HIGH PLAINS-OGALLALA AQUIFER STUDY

UNION AND HARDING COUNTIES, NEW MEXICO*

Robert R. Lansford, Noel R. Gollehon, Bobby J. Creel, Shaul Ben-David, Earl F. Sorensen, James M. Hill, M. Emily Miller, and Craig L. Mapel**

PARTIAL TECHNICAL COMPLETION REPORT

Project No. WRRI 1423697 and 1345681

New Mexico Water Resources Research Institute
in cooperation with
Department of Agricultural Economics and
Agricultural Experiment Station, NMSU;

Department of Economics, UNM;

New Mexico State Engineer Office;

and

New Mexico Energy and Minerals Department

June 1982

---

* The work upon which this publication is based was supported in part by funds provided by the Economic Development Administration, U.S. Department of Commerce, through the High Plains Associates and the New Mexico Water Resources Research Institute under Contract Number CO-A01-78-00-2550. Project Numbers: 1423697 and 1345681.

** Professor, Department of Agricultural Economics, New Mexico State University; Research Specialist, Department of Agricultural Economics and Agricultural Business, New Mexico State University; Research Specialist, Department of Agricultural Economics, New Mexico State University; Professor, Department of Economics, University of New Mexico; Water Resources Engineer, NM State Engineer Office, Santa Fe, NM; Geologist and Chief of the Bureau of Geology, New Mexico Energy and Minerals Department, Santa Fe, NM; Former Economist, New Mexico Energy and Minerals Department, Santa Fe, NM; Research Specialist, Department of Agricultural Economics, New Mexico State University; respectively.

ACKNOWLEDGEMENTS

This study was part of an interdisciplinary research project entitled, "Six-State High Plains Ogallala Aquifer Regional Resources Study," funded by the U.S. Department of Commerce through the High Plains Associates and New Mexico Water Resources Research Institute, New Mexico Interstate Stream Commission, and New Mexico Energy and Minerals Department.

The principal investigators were Robert R. Lansford, Agricultural Economist, New Mexico State University; Shaul Ben-David, Economist, University of New Mexico; Fred Allen, State Engineer Office; and James M. Hill, Chief of Bureau of Geology, New Mexico Energy and Minerals Department. Other investigators included Earl F. Sorensen, Water Resource Engineer, New Mexico State Engineer Office; Noel R. Gollehon, Agricultural Economist, New Mexico State University; Bobby J. Creel, Agricultural Economist, New Mexico State University; and Emily Miller, New Mexico Energy and Minerals Department.

Consultants included J. R. Gray, Agricultural Economist, New Mexico State University; T. W. Sammis, Agricultural Engineer, New Mexico State University; and A. A. Baltensperger, Agronomist, New Mexico State University. Fred Allen from the New Mexico State Engineer Office generally coordinated the hydrology investigation with assistance from P. D. Akin, B. C. Wilson, E. A. Trujillo, and Francis West. These consultants were included in the research effort and made contributions both in advice to the study group and in data development. J. R. Gray provided information and a range livestock budget for ranches in the study region; crop water production functions were supplied by the agricultural engineer; and the agronomist supplied information on future agronomic developments.

David P. Hale and Carl Slingerland of the New Mexico Interstate Stream Commission served as coordinators, under the direction of S. E. Reynolds, 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 formulation of the analysis. They included representatives from the High Plains Associates: Camp, Dresser, and McKee (Harvey O. Banks, Jean Williams, and Joe D. Harris); Arthur D. Little, Inc. (Richard Feeley, David Land, Russell Fries, and Rufus Perkins); and Black and Veatch (Charles L. Banning and Carl A. Vansant).

Graduate students who participated in the study are as follows:

Student Assistants	Degree Sought	Discipline
Bobby J. Creel	Ph.D.	Resource Economics - UNM
John Dillon	M.S.	Ag. Economics - NMSU
Craig Mapel	M.S.	Ag. Economics - NMSU
Raymond Sauer	M.S.	Economics - UNM
Jacques Blair	Ph.D.	Resource Economics - UNM

Special thanks are also due to Kristi Spence, Luz Cadena, and Becky May for efficiently and expertly typing the many manuscripts and to Linda Harris for her able assistance in editing the manuscripts. Needless to say, errors remaining, either in logic or numerical content of this analysis, are attributable to the authors.

DISCLAIMER

The purpose of WRRI technical reports is to provide a timely outlet for research results obtained on projects supported in whole or in part by the Institute. Through these reports, we are promoting the free exchange of information and ideas and hope to stimulate thoughtful discussion and action which may lead to resolution of water problems. The WRRI, through peer review of draft reports, attempts to substantiate the accuracy of information contained in its reports; but the views expressed are those of the authors and do not necessarily reflect those of the WRRI or its reviewers.

Contents of this publication do not necessarily reflect the views and policies of the United States Department of the Interior, Office of Water Research and Technology, nor does mention of trade names or commercial products constitute their endorsement or recommendation for use by the United States government.

ABSTRACT

New Mexico participated with five High Plains states and the High Plains Associates in the Six-State High Plains-Ogallala Aquifer Area Study. The purpose of the study was to estimate the economic impacts over a 40-year planning horizon resulting from rapidly rising energy costs and the declining Ogallala aquifer water tables in Union and Harding counties.

Four management strategies including a baseline, voluntary water conservation, mandatory irrigation water supply reduction, and interstate importation were evaluated.

For the baseline, the total gross output of all goods and services for the two counties was about $340 million in 1977. It is projected to be $484 million in 1985, $525 million in 1990, $586 million in 2000, and $725 million in 2020. The differences in gross output among the management strategies are due mainly to changes in the agricultural sectors.

The most important sector is agriculture which contributed about 88 percent of the total output in 1977. Even though the other sectors are projected to expand, agriculture is projected to contribute about 75 percent of the total in 2020.

The mining sectors are projected to have an economic impact, increasing from about $7 million in 1977 to about $34 million in 2020. The trade sector is expected to expand faster than any of the other sectors, increasing from $11 million in 1977 to almost $59 million in 2020. The manufacturing sectors are projected to also increase from $3 million in 1977 to about $11 million in 2020.

The total employment in the counties in 1977 was 3,589, and is expected to increase to 5,032 by 2020. Agriculture was the largest employer throughout the period accounting for about 50 percent of the total in 1977, 38 percent in 1990, and 31 percent in 2020.

The alternative management strategies basically had very little impact on the economy of the counties. The voluntary strategy resulted in total output in 2020 of $66,000 more than the baseline. Mandatory resulted in $2.405 million more than the baseline and the importation strategy had $3.510 million more than the baseline. The impact on employment of the alternative management strategies in the counties was also minor. The voluntary strategy resulted in 156 more jobs than baseline in 2020. The mandatory had 90 more than baseline and the importation had 376 more than baseline. Population in the county was affected similarly to employment by the alternative strategies. Voluntary resulted in 533 more people than baseline in 2020, mandatory 292 more people than baseline, and importation had 1,202 more people than baseline in 2020.

KEYWORDS: *High Plains, *Ogallala Aquifer, *Union and Harding counties, *New Mexico, *management strategies, energy, water resources, on-farm impacts, regional impacts, gross output, employment, population, economic projections, resources, interdisciplinary.

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

A large part of eastern New Mexico is situated in the High Plains, a somewhat homogenous region extending over large areas of Colorado, Kansas, Nebraska, New Mexico, Oklahoma and Texas (Figure 1). Discovery and subsequent exploitation of extensive ground water resources in the region, primarily from the Ogallala Formation, have generated dramatic economic growth. This growth has exerted greater and greater demands on ground water supplies. Water levels have declined and some irrigated areas have gone out of production. As a result, the area's economic activities that depend on irrigated agriculture are threatened due to the rapidly rising energy costs and the declining water tables. If significant areas were to be forced out of irrigated production in the New Mexico High Plains, the economy of the entire state could be adversely affected. In response to these concerns, New Mexico, five other High Plains states, and the High Plains Associates (general contractor) participated in the Six-State High Plains-Ogallala Aquifer Area Study.

The general purpose of this study was to estimate the economic impacts over a 40-year planning horizon on regional income and employment, population, irrigated and dryland cropping patterns, agricultural output, and farm income. The impacts were measured under alternative sets of assumptions regarding public policy, water and energy costs and availability, and irrigation management practices.

The ground water irrigated acreage of the High Plains region represents about 35 percent of the irrigated acreage in New Mexico (Lansford, et al., November 1981) and accounts for about one-third of the cash receipts from crop sales in the state.

Irrigation has been a fairly recent development in Union and Harding counties. For example, in Union and Harding counties irrigated cropland increased from 10,500 to 62,400 acres from 1940 to 1980 (Lansford, et al., RR 454, September 1981). However, parts of Union and Harding counties already have felt the effects of a declining water supply and rising energy costs. As a result, some irrigated cropland has been abandoned.

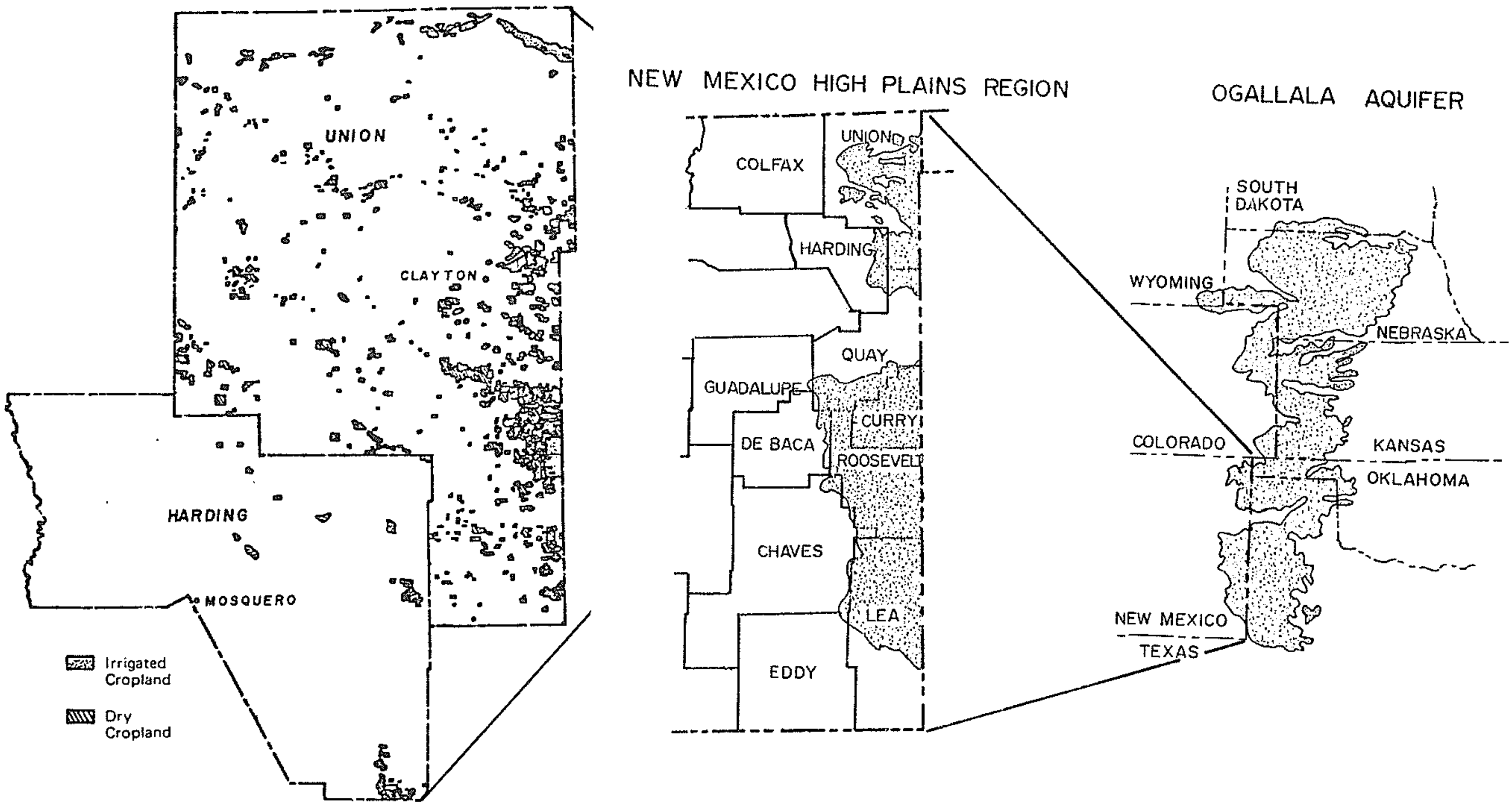

Figure 1. Ogallala Aquifer Region and New Mexico.

This report presents an in-depth look at the water, energy, and related resources in Union and Harding counties, New Mexico, which is a part of the High Plains-Ogallala Aquifer Study region in New Mexico. Other reports have been prepared for Roosevelt County, Curry County, Quay County, Lea County, and for the region (WRRI Reports 147 through 151).

MANAGEMENT STRATEGIES

Four management strategies including a baseline were evaluated: voluntary water conservation (Alternative Management Strategy 1); mandatory irrigation water supply reduction (Alternative Management Strategy 2); and importation, supply augmentation for those areas that physically exhaust their water supply under Alternative Strategy 1 (Alternative Management Strategy 5A). Management Strategy 3, local supply augmentation, and Management Strategy 4, intrastate transfers, were not evaluated for New Mexico.

Baseline

The baseline is defined as "no new public action or deliberate change--continuation of current trends in water and agricultural management in both public and private sectors." It has been consistently assumed that under the baseline neither states nor the federal government will initiate new policies or programs to reduce demands on the Ogallala aquifer or other resources. Neither would they augment the water supply during the study period. It is further assumed that current trends in public and private sector resource demand and supply management would continue throughout the study period. Only those changes in resource management already underway and anticipated to continue as rational economic behavior would be considered to influence long-term baseline projections. Under the baseline, the continuation of present trends in water conservation is expected to result in water savings of about 10 percent on sprinkler-irrigated lands over the study period. It is assumed that there will be no reduction in water applications for furrow irrigated croplands.

Voluntary Irrigation Water Conservation

This alternative adds to the baseline by assuming incentives will be provided for technological change and improved water and agricultural management practices at the farm level. This alternative assumes an accelerated adoption rate of new and promising technologies. The changes in irrigation water and farm management practices are expected to occur through research and development, extension and education, and finally adoption of improved technology, improved farming practices, and improved plant varieties. The area of improved technology probably would include improved water conveyance and application systems. Improved farming practices would include techniques such as irrigation scheduling and evaporation reduction farming methods. Plant varieties might be adapted, through genetic research, to produce the same amount, only requiring less water. Operationally, this strategy is defined for two major irrigation systems: sprinkler and furrow.

Sprinkler water applications would be decreased by an additional 1.2 percent in 1985. There would be a 3 percent reduction in water applications in 1990, an additional 4 percent reduction in 2000, and an additional 5 percent reduction in 2020 for a total reduction of 12 percent from 1990 through 2020.

There would be a 4 percent reduction in water applications for furrow irrigation in 1985, an additional 5 percent reduction in 1990, an additional 6 percent reduction in 2000, and an additional 6 percent reduction in 2020 due to incentive programs and expanded research.

Mandatory Irrigation Water Supply Reduction

The mandatory strategy builds upon the voluntary strategy by adding mandatory water supply management. This strategy encompasses institutional/regulatory changes requiring water conservation, improved water and agricultural management practices at the farm level, and/or restrictions on new irrigated agricultural developments.

This strategy requires the supply of irrigation water to be reduced below what would be available under the voluntary strategy. Water supplies would be required to be reduced by 10 percent below the irrigation water applications in the voluntary strategy by 1985, by 20 percent by 1990, and by 30 percent by 2000.

Importation (Supply Augmentation)

Irrigation water would be imported to fully supply those lands that physically exhaust their natural water supply. The irrigation water would be available in the year 2000 and be applied in a manner consistent with the voluntary strategy technology.

GENERAL DESCRIPTION

Topography

Union and Harding counties lie entirely within the Arkansas-White-Red (AWR) River Basin in New Mexico. Total area of Union County is 3,817 square miles and Harding County is 2,138 square miles.

Union County is in the northeast corner of New Mexico and is bounded on the north by Colorado and on the east by Oklahoma and Texas. Five sub-basins contribute surface drainage to the larger AWR basin in Colorado, Oklahoma, and Texas. The streams in the county are intermittent and flow only after snowmelt and during storms.

All of Union County lies in the Great Plains Province of the western United States. The predominant rocks are horizontal beds of sandstone interspersed with and covered by basaltic lava flows. In the northern part, the Raton Mesa Group extends eastward along the Colorado-New Mexico boundary on the divide between the Purgatory and Dry Cimarron rivers. Topography consists of high mesas, dissected plateaus, deep canyons, and volcanic mountains of various ages. One of the mountains, Sierra Grande, has an elevation of 8,720 feet (MSL) and is the highest point in the county. Another, Capulin Mountain, is a symmetrical volcanic cone of recent age and is a national monument. South of the mesa group, the landscape begins to flatten and is characterized by plains, prairies, scattered hills, and intermittent arroyos. Numerous playas dot the landscape and most of these contain water only after runoff from rainstorms. Elevations of the plains range from about 6,000 feet on the western side to between 4,500 and 5,000 feet along the eastern border where they merge with the High Plains of Oklahoma and Texas. The lowest elevation is in the southeast corner and is about 4,200 feet.

The landscape of Harding County consists of vast and relatively flat mesas and plains. The west edge of the county is formed by the Canadian River which flows in a deep canyon with steep sides and high cliffs. Ute Creek and its tributaries of Mosquero and Tequesquite creeks drain the center and northern parts of the county. West of Ute Creek, about in the center of the county, is a north-south trending escarpment that is 500 to 800 feet high. Extensive basaltic lava flows underlie much of the north-central part. In the southeast, there are extensive sandhill areas. Along the eastern edge, a part of the Northern High Plains of west Texas and eastern New Mexico enters the county. Playa lakes dot the landscape and some contain water throughout the year. Elevations vary from over 6,000 feet (MSL) in the north to about 3,800 feet where Ute Creek leaves the county at the southern end.

There are three Life Zones; namely, the Transition, Upper Sonoran, and Lower Sonoran in Harding County. The latter zone is confined to a small area in the lower reach of Ute Creek. Most of the vegetation consists of rolling grasslands. There is some ponderosa pine and pinon-juniper woodland in the Canadian River canyon and on the higher mesas. Vegetation is sparse in the sandhill area and consists of semidesert grasses and brush.

Climate

Union and Harding counties experience a semiarid climate characterized by clear and sunny days, large diurnal temperature ranges, low humidity, and moderately low rainfall. The mean annual precipitation averages about 14.5 inches in Union County and 15 inches in Harding County. The hot summer months are normally the wettest. Occasionally, thunderstorms are accompanied by hail which may damage crops and property. The average snowfall is light and the snows usually melt within a few days after occurrence. Moderate winds prevail most of the year, and strong winds are common from January to May. Temperatures in the area average about 53 degrees Fahrenheit in Union County and 55 degrees Fahrenheit in Harding County. Winters are usually mild and dry, and temperatures above 100 degrees Fahrenheit are not uncommon in the summer months. The growing season in Union County usually begins in late April and lasts 170 days, ending in mid-October. In Harding County, the growing season usually begins in late April and lasts 165 to 185 days, ending in late October.

Land

Union County consists of approximately 2.4 million acres of land. About 2 percent of the land is under federal ownership, 18 percent under state ownership, and 80 percent is privately owned. Approximately 92 percent of the land in Union County is rangeland used for grazing and 5 percent is cropland (2 percent is irrigated and 3 percent dryland). Urban and urban fringe areas, road systems, and commercial timber each comprise less than 1 percent of the county land. The remainder of the land includes 317 acres of inland water (NMISC, 1975).

Harding County consists of approximately 1.4 million acres of land. About 5 percent of the land is under federal ownership, 25 percent under state ownership, and 70 percent is privately owned. Approximately 94 percent of the land in Harding County is rangeland used for grazing and 5 percent is cropland (1 percent is irrigated and 4 percent dryland). Urban and urban fringe areas and road systems comprise about 1 percent of the county land. The remainder of the land includes 240 acres of inland water (NMISC, 1975).

Hydrology

Union County

Three main aquifers supply water to the high-yield wells that furnish water for irrigation in Union County; namely, the Ogallala aquifer of Tertiary age, the Dakota-Purgatory aquifer of Cretaceous age, and the Morrison-Exeter aquifer of Jurassic age. The aquifers are in hydraulic continuity and, therefore, form an aquifer system.

Outside the boundaries of the Ogallala in Union County, the formations consist of rocks of Cretaceous and Jurassic age. Yields from these formations are low and are used primarily to furnish water for rural domestic and livestock requirements.

As of January 1976, the depth-to-water in the Ogallala-Morrison-Exeter system ranged from 30 to over 300 feet, with an average of 200 feet from the land surface. The saturated thickness of the ground water area ranged from 25 to 150 feet, with an average of approximately 50 feet. A typical irrigation well in this region will yield up to 900 gallons per minute with a specific yield of 40 gallons per minute per foot of drawdown. The pumping head is comprised of the depth-to- water from the land surface, plus the drawdown, plus any head that is to be delivered to the irrigation system, such as a sprinkler. Presently, the pumping head for a typical gravity flow system is approximately 215 feet in this area.

Water level measurements have been maintained in this area by the U.S. Geological Survey since 1966 and reported by the State Engineer in the report series, "Water Levels in New Mexico." The general rate of decline is approximately 0.3 foot per year.

The only ground water sources of any consequence in Union County, other than the aquifers described thus far, are found in the alluvial deposits of Quaternary age and Capulin basalt cinders near the town of Capulin. Alluvium in the dry Cimarron River Valley in the northeastern part of the county yields from 100 up to 300 gallons per minute to wells.

The alluvial deposits within a topographically closed basin west of the town of Capulin represent a fair to good source of ground water in the area. Well yields range from a few gallons per minute to several hundred gallons per minute, with average potential yields ranging from about 100 to 200 gallons per minute in areas of greatest saturated thickness.

The Ogallala Formation is overlain by large areas of either stabilized or active sand dunes. These dunes readily transmit precipitation to the underlying Ogallala aquifer, thus reducing losses by evapotranspiration and runoff. Flow of ephemeral streams during summer thunderstorms also recharges the Ogallala aquifer. Examples are Gramer's

Creek, Carrizo Creek, and Perico Creek. These streams seldom flow their entire length after storms; the volume of flow diminishes as water infiltrates downward through the streambeds.

In some areas of Union County, lateral and upward vertical movement of water from the Dakota-Purgatory and Morrison-Exeter aquifers may recharge the Ogallala aquifer. This water either moves through the intervening confining beds of the upper Dakota Sandstone or through the Graneros Shale. For this movement to occur, the potentiometric surface in the Dakota-Purgatory aquifer must be higher than the water table surface in the Ogallala aquifer. Leakage to the Ogallala aquifer from the Dakota-Purgatory and Morrison-Exeter aquifers is greatest in the eastern part of the subarea and is about 0.02 foot per year.

Water levels in the vicinity of pumping wells generally decline during the irrigation season and rise upon cessation of pumping. The area affected by pumping and the amount of water-level recovery during nonpumping periods are a function of the length of the pumping and nonpumping periods and of the hydraulic properties of the aquifer system involved.

Natural inflow to a system can be increased by leakage from reservoirs. For example, prior to the construction of Clayton Lake, the water level in a well 1,500 feet south of the lake was 156 feet below land surface. After construction of the reservoir in 1956, the water level was 141 feet below land surface in 1978. This rise was caused by filling of the lake, which is located in a small canyon cut in the Dakota Sandstone and Purgatory Formation.

Pumping of ground water from the Ogallala aquifer has resulted in water-level declines that reflect dewatering of the aquifer. Where water is being pumped from the Ogallala aquifer alone, a ground water mining situation exists, with about 60 percent of the pumped water coming from storage being used consumptively. These areas are primarily in the southern part of the subarea. It is probable that declining water levels in the Ogallala aquifer reduce the amount of leakage into the underlying Dakota-Purgatory and Morrison-Exeter aquifers or increase the leakage if the vertical hydraulic gradient is toward the Ogallala aquifer (U.S. Geological Survey unpublished data). However, determination of the magnitude of this effect is beyond the scope of this report.

Rises in water levels have occurred in the Ogallala aquifer in some places, particularly southeast of Clayton. These rises are the result of return flow or irrigation water being pumped from the underlying Dakota-Purgatory aquifer. The Graneros Shale separating the aquifers is about 80 feet thick in this area, and restricts the downward movement of return flow. In general, water-level changes in the Dakota-Purgatory and Morrison-Exeter aquifers are reflected in declines in artesian head. The magnitude of these changes has, in general, been less than the changes in the water table in the overlying Ogallala aquifer.

The artesian head generally recovers to near its original level during the nonpumping season over most of the area where the Ogallala aquifer overlies the Dakota-Purgatory and Morrison-Exeter aquifers.

Harding County

The extent of the Ogallala in the High Plains is outlined on Figure 1. The Ogallala is of Tertiary age and overlies older rocks of Cretaceous, Jurassic, Triassic, and Permian ages. In Harding County, the Ogallala is only present in a small portion of the county on the eastern side.

Outside the boundaries of the Ogallala in Harding County, the formations consist of rocks of Cretaceous and Jurassic ages. Yields from these formations are low and are used primarily to furnish water for rural domestic and livestock requirements.

As of January 1976, the depth-to-water in the Ogallala Formation ranged from 50 to over 300 feet, with an average of 200 feet from the land surface. The saturated thickness of the ground water area ranged from 25 to 150 feet, with an average of approximately 50 feet. A typical irrigation well in this region will yield up to 900 gallons per minute with a specific yield of 40 gallons per minute per foot of drawdown. The pumping head is comprised of the depth-to-water from the land surface, plus the drawdown, plus any head that is to be delivered to the irrigation system, such as a sprinkler. Presently, the pumping head for a typical gravity flow system is approximately 215 feet in this area. The general rate of decline in the water level is approximately 0.3 foot per year.

The principle source of recharge to the Ogallala Formation is precipitation and infiltration into the aquifer. The amount and rate of recharge from precipitation depends on the amount, distribution, and intensity of the precipitation; the amount of moisture in the soil when rain or snowmelt begins; and the temperature, vegetative cover, and permeability of the materials at the site of infiltration. Because of the wide variations in these factors and because of the lack of data, it is difficult to estimate the amount of recharge to the ground water reservoir. An unknown amount of water pumped from the Ogallala Formation for irrigation percolates back to the aquifer. This water does not constitute an addition to the water supply, but only a reduction in net discharge.

Water Quality

The water is predominantly of the calcium magnesium bicarbonate type and moderately hard to hard in both Union and Harding counties. In general, the quality of the water is generally satisfactory for livestock, domestic, and irrigation use.

One analysis of water from a well two miles north of Clayton shows an unusually high concentration of sulfate. The sulfate probably has its source in the Granero shale which is thought to be faulted downward into contact with the Dakota-Purgatory aquifer in this area.

Water Use

Ground water from the Ogallala Formation in Union and Harding counties is used for irrigation, public supply, power generation, and domestic and livestock purposes.

Water Rights Administration

Union County

New appropriations of surface water in the drainages of the Purgatory River, Dry Cimarron River, Carrizo Creek, North Canadian River, and the Carrizo Creek drainage basins may be permitted only if the State Engineer determines, after consideration of the information available to him and additional evidence submitted in support of an application, that there is unappropriated water that could be appropriated without detrimental effect to existing rights. Conservation storage within the North Canadian, Carrizo Creek, and Canadian River drainages below Conchas Dam has been fully allocated. Changes in points of diversion, places, and purposes of use may be made, provided no detrimental effects to existing rights will result. Changes of existing rights or new appropriations of surface water require a permit from the State Engineer.

There are no declared underground water basins within the county and underground water throughout the county may be appropriated without permit from the State Engineer.

Harding County

New appropriations of surface water in the Canadian River drainage above Ute Reservoir generally are not permitted unless the State Engineer determines, after consideration of the information available to him and additional evidence submitted in support of an application, that the new appropriation will not be to the detriment of existing rights.

New appropriations of surface water within the Carrizo Creek drainage may be permitted only in locations where no detrimental effects to existing rights will result. Conservation storage within the Canadian River drainage below Conchas Dam, authorized for New Mexico's use under the Canadian River Compact, has been fully allocated. Changes in points of diversion, places, and purposes of use may be made, provided no detrimental effects to existing rights will result. Changes of existing rights or new appropriations of surface water require a permit from the State Engineer.

The west side of the county is within the Canadian River Underground Water Basin as declared by the State Engineer (Figure 2). Permits from the State Engineer are necessary prior to drilling wells within the boundaries of the declared basin. No permit is required to drill in the portion of the county outside the declared basin.

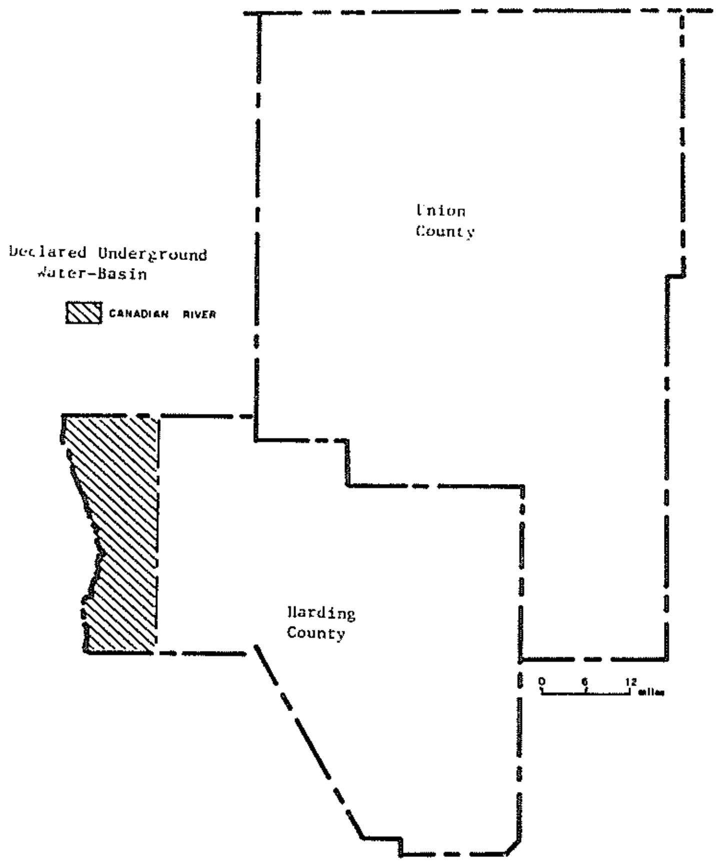

Figure 2. Declared Underground Water Basin, Union and Harding Counties, New Mexico.

Electricity

There is only one electrical generating plant with a rated capacity of 6.7 MW owned by the City of Clayton in the two counties. The primary fuel for the generating plant is natural gas with oil as the alternative fuel.

The annual production between 1974 and 1978 ranged from 10.0 gigawatt-hours in 1976 to 14.977 gigawatt-hours in 1978, with an average of 12.35 gigawatt-hours.

The City of Clayton's electricity sales are assumed to remain at present levels through the year 2020. Since 1974, annual electricity sales have fluctuated only slightly, therefore, an average for 1974 through 1978 was taken. Assessments by the Eastern Plains Council of Governments, the regional planning organization, and the city indicate that Clayton has presently reached a growth plateau, and no plans are foreseen to expand their present generation capacity of 6.7 MW.

Oil and Natural Gas

There is no oil or natural gas production in Union and Harding counties and none is projected in the future.

Other Mining

The development of carbon dioxide (CO_2) reserves in the Bravo Dome field would mean an economic boom for northeastern New Mexico. The renewed interest in the immense reserves, estimated at eight trillion cubic feet, stems from its potential use in the recovery of oil from reserves that no longer respond to direct pumping or flooding with water. Despite the size of the CO_2 reserves, there is not likely to be enough CO_2 to meet the potential market in the Permian/Delaware Basin. It appears that most of it would go to Texas where the oil fields have reached the tertiary recovery stage and where Amoco's (the unit operator) oil fields are concentrated.

Agriculture

Union and Harding counties are an important agricultural area in New Mexico. In 1977, the value of production from the irrigated cropland was estimated to be about \$10.4 million, from dry cropland to be about \$2.5 million, and from range livestock to be about \$43.0 million. Union and Harding counties accounted for about 24 percent of the total value of production from agriculture (irrigated, dry, and rangeland) in the High Plains region. In 1977, they accounted for about 3.8 percent of the total irrigated acreage, about 9.8 percent of the total dryland crop acreage, and 2.5 percent of the cash receipts from crop sales. The important irrigated crops were corn, grain sorghum, alfalfa, and wheat.

OGALLALA HIGH PLAINS MODEL AND COMPONENTS

The purpose of this study was to estimate the economic impacts over a 40-year planning horizon on regional income, employment, population, irrigated and dryland cropping patterns, agricultural output, farm income, and energy production. The impacts were measured under alternative sets of assumptions regarding public policy, water and energy costs and availability, and irrigation management practices.

An interdisciplinary approach to the solution of the water resource problems of the High Plains region in New Mexico was made possible by integrating hydrology, geology, and engineering with economics. Research procedures developed to carry out this study were closely coordinated by the investigators to achieve the stated objectives. Inputs into the economic models were obtained from separate studies covering the hydrological, agricultural, and energy areas.

Assumptions concerning regional economic impacts, employment, population, crop yields, commodity prices, energy prices, input prices, and energy production were developed cooperatively among the six states and the general contractor. All states used basically the same assumptions for compatibility. A detailed description and discussion of the methodology for the separate area studies are presented in WRRI Report 151.

RESULTS

Results are presented for the Union and Harding counties economic impacts and key resources by management strategy for selected years (1977, 1985, 1990, 2000, and 2020).

Water Resources

Projected withdrawals for irrigation, urban, rural, manufacturing, minerals, power, livestock, and recreation uses are presented in Table 1. Table 1 also shows projections for depth-to-water (ground surface to water table), and the remaining saturated thickness of the Ogallala Formation for the years 1977, 1985, 1990, 2000, and 2020 in Union and Harding counties. The base year for all projections is 1977.

Other than areas of future agricultural and urban uses, there is little possibility of reducing water demand in the region through voluntary or mandatory strategies. This does not mean conservation

Table 1. Estimated Withdrawals, Depth-to-Water, and Remaining Saturated Thickness of Ogallala Aquifer, Union and Harding Counties, New Mexico, 1977-2020.

Strategy and Category	Year 1977	1985	1990	2000	2020
Baseline					
Withdrawals (1,000 acre-ft.)					
Irrigation	(132.4)	(146.5)	(155.6)	(166.4)	(195.6)
Ogallala Aquifer	128.5	142.5	151.6	162.4	191.6
Non-Ogallala Aquifer	3.9	4.0	4.0	4.0	4.0
Urban*	0.7	0.8	0.9	1.0	1.3
Rural	(0.2)	(0.2)	(0.3)	(0.3)	(0.4)
Ogallala Aquifer	0.1	0.1	0.1	0.1	0.2
Non-Ogallala Aquifer	0.1	0.1	0.2	0.2	0.2
Manufacturing*	0.0	0.0	0.0	0.0	0.1
Mining	(0.0)	(1.5)	(2.5)	(2.5)	(5.0)
Ogallala Aquifer	0.0	0.3	0.3	0.3	0.5
Non-Ogallala Aquifer	0.0	1.2	2.2	2.2	4.5
Power*	0.2	0.2	0.2	0.2	0.2
Livestock**	(2.4)	(2.3)	(2.3)	(2.3)	(2.3)
Ogallala Aquifer	0.7	0.6	0.6	0.6	0.6
Non-Ogallala Aquifer	1.7	1.7	1.7	1.7	1.7
Fish & Wildlife (Non-Ogallala Aquifer)**	0.2	0.2	0.2	0.2	0.2
Total Withdrawals	(136.1)	(151.7)	(162.0)	(172.9)	(205.1)
Ogallala Aquifer	130.2	144.5	153.7	164.6	194.5
Non-Ogallala Aquifer	5.9	7.2	8.3	8.3	10.6
Ogallala Aquifer					
Depth-to-water (ft.)	200.0	202.0	204.0	207.0	213.0
Remaining saturated thickness (ft.)+	50.0	48.0	46.0	43.0	37.0
Voluntary Strategy					
Withdrawals (1,000 acre-ft.)					
Irrigation	(132.4)	(144.8)	(149.4)	(153.5)	(171.7)
Ogallala	128.5	140.8	145.4	149.5	167.7
Non-Ogallala	3.9	4.0	4.0	4.0	4.0
Urban*	0.7	0.7	0.8	0.9	1.2
Rural	(0.2)	(0.2)	(0.3)	(0.3)	(0.4)
Ogallala Aquifer	0.1	0.1	0.1	0.1	0.2
Non-Ogallala Aquifer	0.1	0.1	0.2	0.2	0.2
Manufacturing*	0.0	0.0	0.0	0.0	0.1
Mining	(0.0)	(1.5)	(2.5)	(2.5)	(5.0)
Ogallala Aquifer	0.0	0.3	0.3	0.3	0.5
Non-Ogallala Aquifer	0.0	1.2	2.2	2.2	4.5
Power*	0.2	0.2	0.2	0.2	0.2
Livestock**	(2.4)	(2.3)	(2.3)	(2.3)	(2.3)
Ogallala Aquifer	0.7	0.6	0.6	0.6	0.6
Non-Ogallala Aquifer	1.7	1.7	1.7	1.7	1.7
Fish & Wildlife (Non-Ogallala Aquifer)**	0.2	0.2	0.2	0.2	0.2
Total Withdrawals	(136.1)	(149.9)	(155.7)	(159.9)	(181.1)
Ogallala Aquifer	130.2	142.7	147.4	151.6	170.5
Non-Ogallala Aquifer	5.9	7.2	8.3	8.3	10.6
Ogallala Aquifer					
Depth-to-water (ft.)	200.0	202.0	204.0	207.0	213.0
Remaining saturated thickness (ft.)+	50.0	48.0	46.0	43.0	37.0

* Ogallala Aquifer only.

** Includes surface water.

\+ Saturated thickness is defined as the thickness of a lens of saturated porous material existing below the water table, capable of yielding significant quantities of ground water to wells. The remaining saturated thickness reflects the impact of all ground water withdrawals on the quantity of water stored in the porous medium and, thus, the thickness of the lens.

Table 1 cont.

Strategy and Category	Year 1977	1985	1990	2000	2020
Mandatory Strategy					
Withdrawals (1,000 acre-ft.)					
Irrigation	(132.4)	(131.0)	(121.0)	(109.7)	(122.3)
Ogallala	128.5	127.0	117.0	105.7	118.3
Non-Ogallala	3.9	4.0	4.0	4.0	4.0
Urban*	0.7	0.6	0.7	0.8	1.0
Rural	(0.2)	(0.2)	(0.3)	(0.3)	(0.4)
Ogallala Aquifer	0.1	0.1	0.1	0.1	0.2
Non-Ogallala Aquifer	0.1	0.1	0.2	0.2	0.2
Manufacturing*	0.0	0.0	0.0	0.0	0.1
Mining	(0.0)	(1.5)	(2.5)	(2.5)	(5.0)
Ogallala Aquifer	0.0	0.3	0.3	0.3	0.5
Non-Ogallala Aquifer	0.0	1.2	2.2	2.2	4.5
Power*	0.2	0.2	0.2	0.2	0.2
Livestock**	(2.4)	(2.3)	(2.3)	(2.3)	(2.3)
Ogallala Aquifer	0.7	0.6	0.6	0.6	0.6
Non-Ogallala Aquifer	1.7	1.7	1.7	1.7	1.7
Fish & Wildlife (Non-Ogallala Aquifer)**	0.2	0.2	0.2	0.2	0.2
Total Withdrawals	(136.1)	(136.0)	(127.2)	(116.0)	(131.5)
Ogallala Aquifer	130.2	128.8	118.9	107.7	120.9
Non-Ogallala Aquifer	5.9	7.2	8.3	8.3	10.6
Ogallala Aquifer					
Depth-to-water (ft.)	200.0	202.0	204.0	206.0	210.1
Remaining saturated thickness (ft.)+	50.0	48.0	46.0	44.0	39.9

* Ogallala Aquifer only.

** Includes surface water.

\+ Saturated thickness is defined as the thickness of a lens of saturated porous material existing below the water table, capable of yielding significant quantities of ground water to wells. The remaining saturated thickness reflects the impact of all ground water withdrawals on the quantity of water stored in the porous medium and, thus, the thickness of the lens.

should be abandoned in all areas of water use. However, the use of water by irrigated agriculture (about 99 percent of the total ground water withdrawals) overshadows all other uses.

For these reasons, the only changes in the voluntary strategy projection and in the mandatory strategy projection (Table 1) from quantities shown in the baseline projection are for "irrigation" and "urban." Water requirements for other water-use categories are the same in all projections.

Other than irrigation and urban, the only significant increases in water demand are the amounts projected for "minerals." Most of this water will be used for carbon dioxide for secondary oil recovery and is expected to increase in the future. The projected amounts were reviewed and concurred with by personnel of the New Mexico Energy and Minerals Division.

The voluntary projections for "urban" were estimated by reducing baseline projections by 10 percent. Mandatory projections were estimated by reducing voluntary projections by an additional 15 percent (a total of 25 percent with respect to the baseline quantities).

In the High Plains area of New Mexico, it was assumed that when the saturated thickness of the Ogallala aquifer in a given area becomes 25 feet or less, the water is no longer economically recoverable for irrigated agriculture and pumping for this purpose would cease. However, even though the water in the lower 25 feet of the aquifer is no longer economically extractable for irrigation use, many widely spaced wells producing small amounts of water could continue to produce sufficient supplies for urban and most other nonirrigation needs.

The estimated hydrologic conditions, well characteristics, irrigation system, and fuel for the 1977 baseline conditions for the Ogallala aquifer are presented in Appendix Table A-1.

The estimated remaining saturated thickness resulting from irrigation from the Ogallala aquifer is presented in Table 2. Except for 1977 conditions, the estimated remaining saturated thickness shown in these tables does not reflect the impact of withdrawals for uses other than irrigation.

To estimate the total effect of all uses upon the saturated thickness, the values shown in Table 2 were modified and are presented in

Table 2. The Projected Effect of Irrigation on Remaining Saturated Thickness of the Ogallala Aquifer, Union and Harding Counties, New Mexico, 1977-2020.

	Year					
	1977	1985	1990	2000	2010	2020
Baseline						
Ground Water Area	50	48	46	43	40	37
Dry Cimarron	50	50	50	50	50	50
Voluntary						
Ground Water Area	50	48	46	43	40	37
Dry Cimarron	50	50	50	50	50	50
Mandatory						
Ground Water Area	50	48	46	44	42	40
Dry Cimarron	50	50	50	50	50	50

Table 1. A linear analysis was used to determine the necessary adjustments for uses other than irrigation. This was done on the basis of the 1975 Water-Use Inventory (Sorensen), and the location of uses as shown on Point Source Maps produced by the New Mexico Environmental Improvement Division (see selected references).

On-Farm Impacts

The on-farm impacts for Union and Harding counties include a discussion by management strategy of the on-farm economic impacts (irrigated and total value of production as well as returns to land and management); land resource--including cropland and cropping patterns (irrigated, dry cropland, and rangeland); and the utilization of ground water for irrigation (see Appendix Table B-1 for a summary of the baseline). Supporting tables, describing the land, water, and economic impacts by the selected years, can be found in WRRI Report 151. A sensitivity analysis of the on-farm impacts to demonstrate the effect of both higher and lower crop prices, crop yield, and energy costs on the irrigated agricultural economy of New Mexico is also presented in WRRI Report 151.

In Union and Harding counties, no aquifer exhaustion is expected over the study period, therefore, no water is expected to be imported by

2020. Thus, the only difference between the voluntary and the importation strategies will be slight changes in commodity prices due to a higher total six-state region production from imported water. These changes in commodity prices result in slightly lower value of production and returns to land and management.

In Union and Harding counties, for hydrologic and agronomic reasons, the counties were divided into two subregions--the ground water irrigated area (95 percent of the acreage) and the Dry Cimarron River Valley (a combined surface and ground water irrigated area). The depth-to-water, acreage, and crop (only hay) remain stable over the period. Thus, the following analysis includes both areas but the ground water impacts, both over time and between strategies, greatly exceed a small stable area like the Dry Cimarron.

Value of Production

The 1977 total agricultural value of production (TVP [irrigated crops, dryland crops, and rangeland]) in Union and Harding counties was about $55.9 million (Figure 3). Under all the management strategies, the total value of production is expected to increase significantly over time due to increasing crop yields and prices as well as expanded irrigated acreage. A large increase, 82 percent ($46.1 million), is expected to occur under the baseline (Table 3). The voluntary strategy is projected to have the largest increase, 83 percent ($46.2 million), and the mandatory strategy about 67 percent. The required changes in the cropping pattern and irrigation technologies necessary to meet the mandatory strategy are expected to cause a 75 percent ($8.5 million) reduction in the total value of production from the baseline in 2020. Under the voluntary strategy, the value of production is expected to increase by a slight amount.

The 1977 value of production for irrigated crops was about $10.4 million (19 percent of total agricultural value of production) in Union and Harding counties (Figure 3). Under all the management strategies, the irrigated value of production is expected to lead the general trend of the TVP--significantly increasing over time due to increasing crop yields and prices, as well as expanding acreage. The largest increase

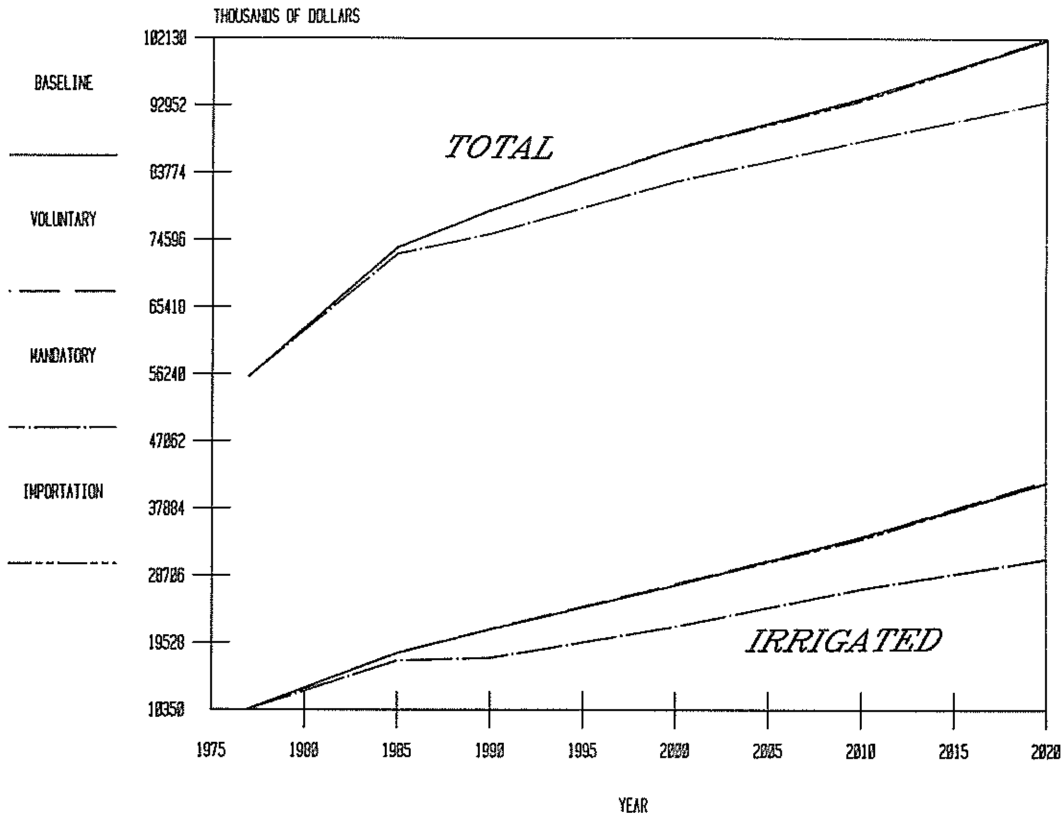

Figure 3. Total and Irrigated Value of Production for Union and Harding Counties, New Mexico, 1977-2020.

of 303 percent ($31.1 million) is expected under the voluntary strategy. Increases under the baseline and mandatory strategies are expected to be 300 and 200 percent, respectively. The required changes in the cropping pattern and irrigation technologies necessary to meet the mandatory water supply reduction strategy are expected to cause a 25 percent ($10.5 million) reduction from the baseline in 2020. The voluntary water conservation strategy increases the expected 2020 value of production slightly ($0.3 million).

The 1977 value of production for rangeland activities made the largest contribution to the agricultural sector, $43.0 million (77 percent of the total). The value of production produced by the rangeland activities is expected to increase under all the management strategies by about $11.5 million (27 percent). This increase is due primarily because of increasing real cattle prices which occur before 2000. Between 2000 and 2020, the value of production from rangeland is almost

Table 3. Value of Production and Returns to Land and Management by Management Strategy for Selected Years, Union and Harding Counties, 1977-2020.

Strategy and Item	1977	1985	1990	2000	2010	2020
	(1,000 dollars)					
			Value of Production			
Baseline	55,871	73,580	78,611	86,998	94,024	101,944
Irrigated Cropland	10,355	18,025	21,265	27,321	34,011	41,478
Dry Cropland	2,488	3,570	4,114	4,815	5,268	5,839
Rangeland	43,028	51,984	53,232	54,862	54,745	54,627
Voluntary	55,871	73,547	78,610	87,053	93,882	102,119
Irrigated Cropland	10,355	18,080	21,354	27,474	33,958	41,752
Dry Cropland	2,488	3,570	4,114	4,815	5,268	5,839
Rangeland	43,028	51,897	53,141	54,765	54,655	54,528
Mandatory	55,871	72,655	75,377	82,447	88,110	93,482
Irrigated Cropland	10,355	17,011	17,373	21,676	26,900	31,026
Dry Cropland	2,488	3,747	4,863	6,005	6,555	7,929
Rangeland	43,028	51,897	53,141	54,765	54,655	54,528
Importation	55,871	73,547	78,610	86,872	93,585	101,871
Irrigated Cropland	10,355	18,080	21,354	27,330	33,699	41,508
Dry Cropland	2,488	3,570	4,114	4,777	5,231	5,835
Rangeland	43,028	51,897	53,141	54,765	54,655	54,528
			Returns to Land and Management			
Baseline	10,250	16,159	17,283	22,180	26,663	31,969
Irrigated Cropland	1,844	4,243	4,488	8,224	12,455	17,505
Dry Cropland	301	912	1,290	1,986	2,383	2,827
Rangeland	8,105	11,004	11,505	11,970	11,826	11,637
Voluntary	10,250	16,203	17,521	22,673	27,152	32,967
Irrigated Cropland	1,844	4,305	4,746	8,738	12,963	18,523
Dry Cropland	301	912	1,290	1,986	2,383	2,827
Rangeland	8,105	10,986	11,485	11,949	11,807	11,616
Mandatory	10,250	16,017	17,086	21,459	24,653	29,148
Irrigated Cropland	1,844	4,068	4,071	7,001	9,854	13,703
Dry Cropland	301	963	1,529	2,509	2,992	3,829
Rangeland	8,105	10,986	11,485	11,949	11,807	11,616
Importation	10,250	16,203	17,521	22,492	26,855	32,718
Irrigated Cropland	1,844	4,305	4,746	8,594	12,703	18,279
Dry Cropland	301	912	1,290	1,949	2,345	2,824
Rangeland	8,105	10,986	11,485	11,949	11,807	11,616

constant due to constant cattle prices (Table 3). The slight declines from 2000 to 2020 are due to the reduction in rangeland carrying capacity as irrigated land is increased.

<u>Returns to Land and Management</u>

The total 1977 returns to land and management (irrigated crops, dryland crops, and rangeland) in Union and Harding counties was about $10.2 million (Figure 4). The greatest expected increase of $22.7 million (222 percent) is expected to occur under the voluntary strategy (Table 3). Under the baseline, the total is expected to increase 212 percent, while the estimated increase under the mandatory strategy is 184 percent.

The 1977 returns to land and management for irrigated crops in Union and Harding counties were about $1.8 million (Figure 4). Significant increases in returns are expected for all strategies. The greatest increase, 904 percent ($16.7 million), is expected to occur under the voluntary strategy. Under the baseline, irrigated returns increase by 849 percent (Table 3). Total returns under the mandatory strategy are expected to increase 643 percent.

As noted above, total returns to land and management are projected to increase by 200 percent, while the total value of production increases by about 83 percent. This implies that returns to land and management will capture a greater portion of the value of production in the future. Of the projected increase in total returns, 74 percent is due to irrigated agriculture. Much of the increased returns to irrigated agriculture is directly attributable to projected improvements in managerial ability, to the increased efficiency of irrigation systems, and to other technological improvements.

The greatest increase in both the irrigated value of production and irrigated returns occurs under the voluntary strategy. This implies that incentives are present to accelerate the development of water savings measures. Technological improvements and changing cropping patterns more than pay for their costs. The results show that an implementation of the mandatory strategy will induce a severe reduction in both the irrigated value of production and returns.

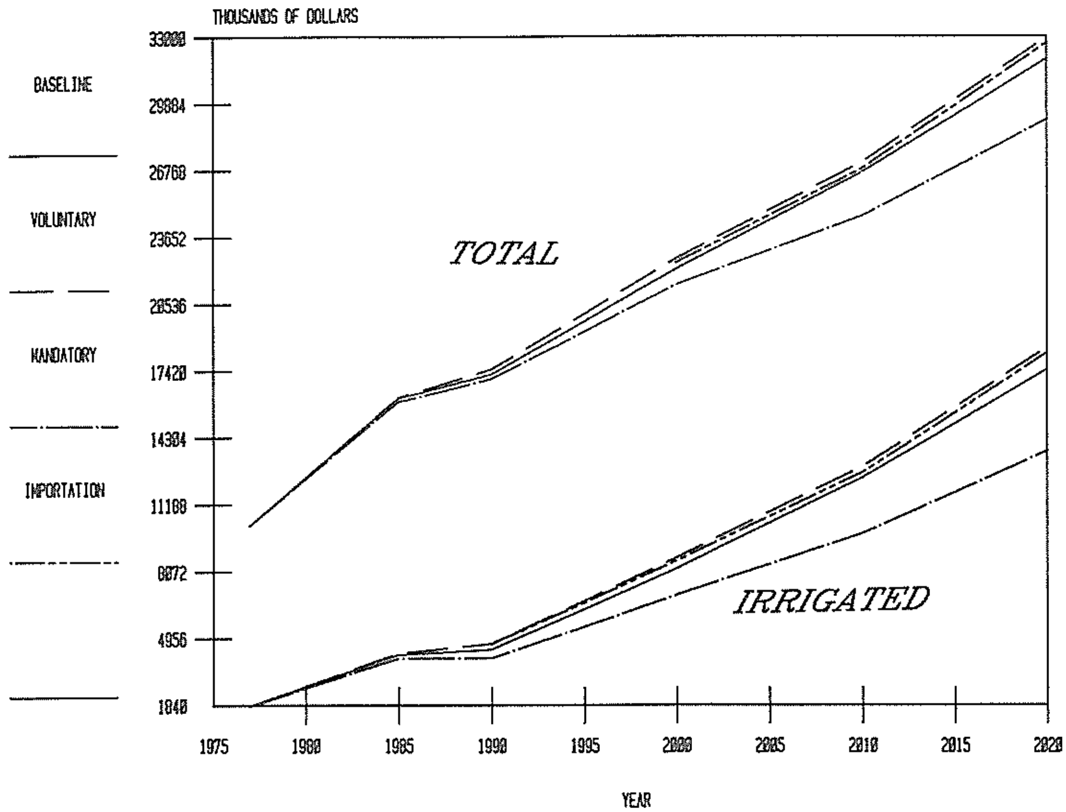

Figure 4. Total and Irrigated Returns to Land, Management, and Risk for Union and Harding Counties, New Mexico, 1977-2020.

The 1977 returns to land and management for rangeland were about $8.1 million, 79 percent of the county total (Table 3). Projected increases in the rangeland sector are about $3.5 million (43 percent). Even though the rangeland sector does not exhibit as large an increase as the other sectors, it still remains an important part of the local economy with over 36 percent of the returns to land and management in 2020.

Any future increase in land value above the inflation rate will result in a reduction in the returns to land and management.

Irrigation Water

The quantity of irrigation water diverted is expected to increase steadily from 132,442 acre-feet in 1977 to 195,586 acre-feet in 2020 under the baseline strategy (Table 4). Under the voluntary strategy, the quantity of irrigation water diverted is expected to be about 12

Table 4. Quantity of Irrigation Water Diverted by Management Strategy for Selected Years, Union and Harding Counties, New Mexico, 1977-2020.

	1977	1985	1990	2000	2010	2020
	(acre-feet)					
Baseline	132,442	146,496	155,620	166,374	181,383	195,586
Voluntary	132,442	144,779	149,362	153,483	166,162	171,735
Mandatory	132,442	130,997	120,962	109,712	118,699	122,334
Importation	132,442	144,779	149,362	153,483	166,162	171,735

percent less than under the baseline in 2020. By the year 2020, the annual diversion of irrigation water needed to irrigate 1,000 more acres is expected to be 23,900 acre-feet less for the voluntary strategy than for the baseline (Figure 5). Under the mandatory strategy, the water used for irrigation is a fixed percentage of that used under the voluntary and, as a result, the lowest water diversions are expected.

Cropland and Cropping Pattern

The irrigated cropland in Union and Harding counties is expected to steadily increase from 52,400 acres in 1977 to 82,000 acres by 2020 under the baseline (Table 5). Under the voluntary and importation strategies, the growth in acres is expected to increase to 83,000 irrigated acres in 2020. However, under the mandatory strategy, the growth in irrigated acres is expected to be substantially less with 64,900 irrigated acres in 2020. The irrigated acreage under mandatory is expected to be 18,100 acres (22 percent) less than under the voluntary strategy in 2020 (Table 5). The dry cropland acreage is expected to remain constant under all management strategies except mandatory at 40,000 acres. Under the mandatory strategy, the acreage that is irrigated in the other options is dry cropped to allow for water concentration on those lands that are irrigated. In 2020, the mandatory option is expected to result in 18,100 more dry cropped acres. The rangeland acreage in Union and Harding counties is expected to remain at about 3.6

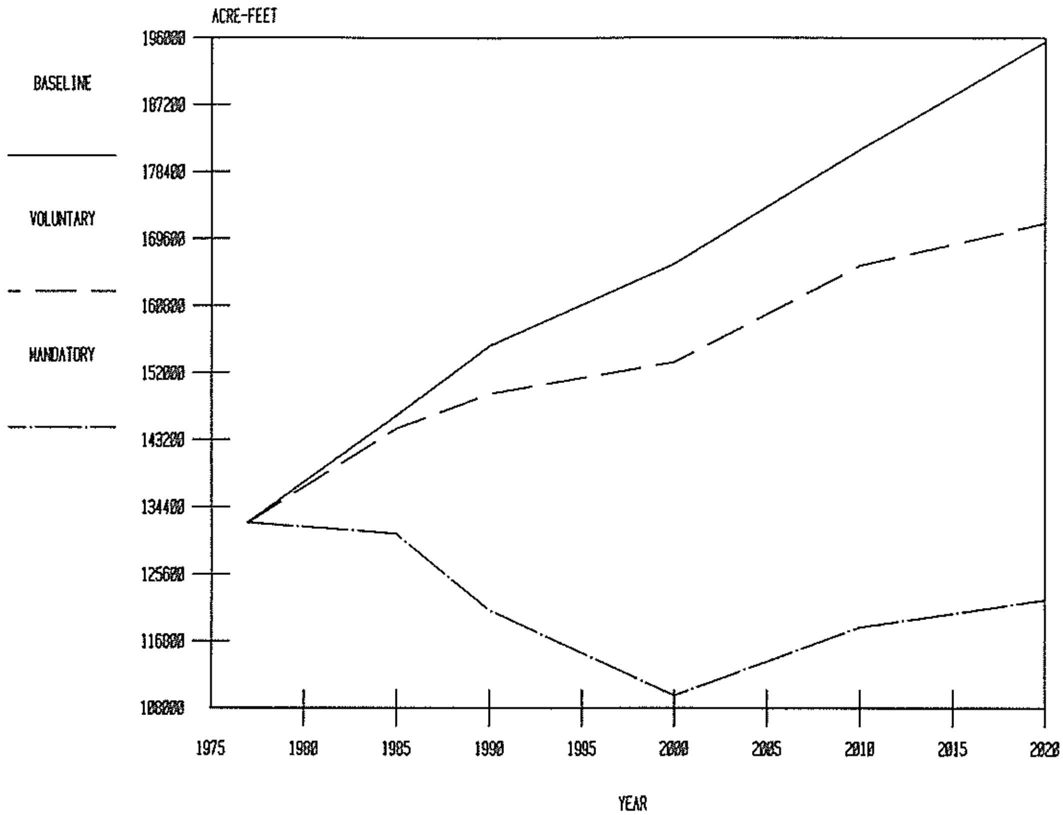

Figure 5. Quantity of Irrigation Applied, Union and Harding Counties, New Mexico, 1977-2020.

million acres for all the management strategies. There are uniform reductions in rangeland acres of about 30,000 acres to allow the increase in cropped acreage under all strategies.

Under the baseline and voluntary strategies, significant increases in the acreage of the more profitable crops of corn, alfalfa, and wheat are expected over time due to reductions in grain sorghum acreages and increases in the acreage cultivated (Table 5). In Union and Harding counties, corn is the most profitable irrigated crop and has the largest acreage of any irrigated crop in all the time periods. This is the case under all management alternatives.

Under the mandatory strategy, significant shifts are expected in the cropping pattern over time (Table 5). While corn steadily increases in acreage, alfalfa, grain sorghum, and wheat acreages exhibit significant changes over time. After 2000, advances in irrigation technology are expected to permit the alfalfa acreage to increase, thereby forcing

Table 5. Irrigated Cropland Acreages by Crop by Management Strategy for Selected Years, Union and Harding Counties, New Mexico, 1977-2020.

Strategy and Crop	1977	1985	1990	2000	2010	2020
	(irrigated acres)					
Baseline	52,397	57,956	60,774	66,524	74,274	82,024
Alfalfa	9,071	11,974	14,174	15,324	16,874	18,424
Corn (grain)	17,430	24,376	29,125	32,000	35,875	39,750
Grain Sorghum	16,966	17,174	0	0	0	0
Wheat	8,930	4,432	17,475	19,200	21,525	23,850
Voluntary	52,397	58,468	61,375	67,320	74,570	83,000
Alfalfa	9,071	12,486	14,775	16,120	17,570	19,400
Corn (grain)	17,430	24,376	29,125	32,000	35,625	39,750
Grain Sorghum	16,966	17,174	0	0	0	0
Wheat	8,930	4,432	17,475	19,200	21,375	23,850
Mandatory	52,397	56,119	52,341	55,522	62,845	64,938
Alfalfa	9,071	12,094	3,118	3,320	15,225	15,788
Corn (grain)	17,430	23,339	24,611	26,101	29,762	30,719
Grain Sorghum	16,966	16,443	0	20,881	17,857	0
Wheat	8,930	4,243	24,611	5,220	0	18,431
Importation	52,397	58,468	61,375	67,320	74,570	83,000
Alfalfa	9,071	12,486	14,775	16,120	17,570	19,400
Corn (grain)	17,430	24,376	29,125	32,000	35,625	39,750
Grain Sorghum	16,966	17,174	0	0	0	0
Wheat	8,930	4,432	17,475	19,200	21,375	23,850

the grain sorghum or wheat acreages to be reduced. The acreage in grain sorghum and wheat shift from one crop to another depending on the relative profitability and water use.

Sensitivity Analysis

Sensitivity analyses were performed for three key on-farm assumptions to determine the effect on returns of an increase or decrease of crop prices, crop yields, and energy costs. Under all six alternatives, no change is expected in the acreage irrigated and only minor changes in irrigation water applications. There are, however, expected changes in both the irrigated value of production and returns to land and management for each alternative (Table 6).

Table 6. Effect of Sensitivity Analysis on Irrigated Value of Production and Returns to Land and Management.

Item	Changes From Baseline Irrigated Value of Production ($million)	(percent)	Changes From Baseline Irrigated Returns to Land and Management ($million)	(percent)
Crop Prices				
Increased	+2.4	+ 5.9	+ 2.4	+14.0
Decreased	-2.4	- 5.9	- 2.4	-13.9
Crop Yields				
Increased	+8.0	+19.3	+ 8.0	+45.6
Decreased	-8.0	-19.3	- 8.0	-45.7
Energy Costs				
Increased	0.0	0.0	-12.6	-72.2
Decreased	0.0	0.0	+ 1.5	+ 8.7

The sensitivity analysis indicates that changes in crop yields will have the greatest impacts on the value of production. The returns to land and management were effected the most by increases in energy prices. Changes in crop prices and decreased energy costs will have only slight impacts on both the value of production and returns. The analysis also indicates that with changed crop price and yield conditions, the percentage change in returns to land and management is equal to the change in the value of production. This implies that farmers "pass through" changes in output value and that in Union and Harding counties a change in sales revenues will directly affect profitability. In Union and Harding counties, farmers don't have the option of reducing the impacts of these variables by changing crops.

Regional Impacts

Baseline

The baseline assumes the continuation of current trends and no new public agricultural policies or programs. Under the baseline, the continuation of present trends in water conservation is expected to result in water savings of about 10 percent on sprinkler-irrigated lands over the study period. The on-farm impact results and the energy impact results were incorporated into the county impacts analysis.

Gross Output

The total gross output of all goods and services projected for Union and Harding counties' economies is reported in Table 7. It was about $390 million in 1977. It is projected to be $484 million in 1985, $525 million in 1990, $586 million in 2000, and $725 million in 2020. The economy of Union and Harding counties is estimated to be predominantly agricultural throughout the period (Figure 6).

Agricultural. The agricultural sectors are expected to increase between 1977 and 2020 with about $343 million in 1977 and $545 million in 2020. This growth is projected to be relatively stable over the period (Figure 6). The agricultural sectors accounted for about 88 percent of the total output in 1977 and are projected to account for about 75 percent in 2020.

Mining. The mining sectors (primarily CO_2 and other mining) are projected to have a significant impact on the local economy by 2020 (Figure 6). In 1977, the mining sectors accounted for about $7 million, or about 2 percent of the total, but are expected to increase to about $16 million in 2000 and $34 million in 2020. Additional CO_2 development is projected for northeastern New Mexico. Huge capital investments--from $400 million minimum up to $1.5 billion--will be necessary for development of 300 to 1,000 wells and the construction of a 200 to 300 mile pipeline to the Permian/Delaware Basin of Texas and southeastern New Mexico. There is essentially no oil or gas production in Union and Harding counties and none is projected.

Electrical Production. There is limited electricity production in Union County (City of Clayton). However, by the year 1990, the 6.7 MW plant is expected to be used only for peak or stand-by electricity production.

Manufacturing. The manufacturing sectors are projected to increase from $3 million in 1977 to about $11 million in 2020. The contribution of the manufacturing sectors to the total is expected to be about 1 percent throughout the period (Table 7).

Table 7. Gross Output by Major Sector for Each of the Alternative Management Strategies, Union and Harding Counties, New Mexico, 1977-2020.

Sector	Gross Output ($1977)				
	1977	1985	1990	2000	2020
	(millions of dollars)				
Baseline					
Agriculture	343.051	423.473	451.455	484.708	544.814
Mining	6.870	9.171	11.464	16.057	33.586
Manufacturing	2.981	3.979	4.974	6.967	10.968
TCU*	4.789	6.393	7.991	11.193	17.620
Construction	9.271	10.662	12.052	15.761	19.469
FIRE**	3.887	4.470	5.053	6.608	8.163
Trade	10.599	14.149	17.687	24.773	58.996
Services	8.489	11.332	14.166	19.841	31.233
Total	389.937	483.629	524.842	585.908	724.849
Voluntary					
Agriculture	343.051	423.468	452.251	484.104	544.891
Mining	6.870	9.171	11.464	16.057	33.586
Manufacturing	2.981	3.979	4.974	6.967	10.968
TCU*	4.789	6.393	7.991	11.193	17.620
Construction	9.271	10.662	12.052	15.761	19.458
FIRE**	3.887	4.470	5.053	6.608	8.163
Trade	10.599	14.149	17.687	24.773	58.996
Services	8.489	11.332	14.166	19.841	31.233
Total	389.937	483.624	525.638	585.304	724.915
Mandatory					
Agriculture	343.051	423.562	452.406	485.520	546.000
Mining	6.870	9.171	11.464	16.057	33.589
Manufacturing	2.981	3.979	4.974	6.969	10.976
TCU*	4.789	6.400	8.008	11.292	17.949
Construction	9.271	10.662	12.055	15.776	19.557
FIRE**	3.887	4.472	5.057	6.630	8.248
Trade	10.599	14.151	17.697	24.821	59.412
Services	8.489	11.335	14.174	19.887	31.523
Total	389.937	483.732	525.835	586.952	727.254
Importation					
Agriculture	343.051	423.468	452.251	484.948	545.390
Mining	6.870	9.171	11.464	16.058	33.594
Manufacturing	2.981	3.979	4.974	6.971	10.984
TCU*	4.789	6.393	7.991	11.298	18.059
Construction	9.271	10.662	12.052	15.862	19.810
FIRE**	3.887	4.470	5.053	6.651	8.383
Trade	10.599	14.149	17.687	24.911	60.208
Services	8.489	11.332	14.166	19.946	31.931
Total	389.937	483.624	525.638	586.645	728.359

* Transportation, Communication, and Utilities.
** Finance, Insurance, and Real Estate.

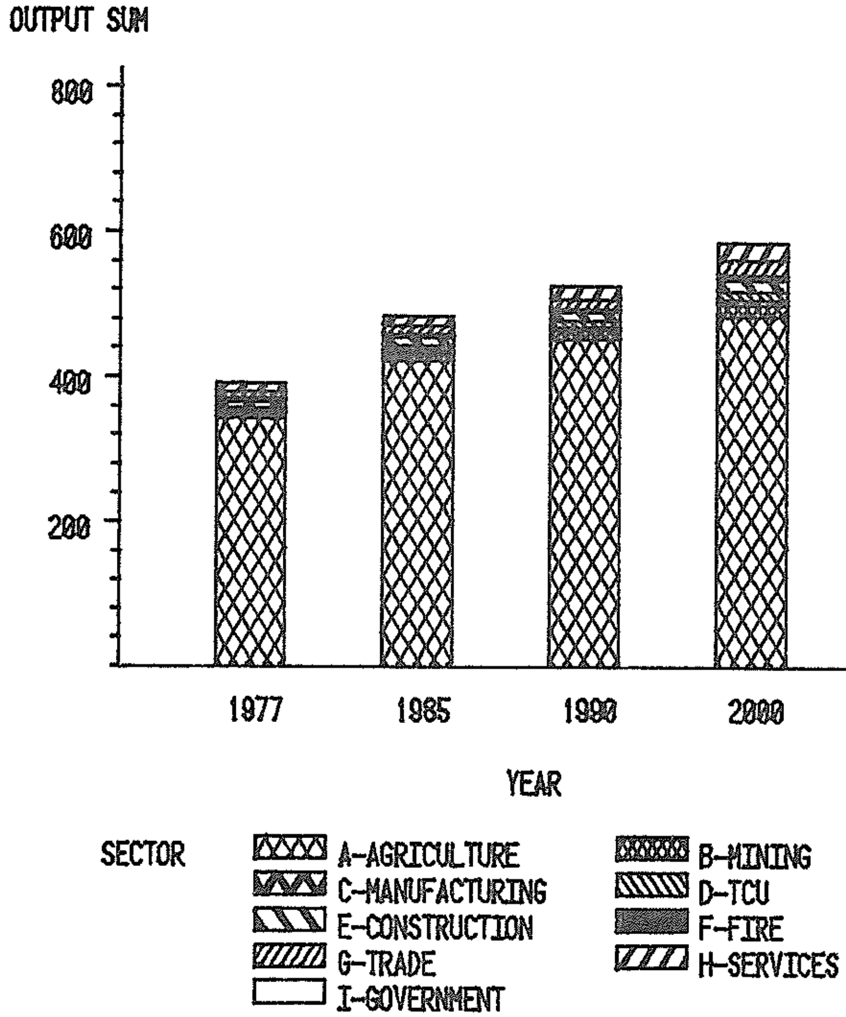

Figure 6. Projected Gross Output for Union and Harding Counties, Baseline Conditions, 1977-2020.

Transportation, Communication, and Utilities (TCU). The TCU sectors, taken together, generally show an increase over the period. These sectors are projected to increase from $5 million in 1977 to $18 million in 2020 (Table 7). The contribution of these sectors to the total was about 1 percent in 1977 and is expected to reach almost 2.5 percent in 2020.

Construction. The construction sectors are projected to increase gradually over the period (Figure 6). These sectors accounted for about $9 million in 1977. They are projected to reach $19 million in 2020.

Finance, Insurance, and Real Estate (FIRE). The FIRE sectors are projected to increase from about $4 million in 1977 to about $8 million in 2020 (Table 7).

Trade. The trade sector is expected to increase significantly over the period from about $11 million in 1977 to about $59 million in 2020 (Table 7). In 1977, it accounted for about 3 percent of the total and by 2020 it is projected to be about 8 percent.

Service. The service sectors are also projected to expand between 1977 and 2020 with about $8 million in 1977 and $37 million in 2020 (Table 7). They accounted for about 2 percent of the total in 1977 and are projected to account for about 4 percent in 2020.

Employment

Total employment in the form of jobs for the baseline and each alternative by major sector is reported in Table 8. Employment projected for the baseline is summarized by major sector in Figure 7. The total jobs were 3,589 in 1977, and are expected to increase to 4,189 in 1985; 4,351 in 1990; 4,565 in 2000; and 5,032 by 2020. Agriculture is the largest employer throughout the period. It accounted for about 50 percent in 1977 and is expected to be about 42 percent in 1985, 38 percent in 1990, 37 percent in 2000, and 31 percent in 2020. Mining employed about 1 percent in 1977, and is expected to employ 2 percent by 2020. The trade sectors employed 18 percent in 1977 and are expected to employ 21 percent in 1985. They are expected to employ 22 percent in 1990 and 2000, and 26 percent in 2020. The government sector accounted for about 11 percent of the jobs in 1977, accounts for 14 percent in 1985 and 1990, then decreases to 10 percent in 2000 and 7 percent in 2020. Construction provided about 7 percent of the jobs in 1977, accounts for 8 percent in 1985, 9 percent in 1990, 11 percent in 2000, and 12 percent in 2020 (Table 8).

The Bravo Dome field spans portions of Harding, Quay, and Union counties and is expected to have an impact upon employment in these counties. CO_2 development would diversify the economic base in the predominantly ranching area. The project, now slated to begin about 1985 and produce for 40-50 years, would require 100 full-time operators

Table 8. Employment by Major Sector for Each of the Alternative Management Strategies, Union and Harding Counties, New Mexico, 1977-2020.

Sector	Jobs 1977	1985	1990	2000	2020
	(number of jobs)				
Baseline					
Agriculture	1,803	1,771	1,670	1,675	1,542
Mining	26	45	56	68	82
Manufacturing	32	48	46	42	38
TCU*	74	110	126	130	111
Construction	261	339	379	486	583
FIRE**	65	75	82	102	113
Trade	660	862	957	988	1,291
Services	267	373	462	624	911
Government	401	566	573	450	361
Total	3,589	4,189	4,351	4,565	5,032
Voluntary					
Agriculture	1,803	1,849	1,757	1,714	1,684
Mining	26	45	56	68	82
Manufacturing	32	48	46	42	38
TCU*	74	111	126	132	111
Construction	261	340	381	490	585
FIRE**	65	75	83	102	113
Trade	660	864	965	998	1,297
Services	267	375	465	630	916
Government	401	570	576	453	362
Total	3,589	4,277	4,455	4,629	5,188
Mandatory					
Agriculture	1,803	1,785	1,694	1,627	1,592
Mining	26	45	56	68	82
Manufacturing	32	48	46	42	38
TCU*	74	112	126	133	113
Construction	261	340	381	490	588
FIRE**	65	75	83	103	114
Trade	660	865	966	1,000	1,307
Services	267	375	466	631	924
Government	401	570	576	453	364
Total	3,589	4,215	4,394	4,547	5,122
Importation					
Agriculture	1,803	1,849	1,753	1,836	1,834
Mining	26	45	56	68	82
Manufacturing	32	48	46	42	38
TCU*	74	111	126	133	114
Construction	261	340	381	493	596
FIRE**	65	75	83	103	116
Trade	660	864	965	1,003	1,325
Services	267	375	465	633	936
Government	401	570	576	454	367
Total	3,589	4,277	4,451	4,765	5,408

* Transportation, Communication, and Utilities.
** Finance, Insurance, and Real Estate.

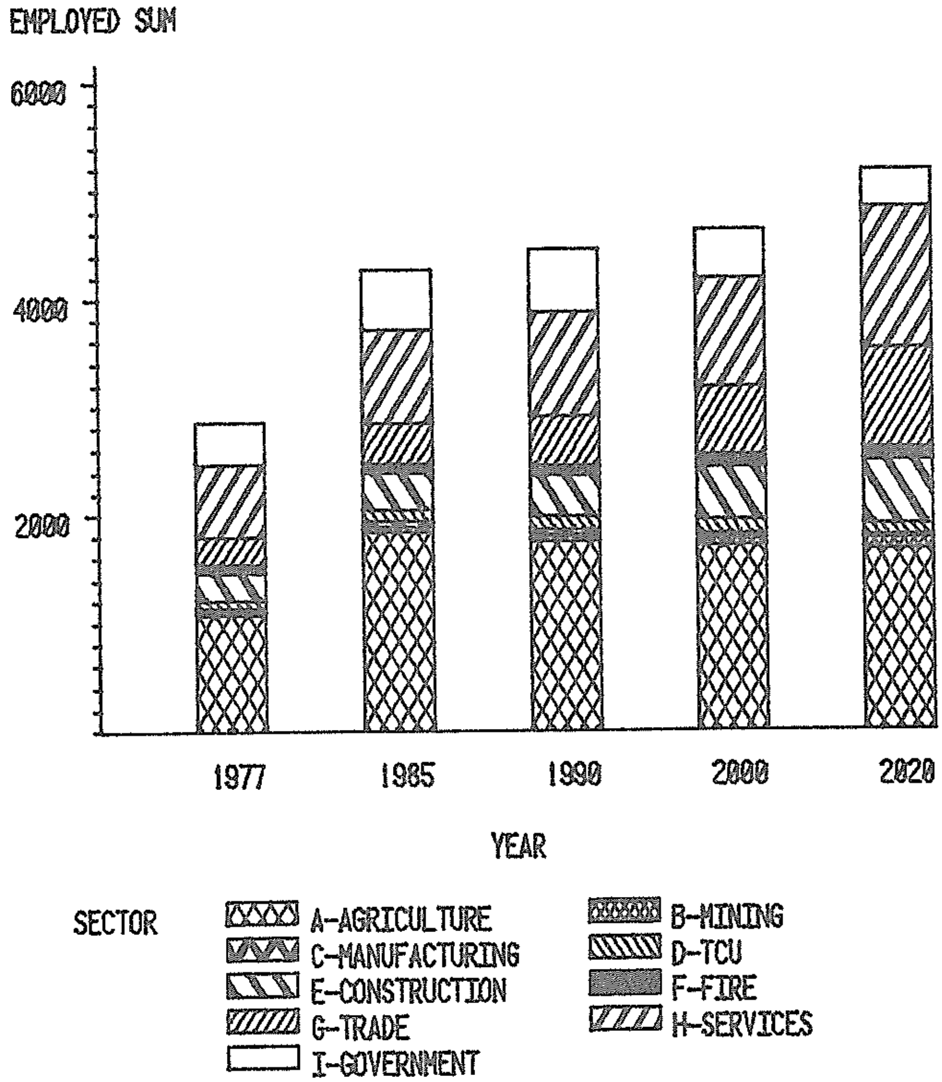

Figure 7. Projected Employment for Union and Harding Counties.

and some 300 construction workers. Additional employment opportunities are expected to be generated in the local service sector. It appears likely that a number of these jobs will be filled by imported labor. While the two counties and the state would receive economic benefits from the project, environmental impacts such as damage to the grassland and potentially adverse socioeconomic impacts are serious factors which might concern the local residents.

Population

The total population projected for the two counties for the baseline and alternative management strategies is presented in Table 9. The region was estimated to have about 13,131 people in 1977. Population is expected to decrease to 12,143 in 1985; then increase to 13,241 in 1990; 15,498 in 2000; and 16,945 in 2020. Between 1977 and 1985, the population is projected to decrease by 988, or about 7.5 percent. Between 1985 and 2020, the population is projected to increase by 4,802. This is an increase of about 40 percent.

Alternative Management Strategies

Gross Output

The gross output by major sector for each of the alternative management strategies is also summarized in Table 7. For 1977, all of the output estimates for the management strategies were the same as the baseline.

Any differences in gross output between the management strategies arises because of changes in the agricultural and mining sectors. The voluntary and importation strategies are both projected to result in output levels slightly below baseline in 1985 and 1990. Under the mandatory strategy, output is projected to be slightly above the baseline. In 2020 under the voluntary strategy, output is estimated to be $66,000 more than under the baseline. This difference is due to $77,000 more output in the agricultural sectors and $10,000 less output in the construction sectors.

In 2020, the mandatory strategy is projected to be about $2.405 million higher than the baseline. The importation strategy results in $3.510 million more than the baseline in 2020. The importation strategy results in a higher level of output in all of the sectors. This is due to the availability of imported water in the Ogallala region which results in more output in the agricultural sectors (primarily cattle feedlots) sufficient to stimulate the rest of the economy.

Table 9. Summary of Population Projections for Union and Harding Counties for Each of the Management Strategies, 1977-2020.

Strategy	Population Projection 1977	1985	1990	2000	2020
Baseline	13,131	12,143	13,241	15,498	16,945
Voluntary	13,131	12,383	13,553	15,685	17,478
Mandatory	13,131	12,204	13,369	15,400	17,237
Importation	13,131	12,383	13,542	16,116	18,147

Employment

Employment in the form of jobs for each of the alternative management strategies is also summarized in Table 8 by major sector. The number of jobs was the same for all management strategies in 1977.

The voluntary strategy results in 88 more jobs than under baseline in 1985 and 104 more in 1990, but is projected to have 64 more jobs in 2000 and 156 more in 2020. The number of jobs in all of the sectors is projected to be greater for the voluntary strategy than for baseline.

The mandatory strategy results in higher levels of employment than baseline through 1990, but they are slightly less in 2000, and slightly higher in 2020. The importation strategy results in the highest employment levels in 2000 and 2020 with 200 more jobs in 2000 and 376 more in 2020 than under the baseline. All of the sectors respond with higher levels of employment as a result of the stimulant that the imported water is projected to have on the agricultural economy.

Population

The total population for each of the management strategies is also summarized in Table 9. For 1977, all of the projections for the management strategies were the same. In 1985, the voluntary and importation strategies are projected to result in 240 more people than the baseline, and under mandatory 61 more than baseline. In 1990, the voluntary strategy is expected to result in 312 more people than the baseline, and mandatory is projected to result in 128 more people than under the baseline. Under the importation strategy, population is projected to increase by 311 more people than under baseline. In 2000, the voluntary strategy is expected to result in 187 more people than under baseline, mandatory to have 98 less than baseline, and importation to have 618 more than baseline. In 2020, voluntary is expected to have 533 more people than under baseline, mandatory to have 292 more, and importation to have 1,202 more than under baseline. The importation strategy is expected to result in the greatest population in the counties in 2000 and 2020.

SUMMARY

In Union and Harding counties, a continuation of a "business as usual" (baseline) policy is estimated to result in slightly reduced irrigated acreage, value of production, and returns to land and management when compared to the voluntary strategy. Baseline also results in the greatest irrigation water diversions of any strategy. If voluntary water demand reduction policies are implemented, the greatest irrigated acreage, the greatest value of production, and the greatest returns over the study period are expected.

The implementation of a mandatory water supply reduction policy in Union and Harding counties is expected to result in a 22 percent decrease in acreage irrigated. However, this would be accomplished with the greatest reduction in water diversions from the baseline. There also are significant reductions in irrigated value of production ($10.5 million) and returns to land and management ($3.8 million) when compared to the baseline due to changes in cropping patterns and levels of irrigation water applications which alter yield and acreage.

If the natural water supply in the High Plains is augmented with imported water from adjacent areas during the last half of the study period, it is anticipated that this policy will result in slightly negative impacts on irrigated and dry agricultural sectors in Union and Harding counties. Since exhaustion is not projected for the ground water supply in Union and Harding counties in the study period, no land is restored to irrigation and the acreage irrigated is the same as the voluntary strategies. There is, however, a reduction in crop prices from increased six-state regional production from imported water. This has the effect of reducing the on-farm value of production and returns while increasing the other agriculture sectors in Union and Harding counties.

The total gross output of all goods and services produced in Union and Harding counties was about $390 million in 1977. It is projected to be $484 million in 1985, $525 million in 1990, $586 million in 2000, and $725 million in 2020 for the baseline.

The differences in gross output among the management strategies are due to changes in the agricultural and mining sectors. Changes such as the increased output in agriculture and mining results in higher levels of output in the rest of the economy.

In all strategies, the output levels are only slightly different from the baseline. By 2020, the voluntary strategy is only $66,000 greater than the baseline, mandatory is $2.405 million more than the baseline, and the importation strategy is $3.510 million more than the baseline. The agricultural sectors account for the majority of the output throughout the period. They generally increase throughout the period with about $343 million in 1977 and about $545 million in 2020. In 1977, the agricultural sectors accounted for about 88 percent of the total output, but by 2020 they are expected to decline to about 75 percent due to the expansion in the other sectors.

The employment levels projected for the baseline and each management strategy are also summarized by major sector in Table 8. These levels follow a similar pattern as the output with essentially minor differences between the strategies and baseline. The voluntary strategy is estimated to result in 156 more jobs than baseline in 2020. The mandatory strategy is projected to have 90 more jobs than baseline, and the importation strategy is projected to have 376 more jobs than baseline. These levels are insignificant when compared to the change in employment over the period. The employment is projected to increase from about 3,589 jobs in 1977 to a peak of 5,032 in 2020.

The population of Union and Harding counties is projected to follow a similar pattern as output and employment, with about 13,131 in 1977, decreasing to about 12,143 in 1985, then increasing to 13,241 in 1990, 15,498 in 2000, and 16,945 in 2020. The management strategies are projected to cause a slightly higher population than the baseline throughout the period. The importation strategy results in the highest level with about 1,202 more than the baseline in 2020.

REFERENCES

Akin, P. D., and Jones, D. M. 1979. The Ogallala and Closely Associated Aquifers in the High Plains in New Mexico, (Study Elements A-3.1 and A-3.3): New Mexico Interstate Stream Commission.

Ash, S. R. 1961. Maps of Northern Lea County, New Mexico, showing (1) topography; (2) contour on the water table and the post-Mesozoic erosional surface; and (3) saturated thickness of the formation of Genozoic age, the approximate depths to water in 1952, and the chemical quality of the ground water: U.S. Geological Survey Open-File Maps; 6 sheets.

Black and Veatch. 1980. Energy Price Projections, Black and Veatch Consulting Engineers, Kansas City, MO, April.

Black and Veatch. 1980. Energy Price Projections Methodology, Black and Veatch Consulting Engineers, Kansas City, MO, April.

Black and Veatch. 1980. Energy Production Projections, Black and Veatch Consulting Engineers, Kansas City, MO, December.

Black and Veatch. 1981. Projections of Energy Production and Directly Associated Water Consumption, Black and Veatch Consulting Engineers, Kansas City, MO, January.

Brown, F. L., et al. 1980. An Energy Management System for the State of New Mexico, Bureau of Business and Economic Research, University of New Mexico, Albuquerque, NM.

Camp, Dresser and McKee. 1982. Agriculture and Water Use Management and Technology Assessments, Camp, Dresser and McKee, Austin, TX.

Creel, B. J., et al. 1982. New Mexico High Plains Ogallala Aquifer Study--Regional Impacts, New Mexico Water Resources Research Institute (NMWRRI) Work Task Report A-3.14 through A-3.17, Contract Number (DOC) CO-A01-78-00-2550 to High Plains Associates.

Havens, J. S. 1966. Recharge Studies on the High Plains in Northern Lea County, New Mexico, U.S. Geological Survey Water-Supply Paper 1819-F: U.S. Geological Survey Open-File Report, 82 pp.

High Plains Associates. 1982. Six-State High Plains Ogallala Aquifer Regional Resources Study, Camp, Dresser and McKee, Austin, TX.

Lansford, R. R., et al. 1980. Costs and Returns for Producing Selected Irrigated and Dryland Crops on Farms with Above-Average Management in Union and Harding Counties, 1979, New Mexico Agricultural Experiment Station Research Report 427.

Lansford, R. R., et al. 1980. Sources of Irrigation Water and Irrigated and Dry Cropland Acreages in New Mexico by County, 1974-1979, New Mexico Agricultural Experiment Station Research Report 422.

Lansford, R. R., et al. 1981. Sources of Irrigation Water and Irrigated and Dry Cropland Acreages in New Mexico by County, 1975-1980, New Mexico Agricultural Experiment Station Research Report 454.

Lansford, R. R., and N. R. Gollehon. 1980. Model Assumptions and Information--Ogallala High Plains Study, NMWRRI Work Task Report Number A-1.3 through A-1.7, Contract Number (DOC) CO-A01-78-00-2550 to High Plains Associates.

Lansford, R. R., et al. 1981. High Plains-Ogallala Aquifer Study On-Farm Results, New Mexico, NMWRRI Work Task Report A-1.9 and A-1.10, Contract No. (DOC) CO-A01-78-00-2550 to High Plains Associates: Camp, Dresser and McKee, Inc.

Lansford, R. R., et al. 1982. High Plains-Ogallala Aquifer Study, Lea County, New Mexico, New Mexico Water Resources Research Institute Report No. 146, New Mexico State University.

Lansford, R. R., et al. 1982. High Plains-Ogallala Aquifer Study, Curry County, New Mexico, New Mexico Water Resources Research Institute Report No. 147, New Mexico State University.

Lansford, R. R., et al. 1982. High Plains-Ogallala Aquifer Study, Roosevelt County, New Mexico, New Mexico Water Resources Research Institute Report No. 148, New Mexico State University.

Lansford, R. R., et al. 1982. High Plains-Ogallala Aquifer Study, Quay County, New Mexico, New Mexico Water Resources Research Institute Report No. 149, New Mexico State University.

Lansford, R. R., et al. 1982. High Plains-Ogallala Aquifer Study, New Mexico, New Mexico Water Resources Research Institute Report No. 151, New Mexico State University.

Miller, E., and J. M. Hill. 1981. Energy Production and Consumption Impacts, Work Task Report A-2, The New Mexico Energy and Minerals Department, Contract Number (DOC) CO-A01-78-00-2550 to High Plains Associates, Santa Fe, NM.

New Mexico Crop and Livestock Reporting Service. 1978. New Mexico Agricultural Statistics, 1977, Vol. VIII, New Mexico Department of Agriculture, New Mexico State University, Las Cruces.

New Mexico Environmental Improvement Division. 1976. Point Source Map - Southern High Plains, New Mexico Environmental Improvement Division, Santa Fe, NM.

New Mexico Interstate Stream Commission. 1979. Plan of Work for New Mexico State Level Research on the Six-State High Plains-Ogallala Aquifer Study, Santa Fe, NM.

New Mexico Interstate Stream Commission (NMISC) and the New Mexico State Engineer Office. 1975. County Profiles - Water Resources Assessment for Planning Purposes - Lea County, New Mexico Interstate Stream Commission and New Mexico State Engineer, Santa Fe, NM.

New Mexico Interstate Stream Commission and the New Mexico State Engineer Office. 1981. Demands and Available Supplies for Alternative Development Strategies in the Southern and Northern Subregions in New Mexico, New Mexico Interstate Stream Commission, Santa Fe, NM.

New Mexico Interstate Stream Commission and the New Mexico State Engineer Office. 1981. Response of the Ogallala Aquifer to Projected Water Demands for Alternative Development Strategies in the Southern and Northern Subregions in New Mexico, New Mexico Interstate Stream Commission.

Quance, L. 1980. The National/Inter-Regional Agricultural Projections (NIRAP) System: An Executive Briefing, International Economics Division, ESCS, USDA, Washington, DC.

Sorensen, E. F. 1977. Water Use by Categories in New Mexico Counties and River Basins and Irrigated and Dry Cropland Acreage in 1975, New Mexico State Engineer Technical Report 44, Santa Fe, NM.

U.S. Army Corps of Engineers. 1982. Water Transfer Elements of High Plains-Ogallala Aquifer Study, Southwest Regional Office, Dallas, TX.

Young, P. C., and P. M. Ritz. 1980. Updated Input-Output Table of the U.S. Economy: 1972, Bureau of Economic Analysis, Interindustry Economics Division, BE-51, U.S. Department of Commerce, Washington, DC.

APPENDIX A

HYDROLOGIC AND IRRIGATION SYSTEMS INFORMATION

Table A-1. Baseline Conditions--Hydrologic and Irrigation Systems Information, Union and Harding Counties, New Mexico, 1977.

Item	Unit of Measure	1977 Estimate
Hydrologic Information		
Saturated thickness	feet	50
Maximum irrigated acreage	acres	45,500
Depth-to-water	feet	200
Average water withdrawals (1977 base)	acre-feet	113,500
Average water decline	ft./yr.	.30
Gallons per minute		
flood	gpm	--
sprinkler	gpm	900
Specific capacity	gpm/ft. drawdown	40
Irrigation Systems		
Type		
flood	percent	--
sprinkler	percent	100
Pumping plant fuels		
natural gas	percent	78
electricity	percent	5
diesel	percent	10
LPG	percent	7
Average pumping plant efficiencies*		
natural gas	percent	11.5
electricity	percent	55.1
diesel	percent	16.6
LPG	percent	15.5

* Good efficiencies were considered to be 13.8 percent for natural gas; 66.1 percent for electricity; 19.9 percent for diesel; and 18.6 percent for LPG.

APPENDIX B
SUMMARY OF ON-FARM IMPACTS

Table B-1. Summary of On-Farm Impacts, Union and Harding Counties, New Mexico, 1977-2020--Baseline.

Item	Unit	1977	1985	1990	2000	2010	2020
Value of Production	$1,000	55,871	73,580	78,611	86,998	94,024	101,944
Irrigated Cropland	$1,000	10,355	18,025	21,265	27,321	34,011	41,478
Dry Cropland	$1,000	2,488	3,570	4,114	4,815	5,268	5,839
Rangeland	$1,000	43,028	51,984	53,232	54,862	54,745	54,627
Returns to Land & Management	$1,000	10,250	16,159	17,283	22,180	26,663	31,969
Irrigated Cropland	$1,000	1,844	4,243	4,488	8,224	12,455	17,505
Dry Cropland	$1,000	301	912	1,290	1,986	2,383	2,827
Rangeland	$1,000	8,105	11,004	11,505	11,970	11,826	11,637
Irrigation Water							
Quantity	acre-ft	132,442	146,496	155,620	166,374	181,383	195,586
Cost	$1,000	1,998	4,007	5,511	5,683	6,292	6,801
Land Use							
Irrigated Cropland	acres	52,397	57,956	60,774	66,524	74,274	82,024
Dry Cropland	acres	50,000	50,000	50,000	50,000	50,000	50,000
Rangeland	acres	3,637,803	3,632,244	3,629,427	3,623,677	3,615,927	3,608,177
Irrigation Energy							
Natural Gas	mcf	991,579	867,853	881,274	868,779	926,785	0
Electricity	1000 kwh	0	3,860	3,925	3,865	4,122	4,359
Diesel	gallons	1,538,459	0	1,065,530	1,050,227	1,120,575	6,621,890
LP Gas	gallons	76,124	1,799,766	67,865	68,115	68,604	69,161
Irrigated Crops							
Alfalfa							
Acreage	acres	9,071	11,974	14,174	15,324	16,874	18,424
Production	ton	34,344	55,547	69,170	82,400	101,940	123,552
Irrigation Water	acre-ft	26,923	35,165	41,354	43,823	47,270	50,532
Irrigation Water Cost	dollars	335,979	834,304	1,300,905	1,341,694	1,482,845	1,601,274
Value of Production	$1,000	2,211	3,639	4,623	5,798	7,555	9,622
Returns to Land & Mgt.	$1,000	601	631	522	1,183	2,422	3,992
Corn for Grain							
Acreage	acres	17,430	24,376	29,125	32,000	35,875	39,750
Production	bu	1,917,300	3,310,253	4,237,683	5,121,559	6,089,705	7,132,984
Irrigation Water	acre-ft	46,538	63,531	74,998	80,435	88,024	95,205
Irrigation Water Cost	dollars	732,808	1,810,495	2,763,381	2,849,496	3,156,185	3,412,680
Value of Production	$1,000	4,183	9,295	12,098	15,580	19,012	22,695
Returns to Land & Mgt.	$1,000	1,045	3,116	3,474	5,738	7,853	10,235
Grain Sorghum							
Acreage	acres	16,966	17,174	0	0	0	0
Production	cwt	763,470	939,202	0	0	0	0
Irrigation Water	acre-ft	38,173	37,720	0	0	0	0
Irrigation Water Cost	dollars	601,095	1,074,924	0	0	0	0
Value of Production	$1,000	2,710	4,131	0	0	0	0
Returns to Land & Mgt.	$1,000	137	403	0	0	0	0
Wheat							
Acreage	acres	8,930	4,432	17,475	19,200	21,525	23,850
Production	bu	446,500	269,176	1,297,190	1,684,354	2,033,583	2,414,189
Irrigation Water	acre-ft	20,807	10,080	39,268	42,115	46,089	49,849
Irrigation Water Cost	dollars	327,634	287,263	1,446,894	1,491,983	1,652,564	1,786,864
Value of Production	$1,000	1,250	960	4,544	5,942	7,445	9,160
Returns to Land & Mgt.	$1,000	61	93	492	1,303	2,180	3,278
Dryland Crops							
Grain Sorghum							
Acreage	acres	22,000	27,000	10,000	30,000	30,000	10,000
Production	cwt	286,000	426,562	173,785	592,448	630,366	221,179
Value of Production	$1,000	1,057	1,929	794	2,880	3,127	1,121
Returns to Land & Mgt.	$1,000	92	517	250	1,217	1,434	548
Wheat							
Acreage	acres	28,000	23,000	40,000	20,000	20,000	40,000
Production	bu	364,000	363,194	772,005	456,179	491,272	1,052,728
Value of Production	$1,000	1,431	1,642	3,320	1,934	2,142	4,718
Returns to Land & Mgt.	$1,000	209	395	1,040	769	949	2,279
Rangeland							
Steers							
Acreage	acres	2,182,682	2,179,346	2,177,656	2,174,206	2,169,556	2,164,906
Production	1977 $	35,534	35,480	35,452	35,396	35,320	35,245
Value of Production	$1,000	35,534	42,931	43,961	45,307	45,210	45,113
Returns to Land & Mgt.	$1,000	4,889	6,710	7,016	7,303	7,221	7,096
Cows							
Acreage	acres	1,455,121	1,452,898	1,451,771	1,449,471	1,446,371	1,443,271
Production	1977 $	7,493,873	7,482,423	7,476,618	7,464,773	7,448,808	7,432,843
Value of Production	$1,000	7,494	9,054	9,271	9,555	9,534	9,514
Returns to Land & Mgt.	$1,000	3,216	4,294	4,489	4,668	4,605	4,541