2020, employment by 929 employees, and water depletions by 61,404 acre-feet. *Agriculture* and *Trade and Services* production sectors would account for all of the reduction in production, employment, and water depletions.

When an additional constraint is imposed on ground water in the LRGR, value of production would be decreased $0.4 million in 2020, employment by an additional 15 employees, and water depletions by 5,764 acre-feet. *Agriculture* production sectors would account for all of the expected reductions in production, employment, and water depletions.

The supply of water for water-based recreation is expected to be the highest under the alternative of no water constraint (Table 34), and reduced about 5 percent when a constraint is placed on the importation of surface water or mining of ground water. The major effect occurs on surface water where all of the water-based recreation occurs.

Table 34. Estimated water-based recreation by type in the Rio Grande region

	Water Skiing	Boating	Fishing
	. . . . (activity-occasion days)		
No Water Constraints			
1970	817,773	480,389	1,872,950
1980	858,247	504,584	1,904,992
2000	939,195	552,975	2,591,525
2020	1,132,085	596,668	2,643,000
Surface Water Constraints			
1970	817,773	480,389	1,872,950
1980	858,347	504,625	2,015,576
2000	939,285	553,210	2,595,245
2020	1,160,546	596,894	2,643,000
Surface & Ground Water Constraints			
1970	817,773	480,389	1,872,950
1980	858,273	504,624	1,904,542
2000	939,332	553,356	2,592,460
2020	1,134,160	596,919	2,643,000

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APPENDIX A

SOIL PRODUCTIVITY GROUPS IN THE LOWER RIO GRANDE REGION, NEW MEXICO

Group I

Soils in productivity Group I have few limitations that restrict their use for irrigated crop production and are suited to a wide range of crops, especially those common to the Lower Rio Grande Region. The soils are generally deep, medium textured, moderately stratified, and almost level. The productive capacity is high since they either have a high fertility level or they respond well to fertilizer inputs. Permeability is moderate and the textures are conducive to easier handling. Some soils in Group I have certain slight limitations which require more careful management practices. As a group, however, they have few limitations, and in most cases corrective management practices are easy to apply. The following limitations may occur either singly or in combination: 1) gentle slopes; 2) moderate susceptibility to shallow watertables and accumulation of alkali; 3) moderate effects of past erosion; 4) somewhat unfavorable soil structure and workability. These soils may require special soil-conserving cropping systems, soil conservation practices, or tillage methods, depending on the occurrence and severity of the above limitations. In some parts of the Region, such practices as terracing, bordering, strip cropping, fertilization, green manure crops, deep plowing, and more specialized land planning may be required. The exact combination of practices varies from area to area depending on the soil characteristics and farming systems. The smallest portion of the irrigated acreage in the Region occurs as Group I.

Group II

Soils in Group II have certain moderate restrictions that reduce the choice of crops, require special management practices, or both. Conservation and management practices are usually more difficult to apply and maintain on these soils than on soils in Group I. The limitations may restrict the amount of clean tillage, timing of planting and harvesting, or some combination of these. The limitations may result from the effects of one or more of the following: 1) moderate slopes; 2) moderately high water-tables and accumulations of alkali; 3) high permeability; 4) low moisture-holding capacity; 5) low fertility; and 6) moderate salinity or sodium content.

Soils in Group II commonly require grade leveling and deep plowing to expose and break up the highly stratified subsoil textures. In some areas of the Region, part of the soils in Group II have limited use because of high water-table, low permeability, and the hazard of alkali accumulation. Each distinctive kind of soil in Group II has one or more special managerial requirements for successful use. The largest portion of the irrigated acreage in the Region occurs as Group II.

Group III

Soils in Group III have severe limitations that restrict the choice of crops, require careful management, or both. Crop selections are more limited for these soils than for soils in Group II. Conservation practices are more difficult to apply and maintain. Soils in Group III may be well suited for only one or two of the common crops, or the yield may be low in relation to inputs over a long period of time. Use for cultivated crops is limited as a result of one or more permanent features such as: 1) steep slopes; 2) severe susceptibility to water and wind erosion; 3) severe effects of past erosion; 4) shallow soils; 5) low moisture-holding capacity; 6) excessively high water-tables; and 7) severe salinity or sodium accumulations.

Soils in Group III account for about 30 percent of the total acreage of irrigated cropland in the Region. The Group III soils are located primarily along the river, near the sides of the valley, and in the tributary areas. In many cases these soils occur in small isolated areas within farming units, where their influence is exerted on the surrounding farm land since they are subject to wind and water erosion and require more special management than either of the other Groups.

The above-described soil productivity Groups and those described in Tables A-1, A-2, and A-3, were defined for purposes of this study and are not necessarily consistent with Soil Conservation Service Classifications.

APPENDIX A

Table A-1. Principal soils in productivity Group I, Lower Rio Grande Region, New Mexico

Map Symbol	Soil Name	Soil Description
(1)4 (1)5 (1)6	Gila clay loam Gila sandy clay loam Gila silty clay loam	These soils are deep, medium-textured alluvial soils that are almost level. Moisture penetration is moderate and the textures are conducive to easier handling. These soils are susceptible to the same detrimental effects of shallow water-table or excessive alkali accumulation as the heavier textured Gila soils in Groups II and III, but generally occur on the higher levels in the valley where these conditions do not exist. The fertility of these soils is generally high.
(1)7 (1)8 (1)9 (1)10	Gila loam Gila silt loam Gila very fine sandy loam Gila fine sandy loam	These soils are similar to those described above except for texture, which is lighter. Moisture penetration is moderate, and textures are such that cultivation practices are very simple. Fertility is generally high, and shallow water-table or accumulation of alkali cause only slight problems. These soils occur primarily in the lower-lying areas of the valley floor, but also occur on the higher levels of the adjacent slopes.

APPENDIX A

Table A-2. Principal soils in productivity Group II, Lower Rio Grande Region, New Mexico

Map Symbol	Soil Name	Soil Description
(1)1 (1)2 (1)3	Gila clay Gila sandy clay Gila silty clay	These soils are characterized by a slow rate of moisture penetration and are affected in some places by shallow water-table or slight to heavy alkali accumulations. Their heavier textures require careful conservation-land use practices. They are moderately stratified, with thin layers of light- and heavy- textured subsoils which restrict the moisture penetration to some extent.
(1)11	Gila sandy loam	The moisture penetration of this soil is moderate to rapid. Wind erosion is a primary problem. The subsoil is composed of mixed alluvial sands and gravels moderately stratified.
(3)1 (3)3 L(3)2	Pima clay Pima silty clay Pima sandy clay, light subsoil phase	These are similar to the Gila soils described above. Some areas have a surface texture of extremely heavy, almost waxy, layer which is difficult to work. These soils are generally high in fertility and have moderate to good drainage. The primary limitations are the conservation-land use measures necessary for successful crop production.
L(1)11 L(1)7 L(1)6	Gila sandy loam, light subsoil phase Gila loam, light subsoil phase Gila silty clay loam, light subsoil phase	The surface layer of these soils is moderate to shallow in depth. The subsoil is a calcareous, light, single-grained coarse sand with occasional lenses of heavier material. Drainage is moderate to high. Water-holding capacity is moderate to low. These soils are considered to be low to medium in productivity.

Table A-2, continued

Map Symbol	Soil Name	Soil Description
L(1)5	Gila sandy clay loam, light subsoil phase	(Soil description similar to soils described in paragraph 4 of page 106).
L(1)1	Gila clay, light subsoil phase	
L(1)2	Gila sandy clay, light subsoil phase	
L(1)10	Gila fine sandy loam, light subsoil phase	
L(1)4	Gila clay loam, light subsoil phase	
L(3)1	Pima clay, light subsoil phase	

APPENDIX A

Table A-3. Principal soils in productivity Group III, Lower Rio Grande Region, New Mexico

Map Symbol	Soil Name	Soil Description
(1)15	Gila loamy sand	These soils have moderate to low productivity. The moisture penetration is high to excessive. Wind erosion is a primary problem. Accumulation of alkali and shallow water-tables are normally rare. These soils occupy the higher alluvial fans and are susceptible to flood damage. Slopes are moderate.
(1)13	Gila fine sand	
(1)14	Gila sand	
H(1)11	Gila sandy loam, heavy subsoil phase	These soils are similar to those in Group II except for the heavy subsoil phase. The subsoil is usually heavy clay with a compact and almost impervious massive structure which extends for 6 to 8 feet. Internal drainage is impeded and perched water-tables or high alkali accumulations are likely to occur.
H(1)10	Gila fine sandy loam, heavy subsoil phase	
H(1)5	Gila sandy clay loam, heavy subsoil phase	
H(1)1	Gila clay, heavy subsoil phase	
H(1)3	Gila silty clay, heavy subsoil phase	
H(1)4	Gila clay loam, heavy subsoil phase	
H(3)1	Pima clay, heavy subsoil phase	
I(1)11	Gila sandy loam, impervious phase	These soils are similar to those in Group II except for the impervious layer which has the same effect as a full heavy subsoil phase. The moisture penetration is slow and badly restricted. Alkali accumulation and perched water tables are primary problems.
I(1)10	Gila fine sandy loam, impervious phase	

APPENDIX A

Table A-3, continued

Map Symbol	Soil Name	Soil Description
I(1)5	Gila sandy clay loam, impervious phase	(Soil description similar to soils described in paragraph 3 of page 108).
I(1)1	Gila clay, impervious phase	
I(1)4	Gila clay loam, impervious phase	
(6)14	Anthony sand	These soils have generally shallow surface layers. They are generally medium to coarse textured with high or excessive drainage, low water-holding capacity, and are susceptible to wind erosion. These soils generally occupy the higher slopes and mesas adjacent to the valley, but also occur in old stream channels and arroyo fans which extend into the valley. They are generally low in productivity and fertility.
(6)014	Anthony gravelly sand	
(6)11	Anthony sandy loam	
(6)011	Anthony gravelly sandy loam	
(6)611	Anthony stony sandy loam	
(4)14	Brazito sand	
(4)13	Brazito fine sand	

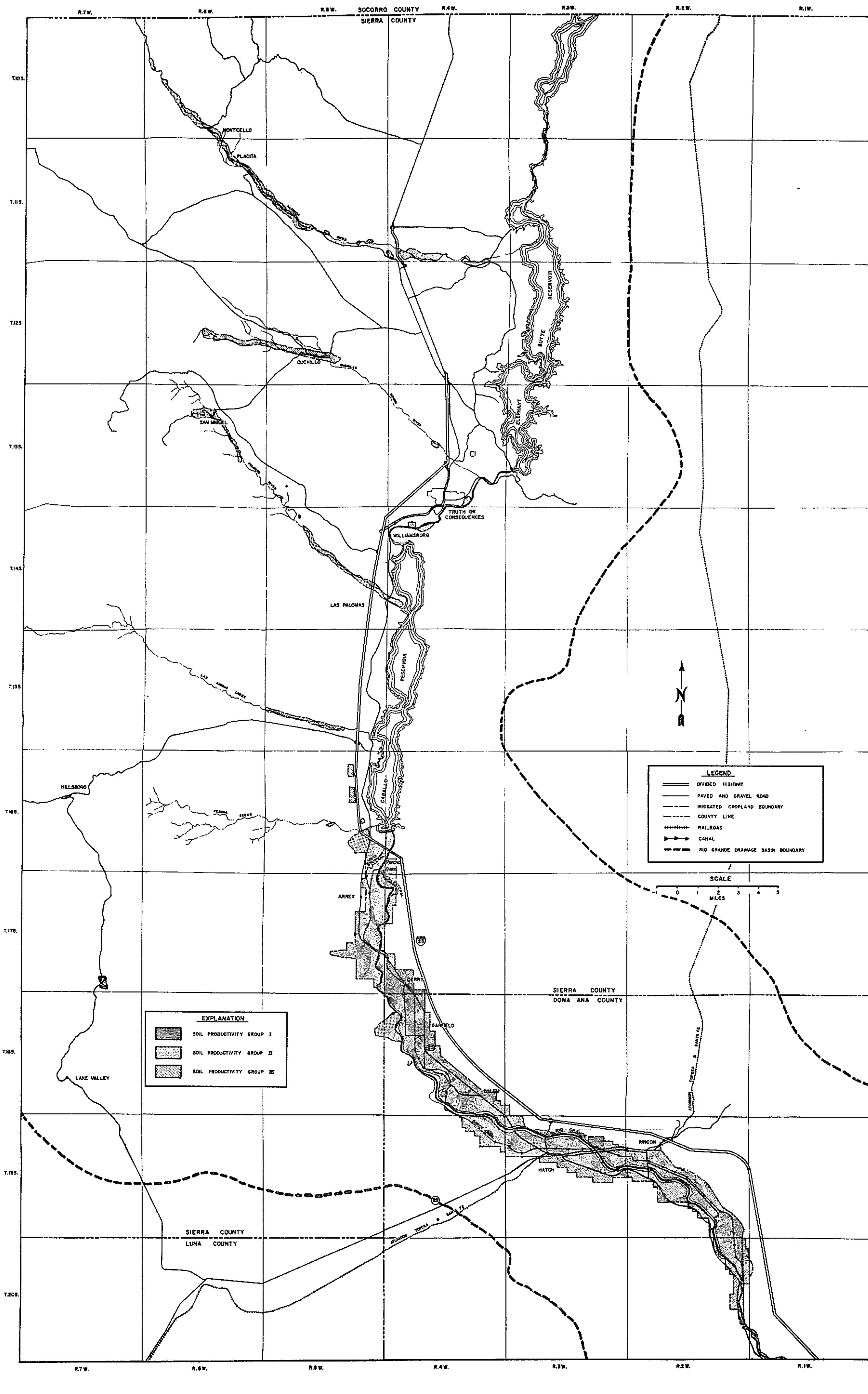

Figure 17. Soil productivity map, Rincon Valley, Lower Rio Grande Region, New Mexico

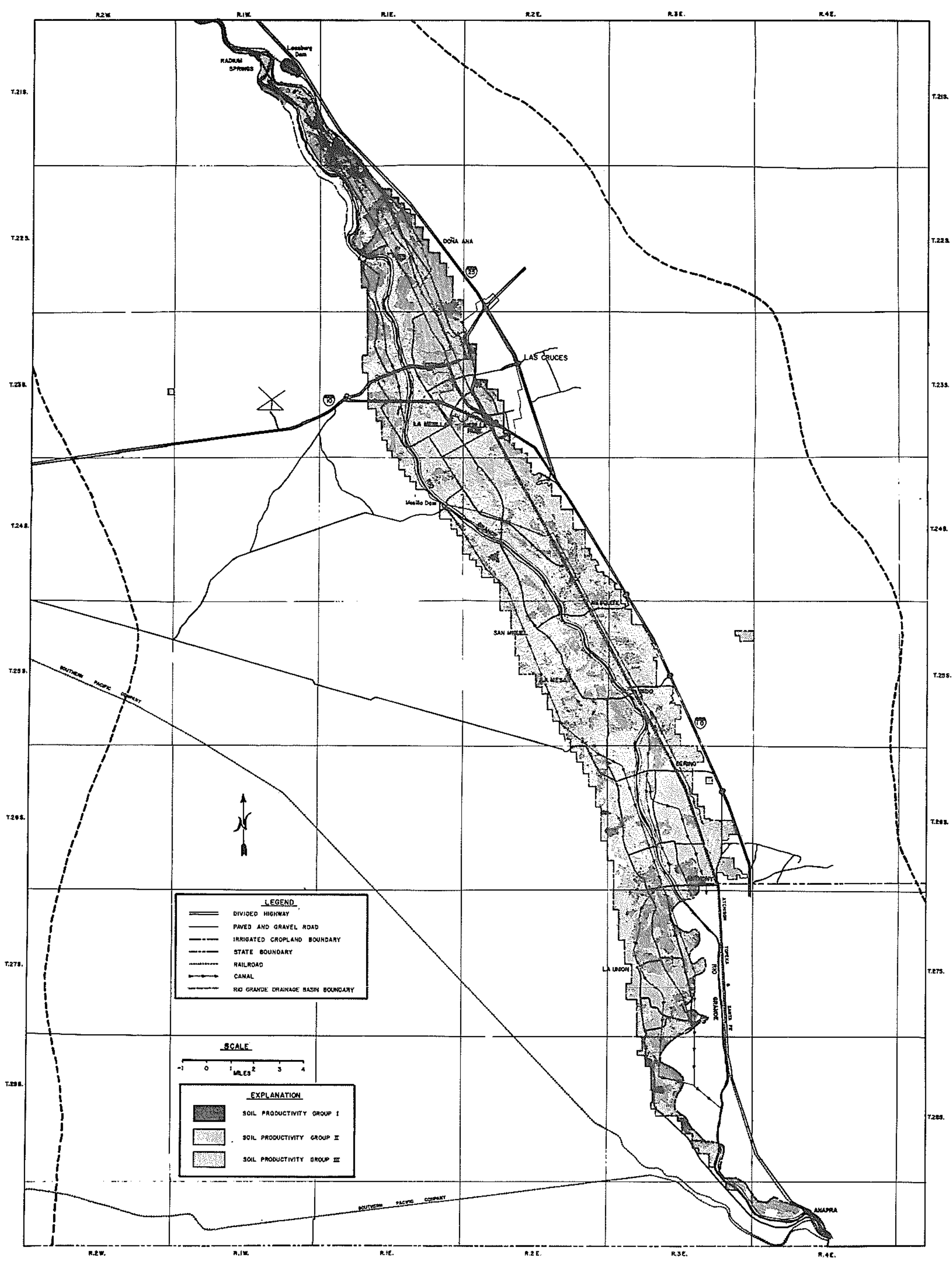

Figure 18. Soil productivity map, Mesilla Valley, Lower Rio Grande Region, New Mexico