June 1982

WRRI Report No. 149

HIGH PLAINS-OGALLALA AQUIFER STUDY
QUAY COUNTY, NEW MEXICO

Partial Technical Completion Report
Project Nos. 1423697 and 1345681

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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

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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

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* 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.

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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.

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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).

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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.

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 Quay County.

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

The total gross output of all goods and services for Quay County was about $77 million in 1977. It is projected to be $100 million in 1985, $116 million in 1990, $145 million in 2000, and $203 million in 2020 for the baseline. The differences in gross output among the management strategies are due to changes in the agricultural sectors.

The most important sector is agriculture which contributed about 59 percent of the total output in 1977. Even though the other sectors are projected to expand, agriculture is projected to contribute about 40 percent of the total in 2020.

The mining sectors are projected to have a minor economic impact. In 1977, the mining sectors accounted for about $118,000 of the total output; in 1985 they are projected to account for $1.9 million. By 2020, the mining activity is expected to increase to $14.5 million. The trade and service sectors are expected to expand faster than any of the other sectors. The manufacturing sectors are projected to increase from $2.6 million in 1977 to about $9.5 million in 2020.

The total employment in Quay County in 1977 was 1,865, and is expected to increase to 3,060 by 2020. Government was the largest employer in 1977 through 1990, but in 2000 and 2020 the trade sector was projected to be the most important.

The majority of the irrigated cropland in Quay County lies in the Arch-Hurley Conservancy District. The conservancy district overshadows much of the impacts the decline in the Ogallala would have in the area. Thus, the alternative management strategies basically had very little impact on the economy of Quay County. The voluntary strategy resulted in total output in 2020 of $1,000 more than the baseline. Mandatory resulted in $1.028 million more than the baseline and the importation strategy had $2.204 million more than the baseline. The impact on employment of the alternative management strategies in Quay County was also minor. The voluntary strategy resulted in 34 more jobs than baseline in 2020. The mandatory had 40 more than baseline and the importation had 111 more than baseline. Population in the county was affected similar to employment by the alternative strategies. Voluntary resulted in 120 more people than baseline in 2020, mandatory 129 more people than baseline, and importation had 337 more people than baseline in 2020.

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

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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 Quay County. For example, in Quay County irrigated cropland increased from 1,000 to 55,490 acres from 1940 to 1980 (Lansford, et al., September 1982). However, parts of Quay County already have felt the effects of a declining water supply and rising energy costs. As a result, some irrigated cropland has been abandoned.

This report presents an in-depth look at the water, energy, and related resources in Quay County, New Mexico, which is a part of the High Plains-Ogallala Aquifer Study region in New Mexico. Other reports

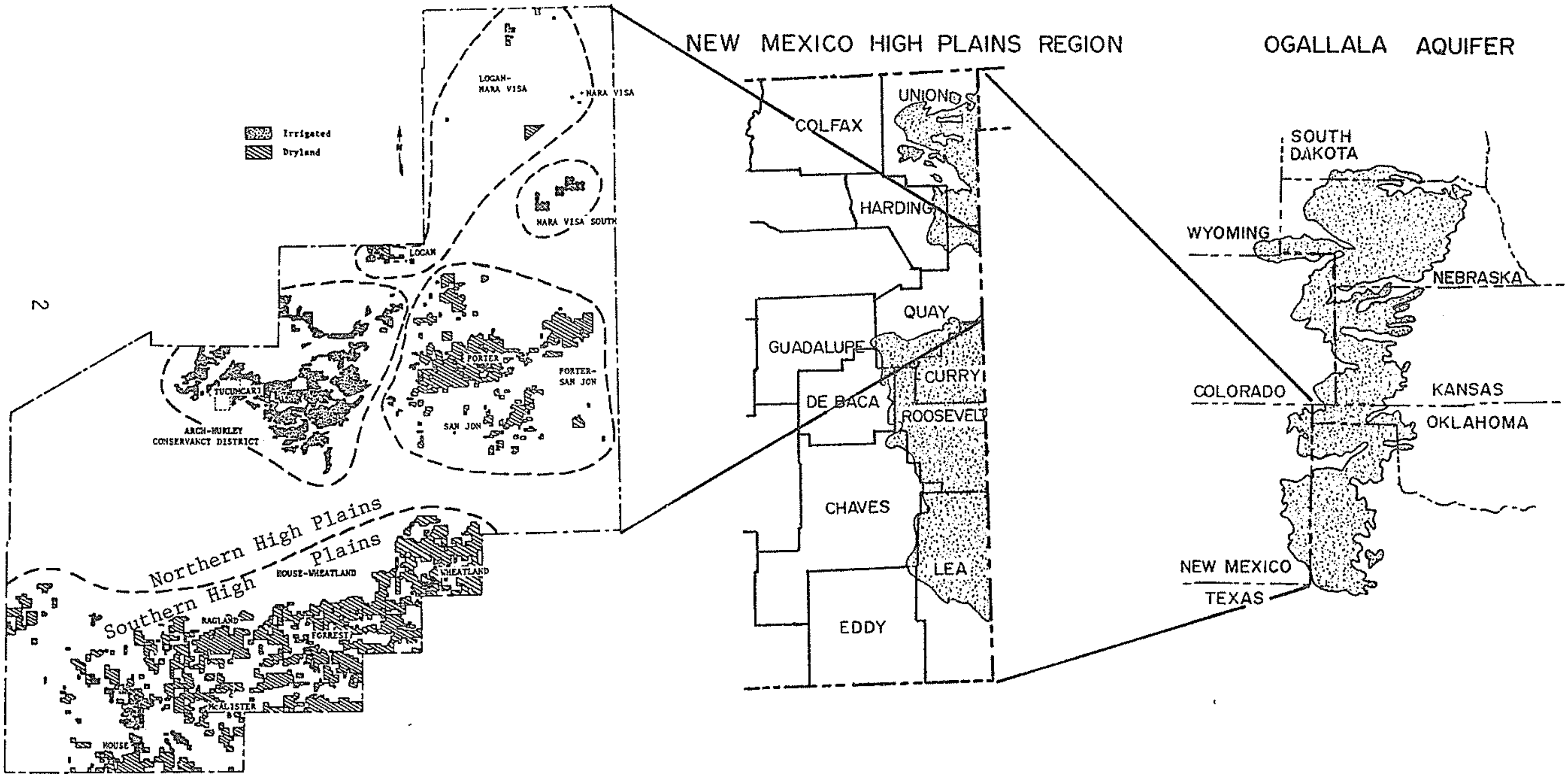

Figure 1. Ogallala Aquifer Region and New Mexico.

have been prepared for Roosevelt County, Curry County, Lea County, Union and Harding counties, and for the New Mexico 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 was consistently assumed that under the baseline neither states nor the federal government would 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 was 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 was assumed that under baseline there would be no reductions 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

Quay County, New Mexico, lies in eastern New Mexico. It is located both on the Southern and Northern High Plains (Figure 1). Quay County lies in the Arkansas-White-Red (AWR, 2,373 square miles) and Pecos River (510 square miles) basins in New Mexico (Figure 2).

Although the Red River drainage in the southern part of Quay County is included as part of the Arkansas-White-Red River Basin, the northern boundary of this small drainage delineates the edge of the Southern High Plains in New Mexico. The edge of the Southern High Plains, often called the "Llano Estacado," is formed by a caprock that is several hundred feet high just north of Cameron, but becomes indefinite a few miles to the west.

In the southwest corner, drainage is to the Pecos River and is included in the Pecos River Basin in the state. The landscape is generally flat with a few small hills and scattered playa lakes.

North of the caprock, most of the drainage is to the Canadian River which flows west to east in the northern half of the county. The landscape consists of mesas, canyons, arroyos, rolling plains, and pinon-juniper breaks on the edges of the caprock and deeper canyons. Intermittent tributaries such as Pajarito, Plaza Larga, Barranca, and Revelto creeks join the Canadian River from the south. Ute Creek joins the river from the north a few miles west of Logan. Ute Dam is located some four miles downstream from the confluence of these two streams. An extensive dune and sandhill area is located just north of the Canadian River and extends into adjacent Harding County.

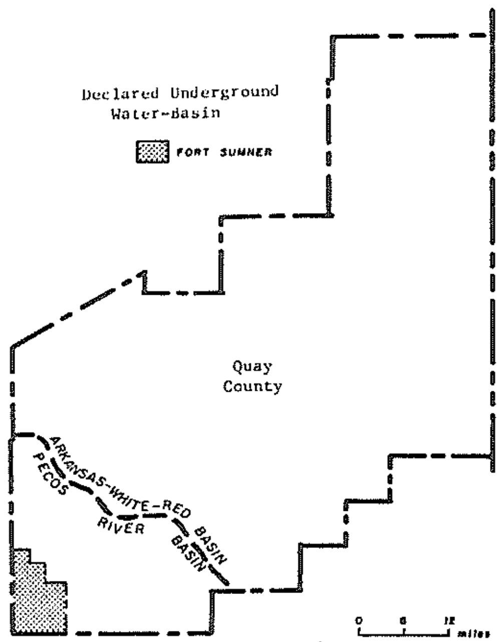

Figure 2. Declared Underground Water Basins, Quay County, New Mexico.

The highest elevation in the county is 5,290 feet (MSL) on top of Mesa Redonda. A prominent landmark--Tucumcari Mountain--is 4,975 feet in altitude. The lowest elevation is about 3,500 feet where the Canadian River leaves the county and enters Texas.

There are two life zones; namely, Upper Sonoran and Lower Sonoran. The latter zone occupies a relatively narrow strip along the Canadian River. Vegetative types include grassland, which covers most of the county; woodland (pinon, juniper) along the edges of the caprock, mesas, and canyons; and semidesert brush and grasses in the sandhill area throughout the Lower Sonoran Zone.

Climate

Quay County experiences 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

15 inches. 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 58 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 mid-April and lasts 185 to 192 days, ending in late October.

Land

Quay County consists of approximately 1.8 million acres of land. Less than 1 percent of the land is under federal ownership, about 13 percent under state ownership, and 86 percent is privately owned. Approximately 79 percent of the land in Quay County is rangeland used for grazing and 19 percent is cropland (3 percent is irrigated and 16 percent dryland). Urban and urban fringe areas and road systems comprise about 1 percent each of the county land. The remainder of the land includes 4,675 acres of inland water (NMISC, 1975).

Hydrology

The extent of the Ogallala Formation in the High Plains is outlined in Figure 1. The Ogallala is of Tertiary age and overlies older rocks of Cretaceous, Jurassic, Triassic, and Permian ages. The Ogallala is not present in the central part of Quay County. Ground water supplies in that part of Quay County where the Ogallala is missing are from rocks of Permian and Triassic ages and from local deposits of more recent alluvium.

Irrigation in the House area is achieved with water pumped from wells finished in the Ogallala Formation. Irrigation in this area began in 1936. Heavy pumping from ground water storage progressed to the mid-1950s, at which time several wells in heavily pumped areas failed. This necessitated the return to dryland farming or to crops that require less water in some areas around House.

As of January 1975, the depth-to-water in this area ranged from 25 to over 150 feet, with an average of from 70 to 100 feet from the land surface. The saturated thickness of the Ogallala ranged from 35 to 100 feet, with an average of approximately 50 feet. Irrigation wells will yield up to 50 to 700 gallons per minute, although irrigation wells yielding up to 1,600 gallons per minute occur in the area. A specific well yield of about 40 gallons per minute per foot of drawdown and pumping lift of 100 feet is common.

Water level measurements have been maintained by the U.S. Geological Survey since 1941 and reported by the State Engineer in the report series, "Water Levels in New Mexico." Irrigation well 5N 29E 08.232 was selected as being representative of the ground water response in this general area. In 1943, the depth-to-water in this well was reported as 34.19 feet, and in 1975 the depth-to-water was 62.12 feet. The general rate of decline is approximately 1.05 feet per year.

Formations other than the Ogallala in Quay County that yield large amounts of water to wells are alluvial deposits of Quaternary age, the Entrada Sandstone of Jurassic age, and the Santa Rosa Sandstone of Triassic age. The alluvium yields as much as 325 gallons per minute, and the Santa Rosa Sandstone yields from 300 up to 500 gallons per minute.

Ground water from the Entrada Sandstone and from Quaternary alluvium furnishes the water supply for Tucumcari. Ground water in the Entrada Sandstone in much of the area west of Tucumcari is under artesian pressure. High yields are obtained from the Entrada where the formation is thick and under artesian pressure.

In the Logan area, irrigation wells in the Santa Rosa Sandstone yield from 300 up to 750 gallons per minute. Some irrigation wells in this area obtain water from the alluvial deposits of Quaternary age.

Some wells near San Jon and Porter may tap perched ground water, as this area is underlain by the Chinle Formation which contains shale beds that yield little or no ground water to wells. The area of T. 21N, R. 32E north of Porter apparently has an unsaturated zone between ground water in the Chinle Formation and the Santa Rosa Sandstone. In the vicinity of Porter, the Quaternary alluvial cover and channel fill furnishes water for domestic, livestock, and irrigation purposes.

The Ogallala Formation in the vicinity of Nara Visa is overlain locally by a covering of Quaternary alluvium derived largely from the underlying rock. The thickness of this alluvial cover ranges from a few inches on some of the higher ground to more than 20 feet in some of the stream valleys. The thickness of this fill is important because present evidence suggests that any shallow ground water to be obtained in quantities large enough for irrigation will come primarily from the Quaternary fill, and not from the Ogallala Formation. Several wells were reported to encounter water-bearing gravel at relatively shallow depths of 15 to 25 feet.

Relatively little is known about aquifers in the vicinity of Nara Visa. Information from landowners in this area indicates there is no uniform horizon at which water is encountered. The yields from wells drilled to the same or similar depths in adjacent fields vary from sufficient water for irrigation to meager or none. Wells tapping the Quaternary gravel and sand deposits generally have good yields, whereas those tapping the Ogallala Formation are reported to be poor.

The principal source of recharge to the Ogallala Formation is precipitation and infiltration into the aquifer. There is some discharge of ground water by natural means, such as through springs and seeps along the escarpments and by evaporation and transpiration; however, these are probably quite small in relation to the amount of water removed from the aquifer by pumping.

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 typically hard and has an objectionably high concentration of fluoride in many areas. The hardness, in addition to a high concentration of silica, makes it somewhat objectionable for domestic uses. The water quality is satisfactory for irrigation and livestock watering.

Water Use

Ground water from the Ogallala Formation in Quay County is used for irrigation, domestic, and livestock purposes. Water for municipal and industrial purposes is obtained from other aquifers, primarily near Tucumcari.

Water Rights Administration

Surface waters of the Pecos River drainage are fully appropriated. New appropriations of surface waters within the Canadian River drainage may be permitted only in locations where no detrimental effect 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 assigned. Changes in points of diversion, places, and purposes of use may be made, provided no detrimental effect to existing rights results. Changes of existing rights or new appropriations require a permit from the State Engineer.

The extreme southwest corner of the county is within the Fort Sumner Underground Water Basin as declared by the State Engineer. 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 (see Figure 2).

Energy

Electricity

There is only one electricity generating plant with a rated capacity of 16.3 MW owned by Southwestern Public Service Co. The primary fuel for the generating plant is natural gas with oil as the alternative fuel.

The annual production was 42.3 gigawatt-hours annually from 1975 through 1978. In 1974, it was 40.3 gigawatt-hours.

Oil and Natural Gas

There is no oil or natural gas production in Quay County 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

In 1977, Quay County's value of production from the irrigated cropland was estimated to be about $602,000, from dry cropland to be about $3.6 million, and from range livestock to be about $2.0 million. Quay County accounted for only about 3 percent of the total value of production from agriculture (irrigated, dry, and rangeland) in the High

Plains region. The important irrigated crops in Quay County were grain sorghum, cotton, alfalfa, planted pasture, and small grains (New Mexico Crop and Livestock Reporting Service, 1978). The important dryland crops in 1977 were grain sorghum and wheat (Lansford, 1980).

About 70 percent of the irrigated land in Quay County is in the Arch-Hurley Conservancy District. Other irrigated areas are located in the vicinity of House, McAlister, Wheatland, Porter, Logan, and Nara Visa. The Arch-Hurley Conservancy District has about 39,000 acres of irrigated cropland; the House-Wheatland area encompasses about 8,200 acres of irrigated cropland; and the Porter-San Jon, Logan-Nara Visa, Nara Visa South, and other scattered areas contain the remaining 8,800 acres of irrigated cropland (Figure 1).

Surface water (the only source) for lands in the Arch-Hurley Conservancy District is provided by the Conchas Dam and Reservoir. The Corps of Engineers constructed and operates this facility. Irrigation water is released upon request by the district. Except for a small tract in the vicinity of Logan, irrigation supply for other lands in the county is furnished from ground water sources.

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 Quay County 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, and 2000 in Quay County. 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 Quay County through voluntary or mandatory strategies. This does not mean conservation should be abandoned in all areas of water use. However, the use of water by irrigated agriculture (about 80 percent of the total ground water withdrawals) overshadows all other uses. For the Southern High Plains (Ogallala), agriculture accounts for over 99 percent of the total water withdrawals.

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 is expected to be used for carbon dioxide for use in secondary oil

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

Strategy and Category	Year 1977	1985	1990	2000	2020
Baseline					
Withdrawals (1,000 acre-ft.)					
Irrigation	(74.4)	(71.6)	(70.6)	(73.0)	(60.8)
Ogallala Aquifer (So. High Plains)	14.0	11.2	10.0	12.3	0.0
Non-Ogallala Aquifer (No. High Plains)	60.4	60.4	60.6	60.7	60.8
Urban (Non-Ogallala Aquifer)	1.8	2.0	2.2	2.4	2.9
Rural	(0.2)	(0.3)	(0.4)	(0.4)	(0.4)
Ogallala Aquifer (So. High Plains)	0.1	0.1	0.1	0.1	0.1
Non-Ogallala Aquifer (No. High Plains)	0.1	0.2	0.3	0.3	0.3
Manufacturing (Non-Ogallala Aquifer)	0.1	0.1	0.1	0.2	0.2
Mining (Non-Ogallala Aquifer)	0.1	0.1	0.5	1.5	3.2
Power (Non-Ogallala Aquifer)	<0.1	<0.1	<0.1	<0.1	<0.1
Livestock*	(1.3)	(1.3)	(1.3)	(1.3)	(1.3)
Ogallala Aquifer (So. High Plains)	0.2	0.2	0.2	0.2	0.2
Non-Ogallala Aquifer (No. High Plains)	1.1	1.1	1.1	1.1	1.1
Recreation, Fish & Wildlife* (Non-Ogallala Aquifer)	15.3	15.3	15.3	2.3	2.3
Total Withdrawals	(93.3)	(90.8)	(90.5)	(81.2)	(71.2)
Ogallala Aquifer	14.3	11.5	10.3	12.6	0.3
Non-Ogallala Aquifer	79.0	79.3	80.2	68.6	70.9
Depth-to-water (ft.)					
Ogallala Aquifer (So. High Plains)	100.0	108.2	112.3	118.5	>125.0
Non-Ogallala Aquifer (No. High Plains)					
Porter-San Jon	60.0	60.0	60.0	60.0	60.0
Logan-Nara Visa	130.0	130.0	130.0	130.0	130.0
Nara Visa-South	300.0	300.0	300.0	300.0	300.0
Remaining saturated thickness (ft.)** (Ogallala Aquifer)	50.0	41.8	37.7	31.5	<25.0
Voluntary Strategy					
Withdrawals (1,000 acre-ft.)					
Irrigation	(74.4)	(71.0)	(69.5)	(71.2)	(60.3)
Ogallala Aquifer (So. High Plains	14.0	10.8	9.3	11.2	0.0
Non-Ogallala Aquifer (No. High Plains)	60.4	60.2	60.2	60.0	60.3
Urban (Non-Ogallala Aquifer)	1.8	1.8	2.0	2.2	2.6
Rural	(0.2)	(0.3)	(0.4)	(0.4)	(0.4)
Ogallala Aquifer (So. High Plains)	0.1	0.1	0.1	0.1	0.1
Non-Ogallala Aquifer (No. High Plains)	0.1	0.2	0.3	0.3	0.3
Manufacturing (Non-Ogallala Aquifer)	0.1	0.1	0.1	0.2	0.2
Mining (Non-Ogallala Aquifer)	0.1	0.1	0.5	1.5	3.2
Power (Non-Ogallala Aquifer)	<0.1	<0.1	<0.1	<0.1	<0.1
Livestock*	(1.3)	(1.3)	(1.3)	(1.3)	(1.3)
Ogallala Aquifer (So. High Plains)	0.2	0.2	0.2	0.2	0.2
Non-Ogallala Aquifer (No. High Plains)	1.1	1.1	1.1	1.1	1.1
Recreation, Fish & Wildlife* (Non-Ogallala Aquifer)	15.3	15.3	15.3	2.3	2.3
Total Withdrawals	(93.3)	(90.0)	(89.2)	(79.2)	(70.4)
Ogallala Aquifer	14.3	11.1	9.6	11.5	0.3
Non-Ogallala Aquifer	79.0	78.9	79.6	67.7	70.1
Depth-to-water (ft.)					
Ogallala Aquifer (So. High Plains)	100.0	107.2	110.3	117.5	>125.0
Non-Ogallala Aquifer (No. High Plains)					
Porter-San Jon	60.0	60.0	60.0	60.0	60.0
Logan-Nara Visa	130.0	130.0	130.0	130.0	130.0
Nara Visa-South	300.0	300.0	300.0	300.0	300.0
Remaining saturated thickness (ft.)** (Ogallala Aquifer)	50.0	42.8	39.7	32.5	<25.0

* 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	(74.4)	(69.0)	(65.9)	(65.1)	(65.2)
Ogallala Aquifer (So. High Plains)	14.0	9.7	7.5	7.8	7.7
Non-Ogallala Aquifer (No. High Plains)	60.4	59.3	58.4	57.3	57.5
Urban (Non-Ogallala Aquifer)	1.8	1.5	1.6	1.8	2.2
Rural	(0.2)	(0.3)	(0.4)	(0.4)	(0.4)
Ogallala Aquifer (So. High Plains)	0.1	0.1	0.1	0.1	0.1
Non-Ogallala Aquifer (No. High Plains)	0.1	0.2	0.3	0.3	0.3
Manufacturing (Non-Ogallala Aquifer)	0.1	0.1	0.1	0.2	0.2
Mining (Non-Ogallala Aquifer)	0.1	0.1	0.5	1.5	3.2
Power (Non-Ogallala Aquifer)	<0.1	<0.1	<0.1	<0.1	<0.1
Livestock*	(1.3)	(1.3)	(1.3)	(1.3)	(1.3)
Ogallala Aquifer (So. High Plains)	0.2	0.2	0.2	0.2	0.2
Non-Ogallala Aquifer (No. High Plains)	1.1	1.1	1.1	1.1	1.1
Recreation, Fish & Wildlife* (Non-Ogallala Aquifer)	15.3	15.3	15.3	2.3	2.3
Total Withdrawals	(93.3)	(87.7)	(85.2)	(72.7)	(74.9)
Ogallala Aquifer	14.3	10.0	7.8	8.1	8.0
Non-Ogallala Aquifer	79.0	77.7	77.4	64.6	66.9
Depth-to-water (ft.)					
Ogallala Aquifer (So. High Plains)	100.0	107.2	110.3	116.6	>125.0
Non-Ogallala Aquifer (No. High Plains)					
Porter-San Jon	60.0	60.0	60.0	60.0	60.0
Logan-Nara Visa	130.0	130.0	130.0	130.0	130.0
Nara Visa-South	300.0	300.0	300.0	300.0	300.0
Remaining saturated thickness (ft.)** (Ogallala Aquifer)	50.0	42.8	39.7	33.4	<25.0

* 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.

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 will 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 in Quay County are presented in Appendix Table A-1.

The estimated remaining saturated thickness resulting from irrigation from the Ogallala aquifer are 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. In order to estimate the total effect of all uses upon the saturated thickness of the Ogallala, the values in Table 2 were modified using a linear analysis to make the necessary adjustments. Results of this analysis are shown in Table 1.

On-Farm Impacts

The on-farm impacts for Quay County include a discussion of the on-farm economic impacts by management strategy (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 for the Southern and Northern High Plains portions of Quay County (see Appendix Table B-1 for a summary of baseline). Supporting

Table 2. Estimated Remaining Saturated Thickness of the Ogallala Aquifer Resulting from Irrigation, Quay County, New Mexico, 1977-2020.

Management Strategy	Year					
	1977	1985	1990	2000	2010	2020
	(feet of remaining saturated thickness)					
Baseline	50	42	38	32	<25	<25
Voluntary	50	43	40	33	25	<25
Mandatory	50	43	40	34	28	<25

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.

Because of widely varying farm characteristics in Quay County, such as irrigation water supply source, cropping patterns, and farm size, an analysis was developed for five parts of Quay County--the Southern High Plains (House-Wheatland) and the Northern High Plains consisting of the Arch-Hurley Conservancy District (surface water only), Porter-San Jon, Logan, and Nara Visa.

In Quay County, the only aquifer exhaustion is expected to be in the Southern High Plains region of the county. Thus, the only difference between the voluntary and the importation strategy for the Northern High Plains portion of the county 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.

For purposes of this analysis, the Southern High Plains (Ogallala aquifer) and the Northern High Plains areas will be discussed. In Appendix B, tables are presented for the Arch-Hurley Conservancy District, Porter-San Jon, Nara Visa South, and Logan-Nara Visa showing acreage irrigated, total water withdrawals, value of production, and returns to land and management by period.

Southern High Plains

Value of Production

The 1977 total agricultural value of production (TVP [irrigated crops, dryland crops, and rangeland]) in the Southern High Plains portion of Quay County was about $6.1 million (Figure 3). Under all the management strategies, the total value of production is expected to increase significantly until 2010 due to increasing crop yields and prices. After 2010, slight decreases are expected under the baseline and the voluntary strategies, and increases are expected under the mandatory and importation strategies. The net result over the study period under the baseline strategy was an increase of $5.6 million (93 percent) from 1977 to 2020 (Table 3). However, it must be noted that the change from a partially irrigated agricultural economy to a totally dryland agricultural economy will induce increased variance in this part of the county's agricultural TVP and income. The voluntary strategy was very similar ($9,000 more value of production) in 2020 to the baseline. Under the mandatory strategy, the TVP is projected to increase $6.4 million between 1977 and 2020 (105 percent). The value of production under the mandatory strategy was 6 percent greater than under the baseline, primarily due to the retention of some irrigated agriculture. The largest increase (109 percent) is expected to occur under the importation strategy. This is due to increases in the value of production provided by the irrigated agriculture sector resulting from imported water (Table 3).

The 1977 value of production for irrigated crops was about $602,000 (10 percent of total agricultural value of production [Figure 3]). Under both the baseline and voluntary strategies, the irrigated value of production is expected to follow the same general trend as TVP--initially increasing, due to increasing crop yields and prices, and then declining. Under the baseline and the voluntary strategies, the irrigated value of production drops to zero in 2020 due to aquifer exhaustion. Under the mandatory strategy, the irrigated value of production is expected to almost double over the study period. With importation,

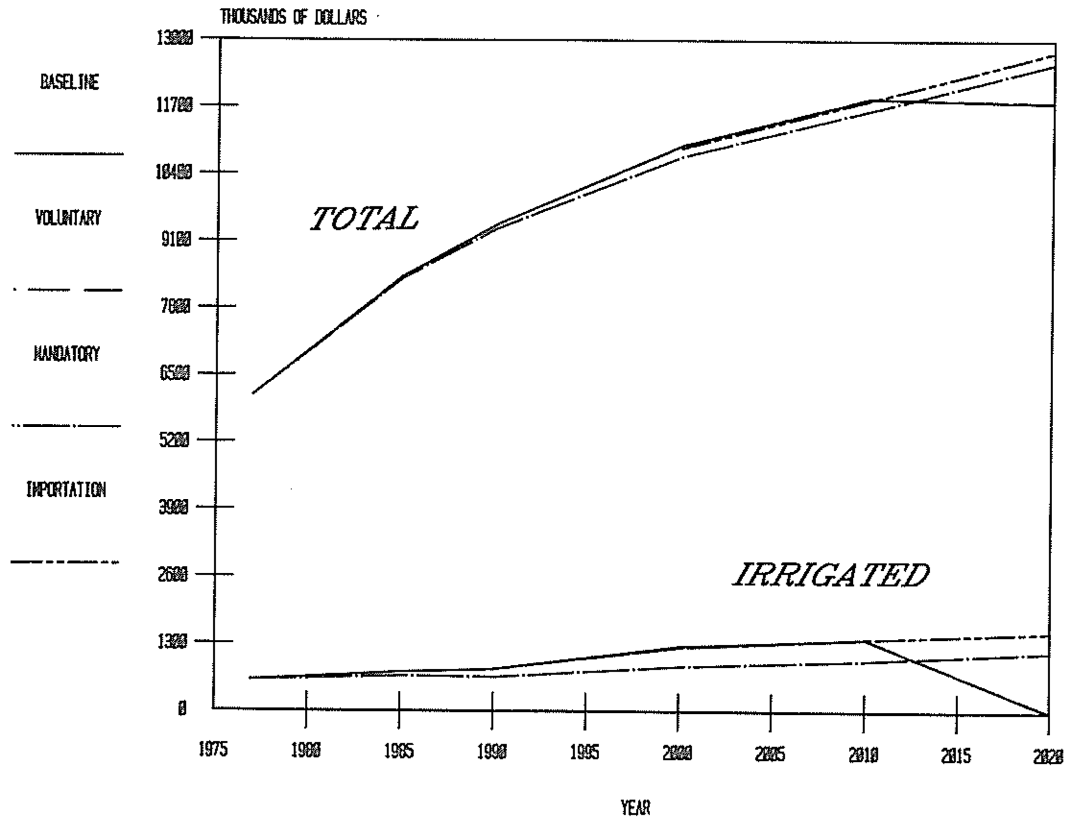

Figure 3. Total and Irrigated Value of Production for Quay County, Southern High Plains, New Mexico, 1977-2020.

the irrigated value of production is expected to increase by about 150 percent ($942,000) by 2020. This increase is due to the full restoration of irrigated lands in Quay County with imported water.

Returns to Land and Management

The total 1977 returns to land and management (irrigated crops, dryland crops, and rangeland) in the Southern High Plains portion of Quay County was about $1.3 million (Figure 4). Projections indicate significant increases in the region's returns to land and management under all strategies in all time periods. This is due to increases in the value of production caused by increases in crop yields and prices. Under the baseline and voluntary strategies, the increased returns from the dry cropland sector contribute to a great percentage of the increase in total returns to land and management. The dry cropland sector exhibits increases in returns from both higher crop yields and prices as

Table 3. Value of Production and Returns to Land and Management by Management Strategy for Selected Years, Southern High Plains, Quay County, 1977-2020.

Strategy and Item	1977	1985	1990	2000	2010	2020
	------	------	------(1,000	dollars)------	------	------
			Value of Production			
Baseline	6,125	8,414	9,421	10,968	11,869	11,799
Irrigated Cropland	602	764	819	1,272	1,408	0
Dry Cropland	3,570	5,276	6,165	7,195	7,961	9,299
Rangeland	1,953	2,374	2,438	2,500	2,500	2,500
Voluntary	6,125	8,419	9,424	10,957	11,883	11,808
Irrigated Cropland	602	757	811	1,244	1,408	0
Dry Cropland	3,570	5,288	6,175	7,213	7,975	9,308
Rangeland	1,953	2,374	2,438	2,500	2,500	2,500
Mandatory	6,125	8,383	9,346	10,754	11,643	12,563
Irrigated Cropland	602	682	655	873	988	1,165
Dry Cropland	3,570	5,321	6,244	7,360	8,133	8,880
Rangeland	1,953	2,380	2,448	2,522	2,522	2,518
Importation	6,125	8,419	9,424	10,920	11,847	12,789
Irrigated Cropland	602	757	811	1,237	1,402	1,544
Dry Cropland	3,570	5,288	6,175	7,182	7,945	8,745
Rangeland	1,953	2,374	2,438	2,500	2,500	2,500
			Returns to Land and Management*			
Baseline	1,324	2,955	3,880	5,091	5,926	6,619
Irrigated Cropland	-207	76	126	289	408	0
Dry Cropland	1,146	2,353	3,202	4,230	4,952	6,061
Rangeland	386	526	552	571	566	558
Voluntary	1,324	2,952	3,866	5,100	5,927	6,585
Irrigated Cropland	-207	81	139	317	434	0
Dry Cropland	1,146	2,344	3,176	4,211	4,927	6,027
Rangeland	386	526	552	571	566	558
Mandatory	1,324	2,963	3,885	5,103	5,908	6,743
Irrigated Cropland	-207	74	113	226	310	436
Dry Cropland	1,146	2,362	3,217	4,301	5,028	5,745
Rangeland	386	528	554	576	570	562
Importation*	1,324	2,952	3,866	5,066	5,890	6,787
Irrigated Cropland	-207	81	139	315	427	572
Dry Cropland	1,146	2,344	3,176	4,180	4,897	5,657
Rangeland	386	526	552	571	566	558

* A charge for irrigated water was not included in the importation strategy. Therefore, the returns are to land, management, and water for the years 2000, 2010, and 2020.

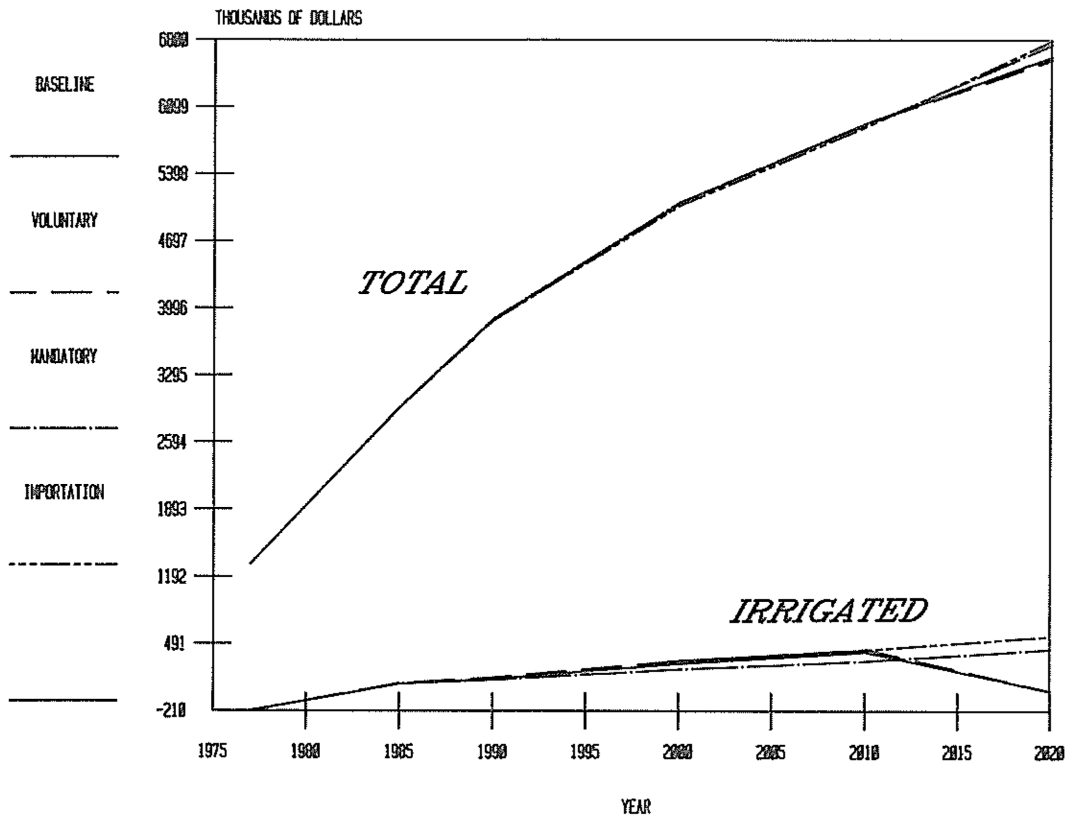

Figure 4. Total and Irrigated Returns to Land, Management, and Risk for Quay County, Southern High Plains, New Mexico, 1977-2020.

well as increased acreage as previously irrigated lands revert to dryland.

The greatest total expected increase of $5.5 million (413 percent) is expected to occur under the importation strategy (Table 3). This significant increase in 2020 is due to the full restoration of irrigated lands in the Southern High Plains at higher crop yields and prices with no charge assessed for the imported water. Under the mandatory strategy, the returns to land and management increased by $5.4 million (409 percent. Under both the baseline and the voluntary strategies, the returns are expected to increase by 400 and 397 percent, respectively, from 1977 to 2020.

The 1977 returns to land and management for irrigated crops in the Southern High Plains portion of Quay County were approximately a negative $207,000 (Figure 4). Significant increases in returns are expected for all strategies through 2010. After 2010, under the baseline and voluntary strategies, irrigated returns drop to zero as aquifer exhaustion occurs. Under the mandatory strategy, some irrigated land is expected to be retained in 2020 with resulting returns of $436,000 (Table 3). Under the importation strategy, irrigated returns are expected to increase to $779,000 by 2020. This is because there are fully irrigated lands with no charge assessed for the imported water and because of higher crop yields and prices.

The greatest increase in both irrigated value of production and in returns to land and management occurs under the importation strategy. This is due primarily to the full restoration of irrigated lands at projected higher crop yields and prices and there being no charge assessed for imported water. Adoption of the mandatory strategy results in the greatest total and irrigated value of production and returns to land and management from the natural water supply in 2020. The accumulated sum over the 43 years examined in the study indicates that the total irrigated value of production is greater for both the voluntary and mandatory strategies than for the baseline.

Any future increase in land values above the inflation rate will result in reductions in the returns to land and management.

Irrigation Water

The quantity of irrigation water diverted in the Southern High Plains portion of Quay County is expected to decline from 14,000 acre-feet in 1977 to 0 acre-feet in 2020 under the baseline with most of the decrease occurring after 2010 (Table 4). Under the voluntary strategy, the quantity of irrigation water diverted is expected to be only slightly less than under the baseline (Figure 5). Under the voluntary strategy, as was the case under the baseline, aquifer exhaustion occurred before 2020. 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. However, under the mandatory strategy, enough water is conserved over the study to support 7,700 acre-feet of irrigation water withdrawals in 2020.

Under the importation strategy, water will be imported to fully irrigate those lands that exhaust their natural water supply under the voluntary strategy. It is estimated that 10,265 acre-feet will be im-

Table 4. Quantity of Irrigation Water Diverted by Management Strategy for Selected Years, Southern High Plains Quay County, New Mexico, 1977-2020.

	1977	1985	1990	2000	2010	2020
	(acre-feet)					
Baseline	13,960	11,242	10,036	12,323	12,029	--
Voluntary	13,960	10,792	9,312	11,207	11,056	--
Mandatory	13,960	9,713	7,451	7,845	7,739	7,722
Importation	13,960	10,792	9,312	11,188	11,056	10,265

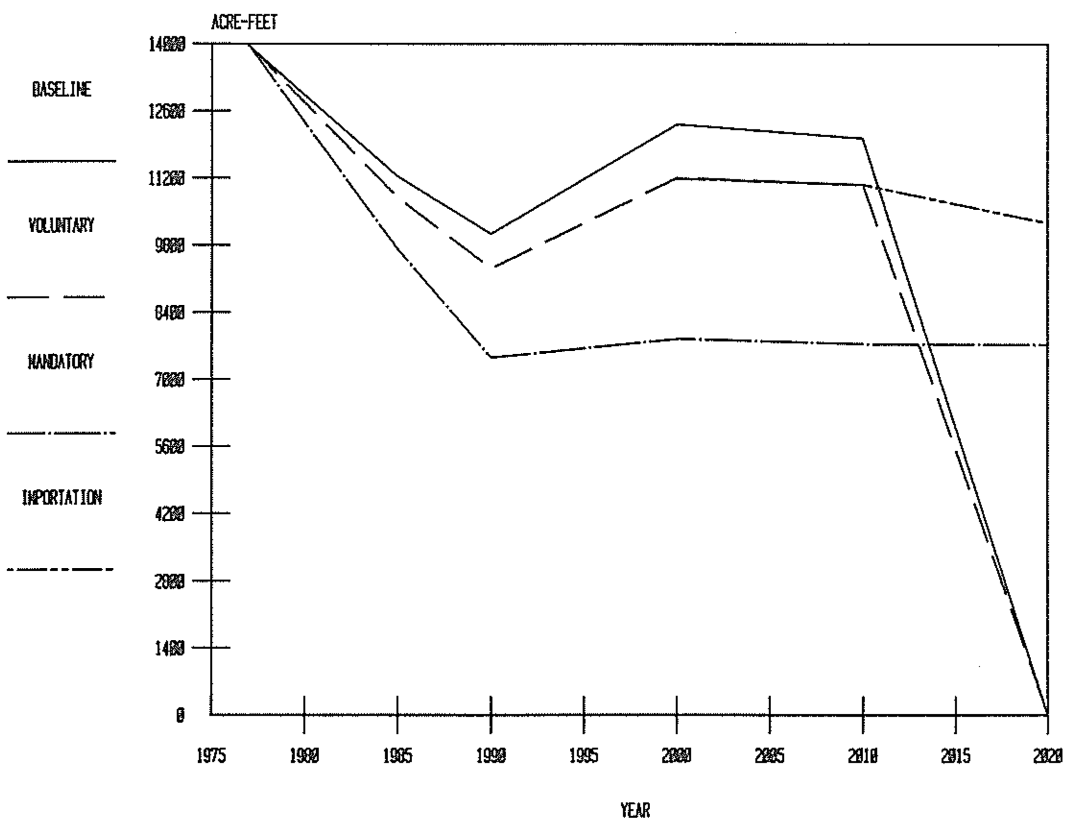

Figure 5. Quantity of Irrigation Applied for Quay County, Southern High Plains, New Mexico, 1977-2020.

ported in 2020. It is estimated that farmers could afford to pay $150 per acre-foot in 2020 and have the same profit levels as dryland producers.

Cropland and Cropping Pattern

The irrigated cropland in the Southern High Plains portion of Quay County is expected to decrease from 5,000 acres in 1977 to 3,893 acres in 1990, increase to 5,000 acres in 2000, and then decline to zero after 2010 for both the baseline and voluntary strategies (Table 5). The initial decline, then increase, back to the original acreage is caused by the irrigation and dryland profitability. Initially, dryland is more profitable, thus 1,100 acres shift to dryland, and when irrigation becomes more profitable the same 1,100 acres shifts back into irrigation. Under the mandatory strategy, the irrigated acreage is expected to decline to 2000, level off to 2010, and then increase slightly to about 3,764 acres in 2020. Under importation, the irrigated acreage is expected to decline to 1990, then increase to about the 1977 level in 2000 where it is expected to remain through 2020.

The dry cropland acreage in 1977 was about 80,000 acres. It varies only slightly across management strategies and time periods. As irrigation water stocks are depleted, acreage reverts to dryland, so the dryland acreage in each period is the base acreage (80,000 acres) plus the change in irrigated acreage (maximum of 5,000 acres). The rangeland acreage is expected to remain constant over time for all the management strategies at about 173,000 acres.

Under the baseline and the voluntary strategies, an increase in the acreage of the more profitable crop (wheat) is expected over time due to the relative profitability of wheat versus grain sorghum.

Under the mandatory strategy, significant reductions in irrigated cropland are expected over time. However, the cropping pattern in percentage terms is expected to remain fairly stable and similar to baseline (Table 5). The grain sorghum acreage is expected to decline and wheat is expected to increase in relative proportion over time. Under the importation strategy, the cropping pattern is the same as the voluntary strategy through 2010 and, due to water importation, irrigation is expected to continue under the same pattern through 2020 (Table 5).

Table 5. Irrigated Cropland Acreages by Crop by Management Strategy for Selected Years, Southern High Plains, Quay County, New Mexico, 1977-2020.

Strategy and Crop	1977	1985	1990	2000	2010	2020
	(irrigated acres)					
Baseline	5,000	4,232	3,893	5,000	5,000	0
Grain Sorghum	2,500	1,608	1,168	1,500	1,500	0
Wheat	2,500	2,624	2,725	3,500	3,500	0
Voluntary	5,000	4,232	3,893	5,000	5,000	0
Grain Sorghum	2,500	1,608	1,168	1,500	1,500	0
Wheat	2,500	2,624	2,725	3,500	3,500	0
Mandatory	5,000	3,809	3,154	3,500	3,500	3,764
Grain Sorghum	2,500	1,448	946	1,050	1,050	1,129
Wheat	2,500	2,362	2,208	2,450	2,450	2,635
Importation	5,000	4,232	3,893	5,000	5,000	5,000
Grain Sorghum	2,500	1,608	1,168	1,500	1,500	1,500
Wheat	2,500	2,624	2,725	3,500	3,500	3,500

Sensitivity Analysis

Sensitivity analyses were performed for three key on-farm variables. Analyses were performed on crop prices, crop yields, and energy prices to determine what effect higher or lower values would have upon irrigated cropland, irrigation water usage, value of production, and returns to land and management.

Under baseline conditions, irrigated crop production is projected to be nonexistent in the Southern High Plains portion of Quay County, having ceased between 2010 and 2020. High energy costs or lower crop yields are projected to extend the life of the Southern Quay area and of irrigated agriculture up to the year 2020 by making irrigation less profitable.

Analysis performed on these variables for the year 2010 indicates that higher or lower crop prices, higher crop yields, or lower energy costs than those assumed under baseline will have no impact upon the number of acres irrigated or upon irrigation water used, but will impact on the value of production and returns to land and management (Table 6).

Table 6. Sensitivity Analysis, Southern High Plains, Quay County.

Item	Irrigated Cropland		Water		Value of Production		Returns to Land and Management	
	(acres)	(%)	(acre-ft)	(%)	(millions)	(%)	(millions)	(%)
Crop Prices*								
Increased	0.0	0.0	0.0	0.0	+ .66	+ 4.7	+ .66	+16.2
Decreased	0.0	0.0	0.0	0.0	- .68	- 4.8	- .66	-16.2
Crop Yields								
Increased	0.0	0.0	0.0	0.0	+ 190	+11.9	+ 188	+47.1
Decreased	+2361	+100	+ 5445	+100	+ 598	+ 100	+ 123	+ 100
Energy Costs								
Increased	+5000	+100	+11,742	+100	+1548	+ 100	+ 320	+ 100
Decreased	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* This section of the sensitivity analysis concerning crop prices pertains to 2010 (see text).

However, it is expected that lower crop yields or higher energy prices will have a significant impact on the acreage irrigated, irrigation water used, as well as the economic indicators (Table 6). Analysis indicates that lower crop yields or higher energy prices will extend the life of the aquifer to 2020.

Analysis was also performed on these variables to determine the effects upon VOP and return to land and management. The analysis indicates that VOP will be severely effected by smaller crop yields and by higher energy costs. Similarly, returns are projected to be severely impacted by lower crop yields, and by higher energy prices. The change in resource use with changes in crop prices, crop yields, or energy costs may be predicted by what happens to the relative profitability of irrigated to dryland. The change in crop prices affects both irrigated and dryland equally, therefore, irrigation is still relatively more profitable. When crop yields are changed, it affects the relative profitability since irrigated yields are greater. With increased crop yields, irrigation is even more profitable. With decreased crop yields, irrigation becomes less profitable and there is a shift to dryland. When energy costs, which effect irrigation much more than dryland, are changed, the relative profitability is also changed. With increased energy costs, a shift occurs to dryland because irrigated farming's profitability decreases. With lower energy costs, irrigation becomes relatively more profitable.

Northern High Plains

Value of Production

The 1977 total agricultural value of production (TVP [irrigated crops, dryland crops, and rangeland]) in the Northern High Plains region of Quay County was about $25.7 million (Figure 6). Under all the management strategies, the total value of production is expected to increase significantly over time as crop yields increase and crop prices increase and because of the expansion in irrigated acreage. The largest increase, 78 percent ($20.1 million), is expected to occur under the voluntary strategy (Table 7). Under the baseline strategy, the TVP is

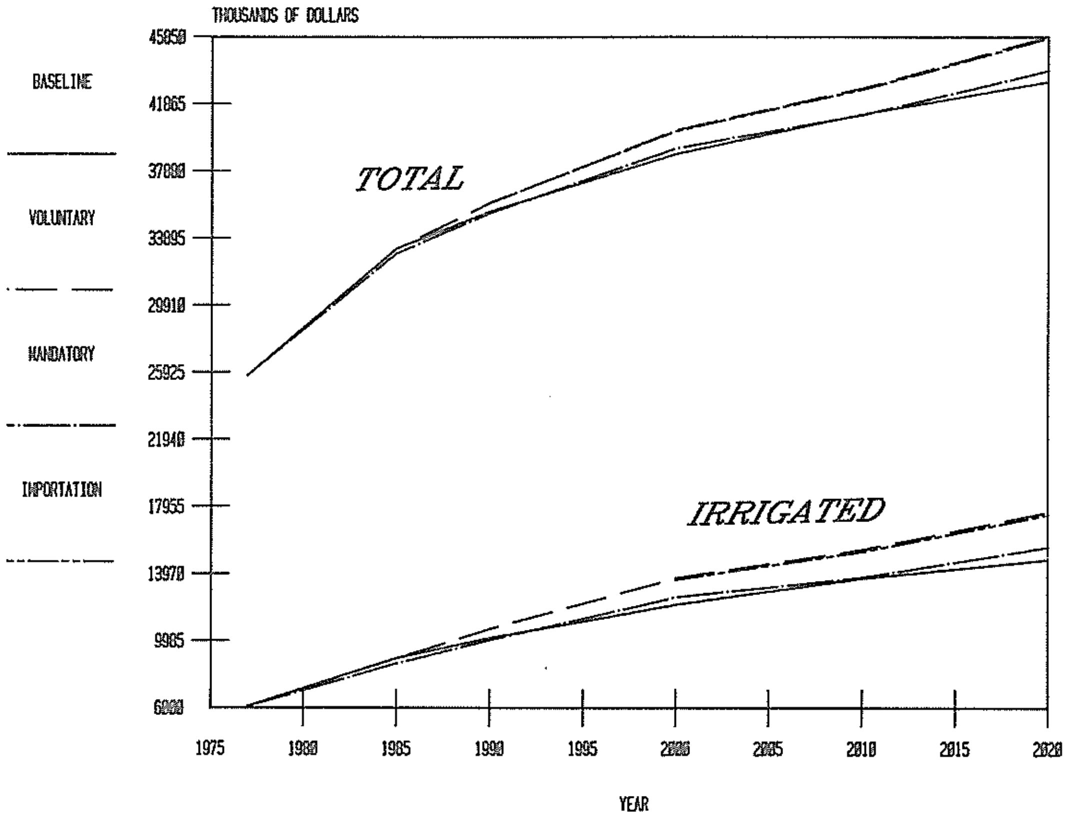

Figure 6. Total and Irrigated Value of Production for Quay County, Northern High Plains, New Mexico, 1977-2020.

projected to increase by 68 percent and under the mandatory strategy by about 70 percent. The required changes in the cropping pattern and irrigation technologies necessary to meet the conditions under the mandatory strategy are expected to cause a 4 percent ($2 million) decrease in the total value of production from the voluntary strategy in 2020. The mandatory strategy is expected to have a TVP in 2020 of 1 percent more than the baseline, due to more land being held in irrigated agricultural production. Under the importation strategy, the value of production in 2020 is expected to be reduced by only $102,000 below the voluntary strategy due to reduced crop prices.

The 1977 value of production for irrigated crops was about $6.1 million (24 percent of total agricultural value of production) in the Northern High Plains region of Quay County (Figure 6). Under all the management strategies, the irrigated value of production is expected to follow the same general trend as TVP--increasing over time due to increasing crop yields and prices, as well as expanding acreage. The

Table 7. Value of Production and Returns to Land and Management by Management Strategy for Selected Years, Northern High Plains, Quay County, 1977-2020.

Strategy and Item	1977	1985	1990	2000	2010	2020
	(1,000 dollars)					
			Value of Production			
Baseline	25,719	33,282	35,486	38,895	41,237	43,189
Irrigated Cropland	6,058	8,917	10,128	12,113	13,668	14,788
Dry Cropland	2,810	3,823	4,310	5,064	5,863	6,716
Rangeland	16,850	20,541	21,049	21,719	21,706	21,684
Voluntary	25,719	33,237	35,973	40,286	42,755	45,837
Irrigated Cropland	6,058	8,889	10,661	13,684	15,359	17,594
Dry Cropland	2,810	3,823	4,310	5,064	5,863	6,716
Rangeland	16,850	20,524	21,002	21,538	21,533	21,527
Mandatory	25,719	32,969	35,351	39,196	41,153	43,803
Irrigated Cropland	6,058	8,599	10,000	12,550	13,723	15,527
Dry Cropland	2,810	3,842	4,340	5,091	5,889	6,732
Rangeland	16,850	20,528	21,012	21,555	21,541	21,543
Importation	25,719	33,237	35,973	40,217	42,666	45,735
Irrigated Cropland	6,058	8,889	10,661	13,609	15,249	17,450
Dry Cropland	2,810	3,823	4,310	5,070	5,884	6,759
Rangeland	16,850	20,524	21,002	21,538	21,533	21,527
			Returns to Land and Management*			
Baseline	4,757	7,508	8,505	10,644	12,332	14,251
Irrigated Cropland	600	1,593	1,928	3,169	4,164	5,345
Dry Cropland	829	1,362	1,812	2,512	3,259	4,068
Rangeland	3,328	4,554	4,764	4,962	4,910	4,838
Voluntary	4,757	7,535	8,689	11,113	12,889	15,141
Irrigated Cropland	600	1,623	2,123	3,680	4,760	6,270
Dry Cropland	829	1,362	1,812	2,512	3,259	4,068
Rangeland	3,328	4,550	4,754	4,921	4,870	4,803
Mandatory	4,757	7,495	8,632	11,050	12,773	15,004
Irrigated Cropland	600	1,576	2,056	3,614	4,640	6,134
Dry Cropland	829	1,368	1,820	2,512	3,261	4,064
Rangeland	3,328	4,551	4,756	4,925	4,872	4,806
Importation*	4,757	7,535	8,689	11,044	12,799	15,039
Irrigated Cropland	600	1,623	2,123	3,605	4,650	6,125
Dry Cropland	829	1,362	1,812	2,518	3,279	4,111
Rangeland	3,328	4,550	4,754	4,921	4,870	4,803

* A charge for irrigated water was not included in the importation strategy. Therefore, the returns are to land, management, and water for the years 2000, 2010, and 2020.

largest increase of 190 percent ($11.5 million) is expected under the voluntary strategy. Increases for the importation, mandatory, and baseline strategies are expected to be 188, 156, and 144 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 12 percent ($2.1 million) reduction from the voluntary strategy in 2020. However, the importation strategy reduces the expected 2020 value of production by only $144,000, or 1 percent from the voluntary strategy.

Returns to Land and Management

The total 1977 returns to land and management (irrigated crops, dryland crops, and rangeland) for the Northern High Plains portion of Quay County was about $4.8 million (Figure 7). There are significant increases expected in the county's returns to land and management under all strategies in all time periods. This is due to greater values of production from increasing crop yields and prices.

The greatest expected increase of $10.4 million (218 percent) is expected to occur under the voluntary strategy (Table 7). This significant increase in 2020 is due to increasing irrigated and dry cropped lands at higher crop yields and prices. Under the importation strategy, the returns to land and management increase by $10.3 million, almost the same as under the voluntary strategy. Since no lands are projected to exhaust their natural water supply under the voluntary strategy, the only difference between voluntary and importation is slightly reduced crop prices with importation. Under the mandatory strategy, the returns are expected to increase $10.3 million by 2020, and under the baseline the returns are expected to be $14.25 million, for an increase in returns of 200 percent.

The 1977 returns to land and management for irrigated crops in the Northern High Plains were about $600,000 (Figure 7). Significant increases in returns are expected for all strategies through 2020. Irrigated returns are expected to follow closely the total returns with the largest increase expected for the voluntary strategy (a 10-fold increase), followed closely by the mandatory and importation strategies with $6.1 million (Table 7).

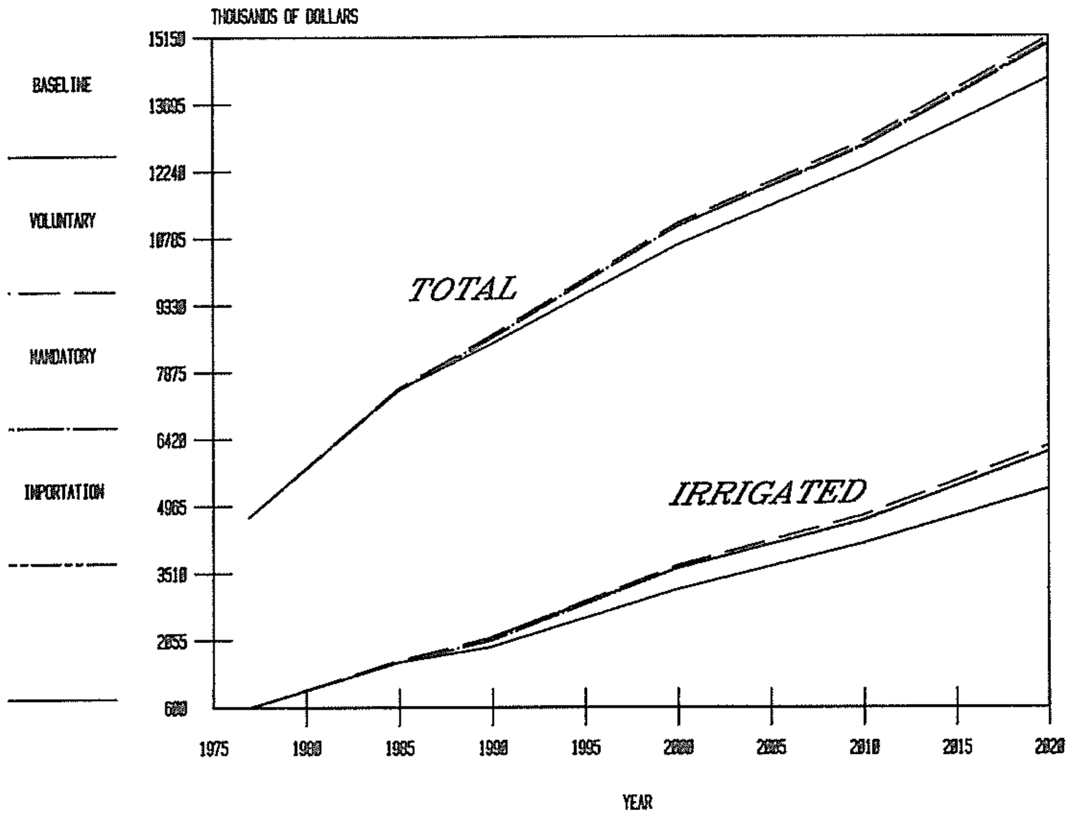

Figure 7. Total and Irrigated Returns to Land, Management, and Risk for Quay County, Northern High Plains, New Mexico, 1977-2020.

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

Irrigation Water

The quantity of irrigation water diverted is expected to increase from 60,400 acre-feet in 1977 to 60,800 acre-feet in 2020 under the baseline (Table 8). Under the voluntary strategy, the quantity of irrigation water diverted is expected to be somewhat less than under the baseline while irrigating more land (Figure 8). By the year 2020, the annual diversion of irrigation water to irrigate the same acreage is expected to be 60,300 acre-feet, or 500 acre-feet less for the voluntary strategy than for the baseline. 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. In

Table 8. Quantity of Irrigation Water Diverted by Management Strategy for Selected Years, Northern High Plains Quay County, New Mexico, 1977-2020.

	1977	1985	1990	2000	2010	2020
	(acre-feet)					
Baseline	60,441	60,445	60,565	60,740	61,138	60,750
Voluntary	60,441	60,190	60,210	60,035	60,230	60,272
Mandatory	60,441	59,264	58,357	57,317	57,430	57,458
Importation	60,441	60,190	60,210	60,035	60,230	60,272

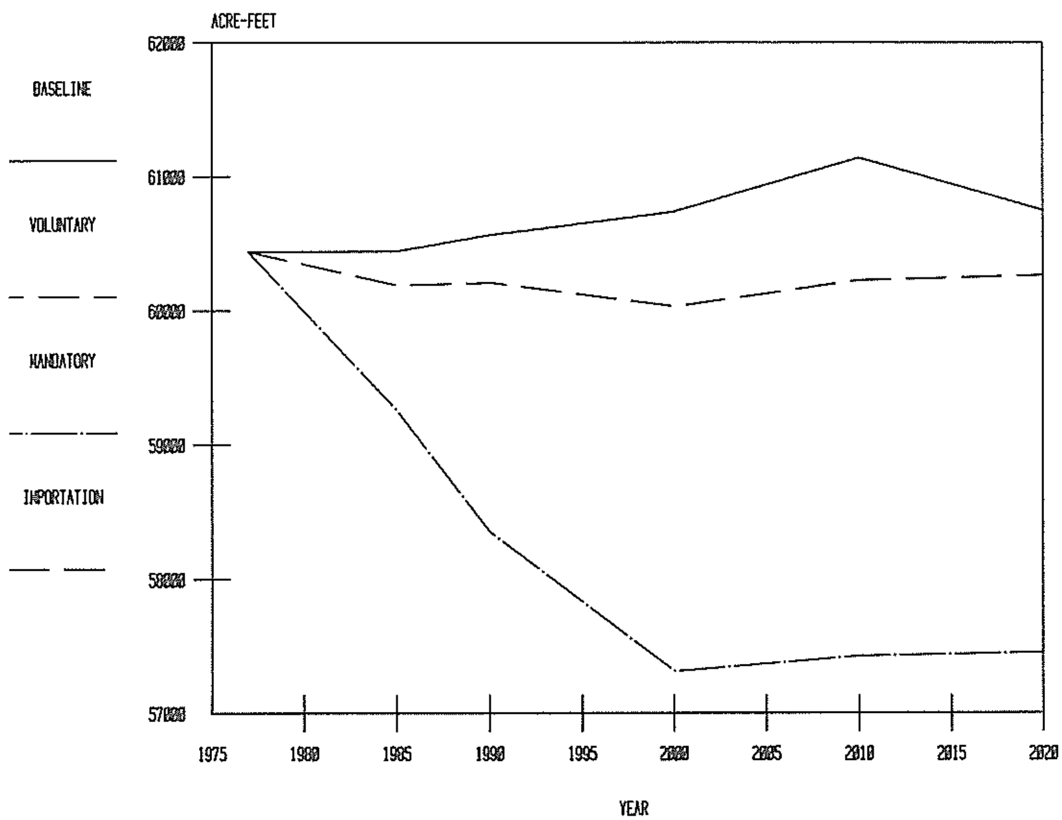

Figure 8. Quantity of Irrigation Applied for Quay County, Northern High Plains, New Mexico, 1977-2020.

2020, the withdrawals for the mandatory strategy are expected to be 3,300 acre-feet less than under the baseline and 2,800 acre-feet less than under the voluntary strategy.

Cropland and Cropping Pattern

The irrigated cropland in the Northern High Plains portion of Quay County is expected to increase from 31,000 acres in 1977 to 33,800 acres by 2020 for the baseline (Table 9). The acreage of irrigated cropland is expected to increase to 44,700 acres for the voluntary and importation strategies and to 43,400 for the mandatory strategy. The dry cropland acreage is expected to remain fairly constant under all management strategies at about 40,000 acres. The rangeland acreage is expected to remain at about 1.5 million acres for all the management strategies.

Under the baseline, increases in the acreages of alfalfa, cotton, and grain sorghum are expected over time, due to reductions in pasture acreages and increasing irrigated acreage. The wheat acreage fluctuates, but in 2020 is close to the initial 1977 acreage (Table 9). Under the voluntary strategy, all crops but wheat show an increase in acreage in 2020 when compared to the baseline with alfalfa, cotton, and grain sorghum expecting the greatest increase.

Under the mandatory strategy, slight shifts are expected in the cropping pattern over time, primarily due to reduced acreage irrigated (Table 9). Slight reductions are expected for alfalfa, grain sorghum, and pasture acreages over time when compared to the voluntary strategy. The cropping pattern and acreage irrigated under the importation strategy is expected to be the same as the voluntary strategy.

Sensitivity Analysis

Analyses of the key on-farm variables in 2020 indicate that higher or lower crop prices, higher or lower crop yields, or lower energy prices will not have any positive or negative impact upon resource use (irrigated cropland or irrigation water). Higher energy prices than

Table 9. Irrigated Cropland Acreages by Crop by Management Strategy for Selected Years, Northern High Plains, Quay County, New Mexico, 1977-2020.

Strategy and Crop	1977	1985	1990	2000	2010	2020
			(irrigated acres)			
Baseline	31,020	31,125	31,199	31,645	32,408	33,829
Alfalfa	7,429	8,221	7,859	8,929	9,068	9,553
Cotton	2,096	3,930	5,240	5,292	5,394	5,618
Grain Sorghum	9,629	9,658	11,381	11,376	11,491	11,719
Wheat	4,213	7,078	4,271	3,352	3,480	4,753
Planted Pasture	7,653	2,238	2,448	2,699	2,975	2,187
Voluntary	31,020	32,369	34,501	44,189	44,437	44,740
Alfalfa	7,429	8,792	9,970	13,068	13,038	13,154
Cotton	2,096	4,117	5,900	7,800	7,800	7,800
Grain Sorghum	9,629	10,068	12,702	16,393	16,303	16,084
Wheat	4,213	7,154	3,481	4,230	4,322	4,423
Planted Pasture	7,653	2,238	2,448	2,699	2,975	3,280
Mandatory	31,020	31,973	33,669	42,808	43,652	43,436
Alfalfa	7,429	8,764	9,925	13,014	12,992	13,057
Cotton	2,096	4,117	5,900	7,800	7,800	7,800
Grain Sorghum	9,629	9,966	12,528	16,172	16,106	15,966
Wheat	4,213	7,042	3,237	3,818	4,952	4,882
Planted Pasture	7,653	2,085	2,077	2,004	1,802	1,732
Importation	31,020	32,369	34,501	44,189	44,437	44,740
Alfalfa	7,429	8,792	9,970	13,068	13,038	13,154
Cotton	2,096	4,117	5,900	7,800	7,800	7,800
Grain Sorghum	9,629	10,068	12,702	16,393	16,303	16,084
Wheat	4,213	7,154	3,481	4,230	4,322	4,423
Planted Pasture	7,653	2,238	2,448	2,699	2,975	3,280

those that were assumed under the baseline will have significant negative effects (Table 10) upon irrigated cropland (-11.4 percent) and upon water usage (-10.5 percent).

The change in resource use caused by higher energy prices indicates a major negative impact upon the value of production (34 percent). The value of production also exhibits a great deal of sensitivity to changing crop yields (15 percent). A change in crop prices has the least effect on the VOP in percentage terms except for decreased energy costs.

Table 10. Sensitivity Analysis, Northern High Plains, Quay County.

Item	Irrigated Cropland		Water		Value of Production		Returns to Land and Management	
	(acres)	(%)	(acre-ft)	(%)	(millions)	(%)	(millions)	(%)
Crop Prices								
Increased	0.0	0.0	+ 980	+ 1.6	+1.8	+12.5	+.68	+12.7
Decreased	0.0	0.0	0.0	0.0	- 64	- 4.3	-.64	-11.9
Crop Yields								
Increased	0.0	0.0	0.0	0.0	+2.3	+15.3	+2.3	+42.5
Decreased	- 138	-.004	+ 744	+ 1.2	-2.3	-15.6	-2.1	-40.2
Energy Costs								
Increased	-3858	-11.4	-6391	-10.5	-5.0	-34.0	-2.2	-41.7
Decreased	0.0	0.0	+ 980	+ 1.6	+1.2	+ 7.9	+.27	+ 5.1

Analysis further indicates that returns to land and management will be greatly influenced by higher or lower crop yields and by higher energy prices, all with changes greater than 40 percent (Table 10). Changes in crop prices have about a 12 percent effect in the returns to land and management, and decreased energy costs have only a 5 percent effect. Thus, the results in the Northern High Plains area of Quay County seem to be the most sensitive to increased energy costs and increased or decreased crop yields.

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 Quay County's economy is reported in Table 11. It was about $77 million in 1977. It is projected to be $100 million in 1985, $116 million in 1990, $145 million in 2000, and $203 million in 2020. The bulk of output generated in Quay County is in the Northern High Plains portion. In the Southern High Plains portion, the economy is primarily agricultural or agricultural related.

Agricultural. The agricultural sectors are a major source of output in Quay County. They accounted for almost 59 percent of the total gross output in 1977, and are projected to be about 58 percent in 1985, 55 percent in 1990, 49 percent in 2000, and 40 percent in 2020. The agricultural sectors are expected to have a major influence in the local economy. The agricultural sectors are expected to increase be-

Table 11. Gross Output by Major Sector for Each of the Alternative Management Strategies, Quay County, New Mexico, 1977-2020.

Sector	Gross Output ($1977)				
	1977	1985	1990	2000	2020
	(millions of dollars)				
Baseline					
Agriculture	45.072	58.069	63.546	71.290	80.169
Mining	0.118	1.928	3.737	7.356	14.536
Manufacturing	2.573	3.435	4.294	6.014	9.467
TCU*	2.813	3.755	4.694	6.575	10.350
Construction	8.725	10.034	11.343	14.833	18.323
FIRE**	2.980	3.427	3.874	5.066	6.258
Trade	8.118	10.837	13.547	18.974	39.868
Services	6.491	8.665	10.832	15.171	23.882
Total	76.890	100.150	115.867	145.279	202.853
Voluntary					
Agriculture	45.072	58.068	63.658	71.201	80.180
Mining	0.118	1.928	3.737	7.356	14.536
Manufacturing	2.573	3.435	4.294	6.014	9.467
TCU*	2.813	3.755	4.694	6.575	10.350
Construction	8.725	10.034	11.343	14.833	18.313
FIRE**	2.980	3.427	3.874	5.066	6.258
Trade	8.118	10.837	13.547	18.974	39.868
Services	6.491	8.665	10.832	15.171	23.882
Total	76.890	100.149	115.979	145.190	202.854
Mandatory					
Agriculture	45.072	58.081	63.680	71.410	80.344
Mining	0.118	1.928	3.737	7.356	14.538
Manufacturing	2.573	3.435	4.294	6.015	9.473
TCU*	2.813	3.760	4.704	6.633	10.544
Construction	8.725	10.034	11.346	14.847	18.406
FIRE**	2.980	3.429	3.877	5.082	6.322
Trade	8.118	10.839	13.555	19.011	40.150
Services	6.491	8.667	10.839	15.207	24.104
Total	76.890	100.173	116.032	145.561	203.881
Importation					
Agriculture	45.072	58.068	63.658	71.325	80.254
Mining	0.118	1.928	3.737	7.357	14.540
Manufacturing	2.573	3.435	4.294	6.017	9.481
TCU*	2.813	3.755	4.694	6.637	10.608
Construction	8.725	10.034	11.343	14.928	18.644
FIRE**	2.980	3.427	3.874	5.099	6.427
Trade	8.118	10.837	13.547	19.080	40.687
Services	6.491	8.665	10.832	15.252	24.416
Total	76.890	100.149	115.979	145.695	205.057

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

tween 1977 and 2020 with about $45 million in 1977 and $80 million in 2020 (Table 11). This growth is projected to be relatively stable over the period (Figure 9).

Mining. The mining sectors are projected to have a minor impact on the local economy in 1977, but are expected to increase with the CO_2 development (Figure 9). This CO_2 development in the Bravo Dome area is projected to result in from 300 to 1,000 wells and pipelines to the Permian/Delaware Basin of Texas and southeastern New Mexico. In 1977, the mining sectors accounted for only $118,000, or less than 0.2 percent of the total. By 1985, they are projected to account for almost $2 million. The mining activity is expected to increase to about $4 million in 1990, $7 million in 2000, and $15 million in 2020. There is no oil or gas production in Quay County and none is expected through 2020.

Electrical Production. There is limited electrical energy production in Quay County. However, by the year 1990, the current generator plant is expected to be used only for peak production during the summer.

Manufacturing. The manufacturing sectors are projected to increase from $3 million in 1977 to about $9 million in 2020. The contribution of the manufacturing sectors to the total was 3 percent in 1977, and is projected to be 4 percent in 1990 and 5 percent in 2020 (Table 11).

Transportation, Communication, and Utilities (TCU). The TCU sectors, taken together, generally show an increase over the period. These sectors are projected to increase from $3 million in 1977 to $10 million in 2020 (Table 11). The contribution of these sectors to the total was about 4 percent in 1977 and is expected to remain at about 5 percent through 2020.

Construction. The construction sectors are projected to also increase over the period. These sectors accounted for about $9 million in 1977. They are projected to be about $10 million in 1985, $11 million in 1990, $15 million in 2000, and $18 million in 2020.

Finance, Insurance, and Real Estate (FIRE). The FIRE sectors are also projected to increase between 1977 and 2020. They contributed about 4 percent in 1977. FIRE is projected to increase in magnitude but decline and remain at 3 percent of total output through 2020 (Table 11).

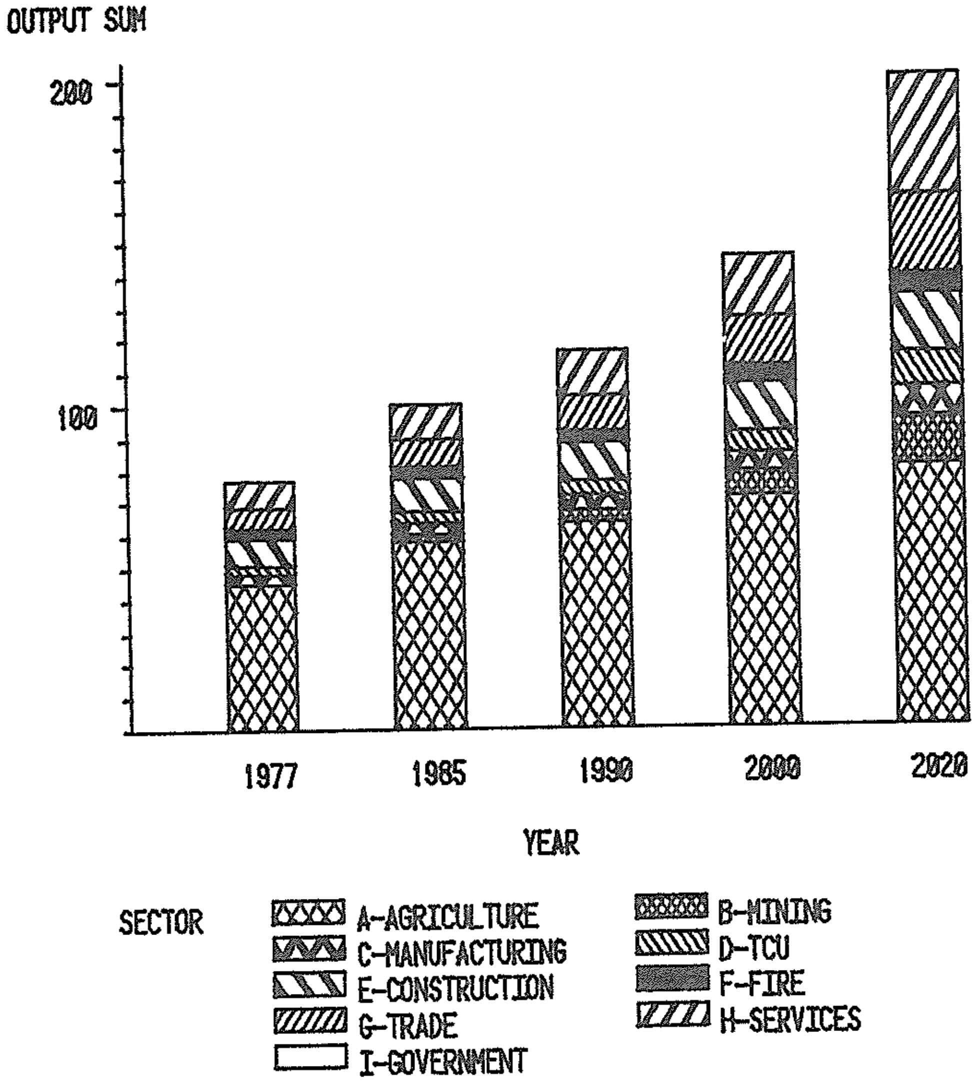

Figure 9. Projected Gross Output for Quay County, Baseline Conditions, 1977-2020.

Trade. The trade sector is also expected to expand between 1977 and 2020 (Figure 9). In 1977, it accounted for about 11 percent of the total and by 2020 it is projected to reach almost 20 percent.

Service. The service sectors are also projected to expand between 1977 and 2020 (Figure 9). In 1977, they accounted for about 8 percent of the total and by 2020 they are projected to contribute almost 12 percent.

Employment

Total employment in the form of jobs for each alternative for each sector by year is reported in Table 12. Employment projected for the baseline is summarized by major sector in Figure 10. The total jobs were 1,865 in 1977, and are expected to increase to 2,458 in 1985; 2,660 in 1990; 2,776 in 2000; and 3,060 in 2020. Government was the largest employer accounting for about 30 percent of the total employment in 1977, is projected to increase to 32 percent in 1985, 30 percent in 1990, and 22 percent in 2000. In 2020, it drops to second position and accounts for 16 percent (Table 12). Most of this is expected to be associated with military activity in the county. Trade was the next most important sector and employed about 27 percent in 1977. It is projected to remain at 27 percent in 1985, increase slightly to 30 percent in 1990, decrease to 27 percent in 2000, and again increase to 28 percent in 2020. Services employed 11 percent in 1977 and is expected to employ 12 percent in 1985. It is expected to increase to 13 percent in 1990, 17 percent in 2000, and 23 percent in 2020. The agricultural sector accounted for about 13 percent of the jobs in 1977, is projected to be only 10 percent in 1985, 9 percent in 1990 and 2000, and about 7 percent in 2020. Construction provided about 13 percent of the jobs in 1977. This is expected to remain constant through 1990, then increase to 16 percent in 2000 and 18 percent in 2020 (Table 12). Employment in the mining sector is projected to expand from zero in 1977 to 35 in 2020 as a result of the CO_2 development in Quay County.

Population

The total population for Quay County for the baseline and alternatives is presented in Table 13. The county had about 6,824 people in 1977. It is projected to increase to about 7,125 in 1985; 8,095 in 1990; 9,425 in 2000; and 10,304 in 2020. Between 1977 and 2020, the population is projected to increase by 3,480, or about 51 percent.

Table 12. Employment by Major Sector for Each of the Alternative Management Strategies, Quay County, New Mexico, 1977-2020.

Sector	1977	1985	1990	2000	2020
	Jobs				
	(number of jobs)				
Baseline					
Agriculture	237	243	235	246	227
Mining	0	9	18	31	35
Manufacturing	28	41	39	36	33
TCU*	44	65	74	76	65
Construction	246	319	356	457	549
FIRE**	49	57	63	78	86
Trade	505	660	733	757	872
Services	204	285	353	477	697
Government	552	779	789	618	496
Total	1,865	2,458	2,660	2,776	3,060
Voluntary					
Agriculture	237	254	247	252	248
Mining	0	9	18	31	35
Manufacturing	28	41	39	36	33
TCU*	44	65	74	77	65
Construction	246	320	359	461	551
FIRE**	49	58	63	79	87
Trade	505	662	739	764	877
Services	204	287	356	481	700
Government	552	783	792	622	498
Total	1,865	2,479	2,687	2,803	3,094
Mandatory					
Agriculture	237	245	238	239	234
Mining	0	9	18	31	35
Manufacturing	28	41	39	36	33
TCU*	44	66	74	78	67
Construction	246	320	359	461	553
FIRE**	49	58	64	79	88
Trade	505	662	740	766	883
Services	204	287	356	483	707
Government	552	783	793	623	500
Total	1,865	2,471	2,681	2,796	3,100
Importation					
Agriculture	237	254	247	270	270
Mining	0	9	18	31	35
Manufacturing	28	41	39	36	33
TCU*	44	65	74	78	67
Construction	246	320	359	464	561
FIRE**	49	58	63	79	89
Trade	505	662	739	769	896
Services	204	287	356	484	715
Government	552	783	792	625	505
Total	1,865	2,479	2,687	2,836	3,171

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

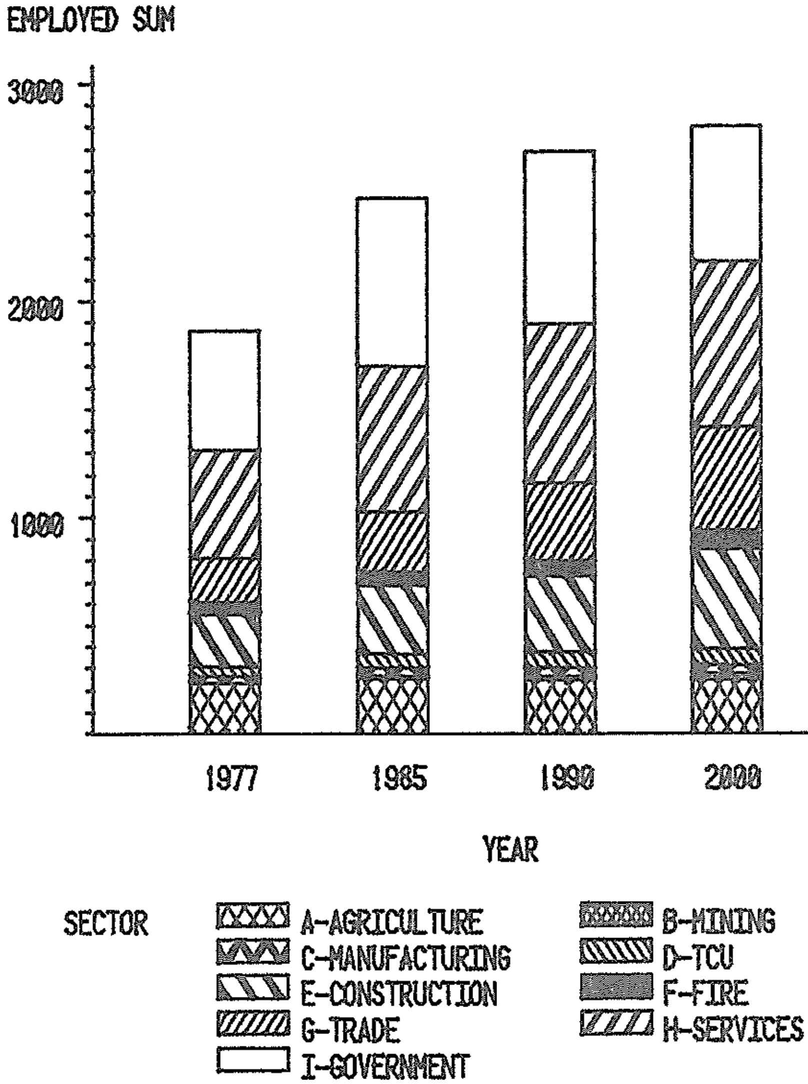

Figure 10. Projected Employment for Quay County.

Table 13. Summary of Population Projections for Quay County for Each of the Management Strategies, 1977-2020.

Strategy	Population Projection 1977	1985	1990	2000	2020
Baseline	6,824	7,125	8,095	9,425	10,304
Voluntary	6,824	7,177	8,174	9,498	10,424
Mandatory	6,824	7,154	8,157	9,470	10,433
Importation	6,824	7,177	8,175	9,592	10,641

Alternative Management Strategies

Gross Output

The gross output by major sector for each of the alternative management strategies is also summarized in Table 11. For 1977, all of the output estimates for the management strategies are the same as the baseline.

The differences in gross output among the management strategies are basically due to changes in the agricultural sectors.

By 2020, output under the voluntary management strategy is expected to be only $1,000 more than the baseline. Output is projected to be $11,000 more in the agricultural sectors and $10,000 less in the construction sectors. The projected output in 2020 under the mandatory management strategy is $1.028 million more than under the baseline. Agriculture is projected to increase $175,000.

By 2020, output under the importation strategy is projected to be $2.204 million more than under the baseline. Agricultural output is projected to have $85,000 more than under the baseline. Output for all other sectors is projected to be $2.119 million more than under the baseline.

Employment

Employment in the form of jobs for each of the alternative management strategies is also summarized in Table 12 by major sector. The number of jobs are the same for all management strategies in 1977.

In 2020, voluntary is projected to result in 34 more jobs than under the baseline. By sector, agriculture is expected to result in 21 more; construction, 3 more; FIRE, 1 more; trade, 5 more; services, 3 more; and government, 2 more. Mandatory is expected to result in 40 more jobs than the baseline in 2020. Agriculture accounts for 7 of these; TCU, 2; construction, 4; FIRE, 2; trade, 11; services, 10; and government, 4 more. Importation is projected to result in 111 more jobs than under the baseline. Agriculture is projected to have 43 more jobs under the importation strategy than under the baseline as a result of the positive impact of imported water.

Population

The total population for each of the management strategies is also summarized in Table 13. For 1977, all of the projections for the management strategies are the same. For 1985, population under the voluntary strategy and importation strategy is projected to be 52 more than under the baseline. The mandatory strategy is projected to result in 29 more people than under the baseline in 1985. In 1990, voluntary is projected to result in 79 more people than under the baseline, and importation is 80 more than under the baseline. In 2020, voluntary is expected to result in 120 more people than the baseline, and mandatory is projected to result in 129 more people than the baseline. The importation strategy is expected to result in the greatest population in 2020 in Quay County with 10,641 people. However, this is only 337 more people than projected under the baseline.

SUMMARY

About 70 percent of the irrigated land in Quay County lies in the Arch-Hurley Conservancy District and overshadows much of the impacts the depletion of the Ogallala has. Thus, even though the aquifer becomes depleted in Quay County, some irrigated agriculture is expected to continue to exist as producers continue to utilize the surface water provided by the conservancy district. The results of this study should be reviewed in this context. 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, decreased water diversions, 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 Quay County 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 would result in slightly negative impacts in Quay County. 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 both the value of production and returns in Quay County.

The total gross output of all goods and services produced in Quay County was about $77 million in 1977. It is projected to be $100 million in 1985, $116 million in 1990, $145 million in 2000, and $203 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 resulted in higher levels of output in the rest of the economy.

In all strategies, the output levels were only slightly different from the baseline. By 2020, the voluntary strategy is only $1,000 greater than the baseline, mandatory is $1.028 million more than the baseline, and the importation strategy is $2.204 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 $45 million in 1977 and about $80 million in 2020. In 1977, the agricultural sectors accounted for about 59 percent of the total output, but by 2020 they are expected to decline to about 40 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 the baseline. The voluntary strategy was estimated to have 34 more jobs than the baseline in 2020. The mandatory strategy was projected to have 40 more jobs than the baseline, and the importation strategy was projected to have 111 more jobs than the baseline. These levels are insignificant when compared to the change in employment over the period. The employment was projected to increase from about 1,865 jobs in 1977 to a peak of 3,060 in 2020.

The population of Quay County was projected to follow a similar pattern as output and employment, with about 6,824 in 1977, increasing to about 7,125 in 1985; 8,095 in 1990; 9,425 in 2000; and 10,304 in 2020. The management strategies were projected to be slightly higher than the baseline throughout the period. The importation strategy resulted in the highest level with about 337 more than the baseline in 2020.

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APPENDIX A

HYDROLOGIC AND IRRIGATION SYSTEMS ASSUMPTIONS

Table A-1. Baseline Conditions--Hydrologic and Irrigation Systems Information, Quay County, New Mexico, 1977.

Item	Unit of Measure	1977 Estimate
Hydrologic Information		
Saturated thickness	feet	50
Maximum irrigated acreage	acres	5,000
Depth-to-water	feet	100
Average water withdrawals (1977 base)	acre-feet	13,900
Average water decline	ft./yr.	1.0
Gallons per minute		
flood	gpm	680
sprinkler	gpm	450
Specific capacity	gpm/ft. drawdown	40
Irrigation Systems		
Type		
flood	percent	10
sprinkler	percent	90
Pumping plant fuels		
natural gas	percent	--
electricity	percent	80
diesel	percent	5
LPG	percent	15
Average pumping plant efficiencies*		
natural gas	percent	--
electricity	percent	36.3
diesel	percent	10.9
LPG	percent	10.2

* Good efficiencies were considered to be 13.9 percent for natural gas; 66.1 percent for electricity; 19.9 percent for diesel; and 18.6 percent for LPG.

APPENDIX B
SUBAREA ANALYSIS

SOUTHERN HIGH PLAINS

Value of Production

The 1977 agricultural value of production (TVP)--total irrigated crops, dryland crops, and rangeland--in the Southern High Plains (SHP [House-Wheatland area]) of Quay County was about $6.1 million (Table B-1). The total agricultural value of production is expected to almost double by 2010 and then decrease slightly by 2020. The 1977 value of production for irrigated crops was about $602,000 (10 percent of the TVP) in the SHP area of Quay County (Table B-1). The TVP for irrigated crops is expected to more than double by 2010 and then decrease to zero by 2020 as the Ogallala aquifer becomes dewatered.

The 1977 TVP for dry cropland was about $3.6 million (58 percent of TVP). The TVP for dry cropland is expected to almost triple by 2020 (Table B-1). The 1977 TVP for rangeland was about $2.0 million (32 percent of TVP). The TVP for rangeland is expected to increase by 28 percent by 2020 (Table B-1).

Returns to Land and Management

The 1977 returns to land and management (RLM)--total irrigated crops, dryland crops, and rangeland--in the SHP area of Quay County were about $1.3 million (Table B-1). Under the baseline, the RLM is expected to increase 182 percent.

The 1977 returns to land and management for irrigated crops were -$207,000 (Table B-1). Significant increases are expected to occur under the baseline at slightly less than 355 percent (Table B-1). The RLM for dry cropland is expected to increase from $1.1 million in 1977 to $6.1 million in 2020. Rangeland is expected to increase from $386,000 in 1977 to $566,000 in 2010 and then decline to $558,000 in 2020.

Irrigation Water

The quantity of irrigation water diverted is expected to decrease from 14,000 acre-feet in 1977 to 10,000 acre-feet in 1990 then increase to 12,000 acre-feet in 2010 and then decrease to zero as the Ogallala aquifer is dewatered (Table B-1).

Cropland and Cropping Pattern

The irrigated cropland in the SHP of Quay County is expected to decrease from 5,000 acres in 1977 to 3,900 acres by 1990, then increase through 2010 and then decrease to zero by 2020 (Table B-1). The dry cropland acreage is expected to remain fairly constant at about 80,000 acres through 2010 and then increase to 85,000 acres by 2020. The rangeland acreage is expected to remain fairly constant at about 174,000 acres.

Irrigated grain sorghum acreages are expected to decrease over time starting with 2,500 acres in 1977 and ending with 1,500 acres in 2010 (Table B-1). Irrigated wheat is expected to increase from 2,500 acres in 1977 to 3,500 acres in 2010. Dryland grain sorghum is expected to decrease from 18,400 acres in 1977 to 17,000 acres in 2020. Dryland wheat is expected to increase from 61,600 acres in 1977 to 68,000 acres in 2020.

Table B-1. Summary of On-Farm Impacts, Southern High Plains, Quay County, New Mexico, 1977-2020--Baseline.

Item	Unit	1977	1985	1990	2000	2010	2020
Value of Production	$1,000	6,125	8,414	9,421	10,968	11,869	11,799
Irrigated Cropland	$1,000	602	764	819	1,272	1,408	0
Dry Cropland	$1,000	3,570	5,276	6,165	7,195	7,961	9,299
Rangeland	$1,000	1,953	2,374	2,438	2,500	2,500	2,500
Returns to Land & Management	$1,000	1,324	2,955	3,880	5,091	5,926	6,619
Irrigated Cropland	$1,000	-207	76	126	289	408	0
Dry Cropland	$1,000	1,146	2,353	3,202	4,230	4,952	6,061
Rangeland	$1,000	386	526	552	571	566	558
Irrigation Water							
Quantity	acre-ft	13,960	11,242	10,036	12,323	12,029	0
Cost	$1,000	375	217	208	292	295	0
Land Use							
Irrigated Cropland	acres	5,000	4,232	3,893	5,000	5,000	0
Dry Cropland	acres	80,000	80,768	81,107	80,000	80,000	85,000
Rangeland	acres	173,300	174,068	174,407	173,300	173,300	173,300
Irrigation Energy							
Electricity	1000 kwh	8,297	3,633	3,014	3,296	3,151	0
Diesel	gallons	41,555	0	14,975	16,418	15,708	0
LP Gas	gallons	129,569	88,936	51,126	81,407	77,885	0
Irrigated Crops							
Grain Sorghum							
Acreage	acres	2,500	1,608	1,168	1,500	1,500	0
Production	cwt	85,000	65,831	52,042	79,753	84,857	0
Irrigation Water	acre-ft	7,910	5,044	3,676	4,349	4,246	0
Irrigation Water Cost	dollars	204,198	95,524	75,335	103,169	103,998	0
Value of Production	$1,000	307	293	235	383	415	0
Returns to Land & Mgt.	$1,000	-136	2	3	49	78	0
Wheat							
Acreage	acres	2,500	2,624	2,725	3,500	3,500	0
Production	bu	100,000	127,487	161,830	245,635	264,531	0
Irrigation Water	acre-ft	6,050	6,198	6,360	7,974	7,784	0
Irrigation Water Cost	dollars	170,405	121,689	133,091	189,144	190,664	0
Value of Production	$1,000	295	471	584	890	993	0
Returns to Land & Mgt.	$1,000	-71	73	124	240	331	0
Dryland Crops							
Grain Sorghum							
Acreage	acres	18,400	16,961	16,221	16,000	16,000	17,000
Production	cwt	239,200	267,964	281,903	315,972	336,195	376,005
Value of Production	$1,000	884	1,212	1,289	1,536	1,668	1,906
Returns to Land & Mgt.	$1,000	175	420	499	742	858	1,031
Wheat							
Acreage	acres	61,600	63,807	64,886	64,000	64,000	68,000
Production	bu	800,800	1,007,574	1,252,299	1,459,774	1,572,071	1,789,638
Value of Production	$1,000	2,686	4,064	4,876	5,659	6,293	7,393
Returns to Land & Mgt.	$1,000	971	1,933	2,703	3,488	4,094	5,031
Rangeland							
Steers							
Acreage	acres	95,315	95,737	95,924	95,315	95,315	95,315
Production	1977 $	1,551,728	1,558,605	1,561,640	1,551,728	1,551,728	1,551,728
Value of Production	$1,000	1,552	1,886	1,936	1,986	1,986	1,986
Returns to Land & Mgt.	$1,000	214	295	309	320	317	312
Cows							
Acreage	acres	77,985	78,331	78,483	77,985	77,985	77,985
Production	1977 $	401,623	403,403	404,188	401,623	401,623	401,623
Value of Production	$1,000	402	488	501	514	514	514
Returns to Land & Mgt.	$1,000	172	232	243	251	248	245

PORTER-SAN JON

Value of Production

The 1977 agricultural value of production (TVP)--total irrigated crops, dryland crops, and rangeland--in the Porter-San Jon area of Quay County was about $3.0 million (Table B-2). The total agricultural value of production is expected to more than double by 2020. The 1977 value of production for irrigated crops was about $176,900 (6 percent of the TVP [Table B-1]). The TVP for irrigated crops is expected to increase to $205,700 by 2000 and then decrease to $191,600 by 2020.

The 1977 TVP for dry cropland was about $2.8 million (94 percent of TVP). The TVP for dry cropland is expected to increase about 140 percent by 2020 (Table B-2).

Returns to Land and Management

The 1977 returns to land and management (RLM)--total irrigated crops, dryland crops, and rangeland--were about $786,600 (Table B-2). Under the baseline, the RLM is expected to increase over four-fold (425 percent) by 2020.

The 1977 returns to land and management for irrigated crops were -$42,200 (Table B-2). Increases are expected to occur under the baseline to about $58,200 in 2020. The RLM for dry cropland is expected to increase from $829,000 in 1977 to $4.0 million in 2020.

Irrigation Water

The quantity of irrigation water diverted is expected to decrease from 2,518 acre-feet in 1977 to 1,181 acre-feet in 2010 then increase to 1,229 acre-feet in 2020 (Table B-2).

Cropland and Cropping Pattern

The irrigated cropland in the Porter-San Jon area is expected to decrease from 1,200 acres in 1977 to 568 acres by 2020 (Table B-2). The dry cropland acreage is expected to remain fairly constant at about 40,000 acres.

Irrigated grain sorghum acreages are expected to decrease over time starting with 792 acres in 1977 and ending with 284 acres in 2020 (Table B-2). Irrigated alfalfa is expected to decrease from 408 acres in 1977 to 168 acres in 2010 and then increase to 284 acres by 2020. Dryland alfalfa is expected to steadily increase from 13,800 acres in 1977 to 16,250 acres in 2020. Dryland grain sorghum is expected to decrease from 5,900 acres in 1977 to 2,000 acres in 2020. Dryland wheat is expected to increase from 19,700 acres in 1977 to 22,300 acres in 2020.

Table B-2. Summary of On-Farm Impacts, Porter-San Jon, Quay County, New Mexico, 1977-2020--Baseline.

Item	Unit	1977	1985	1990	2000	2010	2020
Value of Production	dollars	2,986,280	4,025,443	4,512,689	5,269,609	6,056,936	6,907,974
Irrigated Cropland	dollars	175,878	202,338	203,183	205,669	193,524	191,608
Dry Cropland	dollars	2,810,402	3,823,105	4,309,506	5,063,940	5,863,412	6,716,366
Returns to Land & Management	dollars	786,573	1,371,874	1,826,989	2,548,290	3,307,661	4,126,644
Irrigated Cropland	dollars	-42,216	9,978	14,707	36,252	48,750	58,248
Dry Cropland	dollars	828,789	1,361,896	1,812,282	2,512,038	3,258,911	4,068,396
Irrigation Water							
Quantity	acre-ft	2,518	1,962	1,729	1,428	1,181	1,229
Cost	dollars	62,051	31,487	29,459	26,284	21,698	22,383
Land Use							
Irrigated Cropland	acres	1,200	1,016	935	791	671	568
Dry Cropland	acres	39,360	39,729	39,891	40,178	40,420	40,625
Irrigation Energy							
Electricity	1000 kwh	1,632	674	542	383	298	292
Irrigated Crops							
Alfalfa							
Acreage	acres	408	284	234	198	168	284
Production	ton	1,224	1,007	855	793	751	1,405
Irrigation Water	acre-ft	1,393	948	769	635	525	868
Irrigation Water Cost	dollars	34,329	15,213	13,104	11,692	9,652	15,807
Value of Production	dollars	75,888	63,976	55,491	54,360	54,352	107,100
Returns to Land & Mgt.	dollars	-20,568	-2,974	-3,496	703	8,938	30,428
Grain Sorghum							
Acreage	acres	792	732	701	593	503	284
Production	cwt	27,720	31,115	32,810	31,542	28,427	16,882
Irrigation Water	acre-ft	1,125	1,014	960	793	656	361
Irrigation Water Cost	dollars	27,722	16,274	16,355	14,592	12,046	6,576
Value of Production	dollars	99,990	138,362	147,692	151,309	139,172	84,508
Returns to Land & Mgt.	dollars	-21,648	12,952	18,203	35,549	39,812	27,820
Dryland Crops							
Alfalfa							
Acreage	acres	13,776	15,097	15,956	16,071	16,168	16,250
Production	ton	27,552	35,627	38,910	42,984	48,329	53,689
Value of Production	dollars	1,708,224	2,263,376	2,525,256	2,945,230	3,497,593	4,092,696
Returns to Land & Mgt.	dollars	926,126	1,270,764	1,441,625	1,840,345	2,374,160	2,952,941
Grain Sorghum							
Acreage	acres	5,904	3,576	1,995	2,009	2,021	2,031
Production	cwt	64,944	47,798	29,329	33,569	35,932	38,016
Value of Production	dollars	244,130	218,671	135,511	164,742	179,861	194,478
Returns to Land & Mgt.	dollars	-94,582	-43,395	-15,062	10,200	21,313	32,538
Wheat							
Acreage	acres	19,680	21,056	21,940	22,098	22,231	22,344
Production	bu	255,840	332,493	423,435	504,030	546,074	588,062
Value of Production	dollars	858,048	1,341,058	1,648,739	1,953,968	2,185,958	2,429,192
Returns to Land & Mgt.	dollars	-2,755	134,527	385,719	661,493	863,438	1,082,917

ARCH-HURLEY CONSERVANCY DISTRICT

Value of Production

The 1977 agricultural value of production total in the Arch-Hurley Conservancy District of Quay County was about $3.5 million (Table B-3). The total agricultural value of production is expected to almost triple by 2020. All of the cropland in the district is irrigated (Table B-3).

Returns to Land and Management

The 1977 irrigated returns to land and management total in the district was about $432,100 (Table B-3). Under the baseline, the RLM is expected to increase almost ten-fold. This large increase is due primarily to the surface water supplies available to the district.

Irrigation Water

The quantity of irrigation water diverted is expected to remain fairly stable over time at about 50,900 acre-feet (Table B-3).

Cropland and Cropping Pattern

The irrigated cropland in the district is expected to increase from 26,200 acres in 1977 to 29,000 acres by 2020 (Table B-3). The important crops over time are expected to be alfalfa, cotton, and grain sorghum (Table B-3). These crops are expected to increase in acreage over time while irrigated pasture and wheat are expected to decrease over time.

Table B-3. Summary of On-Farm Impacts, Arch-Hurley Conservancy District, Quay County, New Mexico, 1977-2020--Baseline.

Item	Unit	1977	1985	1990	2000	2010	2020
Value of Production	$1,000	3,520	5,320	6,112	7,522	8,602	10,346
Irrigated Cropland	$1,000	3,520	5,320	6,112	7,522	8,602	10,346
Returns to Land & Management	dollars	432,119	1,118,913	1,468,290	2,559,337	3,467,763	4,557,443
Irrigated Cropland	dollars	432,119	1,118,913	1,468,290	2,559,337	3,467,763	4,557,443
Irrigation Water							
Quantity	acre-ft	50,893	50,879	50,908	50,892	51,002	50,970
Cost	dollars	188,083	250,932	255,741	266,101	266,690	365,075
Land Use							
Irrigated Cropland	acres	26,200	26,200	26,200	26,458	26,970	28,090
Irrigation Energy							
Diesel	gallons	340,676	243,484	248,245	258,156	252,272	366,429
Irrigated Crops							
Alfalfa							
Acreage	acres	7,021	7,937	7,625	8,731	8,900	9,270
Production	ton	24,575	32,777	32,538	40,864	46,559	58,697
Irrigation Water	acre-ft	20,654	23,347	22,429	25,683	26,182	25,737
Irrigation Water Cost	dollars	20,654	23,347	22,429	25,683	26,182	150,601
Value of Production	dollars	1,523,621	2,082,346	2,111,744	2,800,001	3,369,495	4,474,470
Returns to Land & Mgt.	dollars	422,343	656,554	704,033	1,166,519	1,688,905	2,300,732
Cotton							
Acreage	acres	2,096	3,930	5,240	5,292	5,394	5,618
Production	cwt	7,860	17,146	24,508	29,439	31,368	33,982
Irrigation Water	acre-ft	4,192	7,472	10,072	8,432	8,278	8,416
Irrigation Water Cost	dollars	4,192	32,432	31,626	85,565	80,217	71,534
Value of Production	dollars	534,480	1,164,597	1,700,157	2,091,294	2,253,766	2,518,947
Returns to Land & Mgt.	dollars	93,356	181,506	310,971	545,432	663,348	855,862
Grain Sorghum							
Acreage	acres	8,437	8,646	10,480	10,583	10,788	11,236
Production	cwt	243,668	315,218	420,291	482,283	523,129	573,479
Irrigation Water	acre-ft	12,923	11,984	14,352	14,147	14,078	14,312
Irrigation Water Cost	dollars	150,113	187,077	197,631	152,223	136,418	121,651
Value of Production	dollars	892,217	1,413,107	1,906,005	2,328,569	2,577,315	2,888,515
Returns to Land & Mgt.	dollars	-56,904	232,530	388,088	763,413	972,347	1,208,213
Pasture							
Acreage	acres	5,764	0	0	0	0	0
Production	1977 $	345,840	0	0	0	0	0
Irrigation Water	acre-ft	9,032	0	0	0	0	0
Irrigation Water Cost	dollars	9,032	0	0	0	0	0
Value of Production	dollars	345,840	0	0	0	0	0
Returns to Land & Mgt.	dollars	9,897	0	0	0	0	0
Wheat							
Acreage	acres	2,882	5,687	2,855	1,852	1,888	1,966
Production	bu	72,050	172,709	105,977	81,234	107,021	119,417
Irrigation Water	acre-ft	4,092	8,076	4,055	2,630	2,464	2,505
Irrigation Water Cost	dollars	4,092	8,076	4,055	2,630	23,873	21,289
Value of Production	dollars	223,355	659,612	393,673	301,930	401,700	464,002
Returns to Land & Mgt.	dollars	-36,573	48,323	65,198	83,973	143,163	192,636

NARA VISA AREA

Value of Production

The 1977 irrigated agricultural value of production total in the Nara Visa area (Nara Visa and Nara Visa South) of Quay County was about $2.3 million (Table B-4). The total and irrigated agricultural value of production is expected to almost double by 2020.

Returns to Land and Management

The 1977 irrigated returns to land and management (RLM) total in the Nara Visa area of Quay County was about $218,000 (Table B-4). Under the baseline, the RLM is expected to increase 200 percent.

Irrigation Water

The quantity of irrigation water diverted is expected to increase from 5,900 acre-feet in 1977 to 7,500 acre-feet in 2020 (Table B-4).

Cropland and Cropping Pattern

The irrigated cropland is expected to increase from 2,800 acres in 1977 to 4,400 acres by 2020 (Table B-4).

Irrigated pasture acreages are expected to increase over time starting with 1,900 acres in 1977 and ending with 3,000 acres in 2010 and then decrease to 2,200 acres by 2020 (Table B-4). Irrigated wheat is expected to increase from 900 acres in 1977 to 2,200 acres in 2020.

Table B-4. Summary of On-Farm Impacts, Nara Visa, Quay County, New Mexico, 1977-2020--Baseline.

Item	Unit	1977	1985	1990	2000	2010	2020
Value of Production	dollars	2,265,306	3,249,218	3,642,332	4,181,496	4,646,403	4,002,362
Irrigated Cropland	dollars	2,265,306	3,249,218	3,642,332	4,181,496	4,646,403	4,002,362
Returns to Land & Management	dollars	218,090	452,261	418,400	521,522	575,322	636,324
Irrigated Cropland	dollars	218,090	452,261	418,400	521,522	575,322	636,324
Irrigation Water							
Quantity	acre-ft	5,893	6,495	6,831	7,350	7,911	7,532
Cost	dollars	343,314	352,718	405,007	419,850	458,273	444,296
Land Use							
Irrigated Cropland	acres	2,820	3,109	3,264	3,599	3,967	4,374
Irrigation Energy							
LP Gas	gallons	1,072,856	665,332	663,053	667,117	703,567	662,234
Irrigated Crops							
Pasture							
Acreage	acres	1,889	2,238	2,448	2,699	2,975	2,187
Production	1977 $	2,135,022	2,529,482	2,766,240	3,049,305	3,362,032	2,470,745
Irrigation Water	acre-ft	4,572	5,288	5,713	6,148	6,617	4,747
Irrigation Water Cost	dollars	266,339	287,185	338,750	351,165	383,302	279,999
Value of Production	dollars	2,135,022	3,060,674	3,430,138	3,903,110	4,303,402	3,162,554
Returns to Land & Mgt.	dollars	251,866	437,878	388,510	449,485	463,631	315,631
Wheat							
Acreage	acres	931	871	816	900	992	2,187
Production	bu	46,530	52,871	60,573	78,910	93,696	221,326
Irrigation Water	acre-ft	1,321	1,207	1,118	1,202	1,294	2,785
Irrigation Water Cost	dollars	76,975	65,533	66,257	68,685	74,971	164,297
Value of Production	dollars	130,284	188,544	212,194	278,386	343,001	839,808
Returns to Land & Mgt.	dollars	-33,776	14,383	29,890	72,037	111,691	320,693

LOGAN AREA

Value of Production

The 1977 irrigated agricultural value of production total in the Logan area of Quay County was about $97,700 (Table B-5). The agricultural value of production total is expected to increase 150 percent by 2020.

Returns to Land and Management

The 1977 irrigated returns to land and management total in the Loga area was about -$7,750 (Table B-5). Under the baseline, the RLM is expected to increase $248,400 by 2020.

Irrigation Water

The quantity of irrigation water diverted is expected to remain fairly constant, varying from 1,136 acre-feet in 1977 to 1,019 acre-feet in 2020 (Table B-5).

Cropland and Cropping Pattern

The irrigated cropland in the Logan area of Quay County is expected to remain constant at 800 acres over time (Table B-5).

Irrigated grain sorghum acreages are expected to decrease over time starting with 400 acres in 1977 and ending with 200 acres through 2020 (Table B-5). Irrigated wheat is expected to increase from 400 acres in 1977 to 600 acres from 1990 through 2020.

Table B-5. Summary of On-Farm Impacts, Logan, Quay County, New Mexico, 1977-2020--Baseline.

Item	Unit	1977	1985	1990	2000	2010	2020
Value of Production	dollars	97,700	146,258	170,711	203,543	225,606	248,407
Irrigated Cropland	dollars	97,700	146,258	170,711	203,543	225,606	248,407
Returns to Land & Management	dollars	-7,748	11,481	26,823	52,148	72,069	93,085
Irrigated Cropland	dollars	-7,748	11,481	26,823	52,148	72,069	93,085
Irrigation Water							
Quantity	acre-ft	1,136	1,109	1,096	1,069	1,044	1,019
Cost	dollars	32,672	35,174	32,736	29,539	28,781	27,800
Land Use							
Irrigated Cropland	acres	800	800	800	800	800	800
Irrigation Energy							
Diesel	gallons	75,980	40,083	36,796	32,183	30,182	28,574
Irrigated Crops							
Grain Sorghum							
Acreage	acres	400	280	200	200	200	200
Production	cwt	14,000	11,910	9,358	10,634	11,314	11,910
Irrigation Water	acre-ft	568	388	274	267	261	255
Irrigation Water Cost	dollars	16,336	12,311	8,184	7,385	7,195	6,950
Value of Production	dollars	50,500	52,960	42,122	51,010	55,392	59,618
Returns to Land & Mgt.	dollars	-5,096	3,433	4,375	11,444	15,376	19,249
Wheat							
Acreage	acres	400	520	600	600	600	600
Production	bu	16,000	25,266	35,631	42,109	45,348	48,587
Irrigation Water	acre-ft	568	721	822	802	783	764
Irrigation Water Cost	dollars	16,336	22,863	24,552	22,154	21,586	20,850
Value of Production	dollars	47,200	93,298	128,589	152,533	170,214	188,789
Returns to Land & Mgt.	dollars	-2,652	8,048	22,448	40,704	56,693	73,836