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THE ENERGY IMPACT ON IRRIGATED AGRICULTURAL PRODUCTION OF THE SOUTHWESTERN CLOSED BASINS, NEW MEXICO

Partial Technical Completion Report

Project Nos. 3109-410,

1423693, 1423694

New Mexico Water Resources Research Institute

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PARTIAL TECHNICAL COMPLETION REPORT

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New Mexico Water Resources Research Institute
in cooperation with
Department of Agricultural Economics
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and
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ABSTRACT

A linear programming model was utilized to simulate a 20 year (1978-1998) crop production and irrigation water utilization pattern in the Southwestern Closed Basins of New Mexico under four alternative energy price projections--base, low, medium and high.

Under the simulation, approximately 75,700 acres of land would be farmed in 1978, remaining constant through 1998. Cotton accounted for 47 percent of the irrigated cropland, corn for grain 31 percent, grain sorghum 16 percent, and wheat 6 percent. However, under the high energy price alternative, irrigated crop agriculture ceased in some areas in 1996 and in other areas in 1998.

Net returns to land and risk varied widely among the four energy price projections ranging from an increase of one percent in the base alternative from 1978 to 1998 to a 62 percent reduction in net returns in the high energy price alternative through 1998. The reduction in net returns from 1978 to 1998 for the low energy price alternative was about 23 percent and about 40 percent for the medium energy price alternative. The reduction in net returns was due primarily to the rapid escalation of diesel fuel prices. The diesel fuel cost for the high alternative was expected to increase 269 percent, 185 percent for the medium alternative, and about 119 percent for the low alternative over present costs.

The returns to risk, after imposing a charge for the use of irrigated cropland valued at $800 per acre, was $70 per acre in the base year of 1978. The returns to risk declined under the low ($49) and medium ($23) energy price alternatives in 1998. Under the high price alternative the net return to risk was estimated at a negative $10 per acre in 1998.

The amount of irrigation water pumped in the Southwestern Closed Basins would remain constant over the 20 year period for the energy price alternatives, except 1996 and 1998 under the high alternative when pumpage declined. The total declines in the water tables were estimated to be about 41 feet in the Mimbres-Uvas Basins, from 102 to 126 feet in the Columbus-Hermanas Area, about 34 feet in the Lordsburg-Animas Basins, and from 6 to 7 feet in the Playas Basin. In addition, there were changes in energy sources for pumping irrigation water, irrigation pumping plant efficiencies and energy costs for pumping irrigation water among the alternative energy price projections.

The annual labor requirements and cost as well as the annual operating capital requirements remained constant except under the high alternative when a decline occurred in relation to the decline in acreage.

TABLE OF CONTENTS

Table of Contents (con'd)

LIST OF TABLES

LIST OF APPENDIX TABLES

THE ENERGY IMPACT ON IRRIGATED AGRICULTURAL PRODUCTION OF THE SOUTHWESTERN CLOSED BASINS, NEW MEXICO

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INTRODUCTION

The Southwestern Closed Basins are important, productive, groundwater irrigated agricultural areas in New Mexico (Figure 1). The groundwater irrigated acreage of the Southwestern Closed Basins represents about 7.5 percent of the irrigated acreage in New Mexico (Lansford, et al., November, 1979) and accounts for over eight percent of the cash receipts from crop sales in the state. The area is faced with a declining water table and rising energy costs. Some of the developed areas are now discontinuing irrigation. Concern has been voiced about the rapidly rising energy costs and the declining water tables and their impact on the economy of the region and the state.

Objectives

The primary objective of this study was to evaluate the economic impacts of alternative energy prices and declining groundwater levels on the groundwater irrigated agriculture in the Southwestern Closed Basins of New Mexico. To pursue this objective, it was necessary to develop an economic model for the evaluation of alternative energy prices. The following sub-objectives were required to carry out the overall objectives:

1. Hydrology - To estimate availability and projected decline of the groundwater resource in the Southwestern Closed Basins.

2. Agriculture - To estimate current and future water use for irrigated agriculture in the Southwestern Closed Basins at alternative energy prices.

3. Energy - To estimate alternative future energy prices for a 20 year period (1978-1998).

4. Economic - To develop a mathematical programming model with net returns to land and risk for the basis of economic comparison. Constraints on the model are water availability, cropping patterns, irrigated cropland availability, and the price of energy.

GENERAL DESCRIPTION

The Southwestern Closed Basins, located in southwestern New Mexico, are composed of numerous drainage basins. The primary sub-basins with irrigated cropland are the Mimbres Valley in Grant and

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*Principal contributors to this interdisciplinary research effort: Professor, Agricultural Economics and Agricultural Business Department; Assistant Professor, Civil Engineering Department; Research Specialist, Agricultural Economics and Agricultural Business Department; Research Assistant, Agricultural Economics and Agricultural Business Department; Research Specialist, Agricultural Economics and Agricultural Business Department, Research Specialist, Agricultural Economics and Agricultural Business Department, respectively.

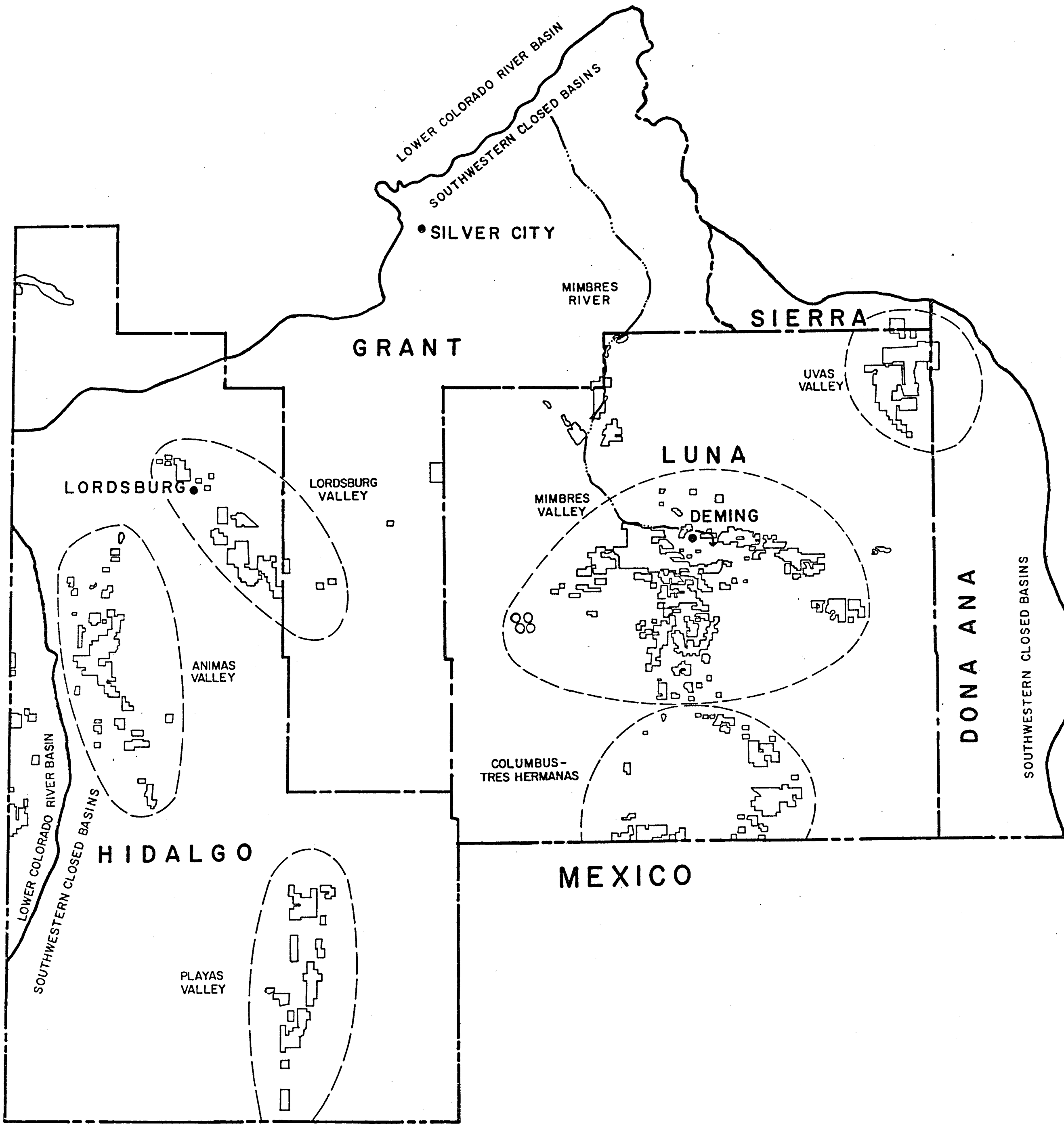

Figure 1. Location of irrigated cropland and underground water basins in Southwestern New Mexico, 1978

Luna Counties, the Lordsburg Valley in Grant and Hidalgo Counties, Animas Basin in Hidalgo County, and the Playas Basin in Hidalgo County. The Southwestern Closed Basins are bounded geographically on the north by the lower Colorado River Basin, on the south by Mexico, on the east by the Rio Grande River Basin, and on the west by the Peloncillo Mountains and Arizona. The Southwestern Closed Basins include all of Luna County, a large part of Hidalgo County, a portion of eastern and southern Grant County, and small areas in both Sierra and Dona Ana Counties. The principal communities in the area are the cities of Deming, Lordsburg, and Silver City. The basin has a total drainage area of approximately 8,500 square miles.

For purposes of this study, areas of major groundwater irrigation were selected, including all of Luna County, the southern panhandle of Grant County and that portion of Hidalgo County included in the Southwestern Closed Basins (Figure 1).

Topography and Climate

The Southwestern Closed Basins constitute the southwestern-most component of the Basin and Range physiographic province of New Mexico, which consists of isolated mountain ranges separated by wide desert plains. It is physically separated from the other basins in the region by low-lying hills and ridges. The Peloncillo Mountains in the west and the Pinos Altos and Mimbres Mountains in the north separate the basin from the Lower Colorado Basin. Similarly, in the east, the basin is separated from the Rio Grande Basin by the Sierra de las Uvas Mountains and low hills and ridges.

The topography of the Southwestern Closed Basins varies from mountains in the north to open plains interspersed with low-lying hills in the center, to broken hills and ridges on the west, east and south. Runoff from local rainfall is collected in channels originating in the mountains and hills, or arroyos on the plains. The majority of these channels broaden and disappear, however, with only a few contributing to the playas in the southern part of the study area. The majority of the land in Luna and Hidalgo Counties consists of semi-arid desert plains interrupted by low mountain ranges, alkali flats and playas. The northern portion of Luna and Grant Counties consists of rugged mountain ranges which are outside of the study area.

The climate in the Southwestern Closed Basins is characterized by clear, warm, sunny days, large diurnal temperature variations, low humidity, and low rainfall. The mean annual precipitation averages about 8.6 inches at Deming and 10.1 inches at Lordsburg. The majority of precipitation occurs in the summer and early fall months at irregular and infrequent intervals in the major irrigated regions within the basin. The precipitation in the area is usually accounted for by the replacement of soil moisture, evaporation, and surface runoff.

Temperatures in the major irrigated area average about 60 degrees Fahrenheit at Deming and 61.5 degrees Fahrenheit at Lordsburg. Winters are cool, with a mean temperature of about 41 degrees Fahrenheit at Deming and 42 degrees Fahrenheit at Lordsburg in January, and a mean temperature of about 80 degrees Fahrenheit at Deming and Lordsburg in July. The growing season usually begins in mid-April, and lasts about 200 days, until the end of October or early November.

Drainage Area

The Southwestern Closed Basins in New Mexico consist of several closed drainage systems, having no outlet to adjacent river basins. The drainage area encompasses a total of approximately 8,500 square miles which lie in Luna, Hidalgo, and Grant Counties. The basin has no permanent streams. A few streams on the north side of the study area are perennial in their upper reaches; however, no other surface water exists with the exception of the playas in the southern portion of the basin. The Mimbres River is perennial only in its upper reaches, extending to the vicinity of the Grant-Luna County line. Flows vary widely, with the perennial supply originating primarily from snow melt and springs.

Water Resources

The vast majority of water used for irrigation, municipal, industrial, and domestic purposes comes from groundwater sources. The principal aquifers in the Southwestern Closed Basins are those of alluvium and bolson deposits. These aquifers probably account for more water in the basin than all other aquifers combined. Relatively small amounts of water come from surface water sources. The alluvium of the stream valleys and the bolson deposits constitute the most important and only known extensive groundwater reservoirs in the study area. The alluvial reservoirs are stream-connected, but, the principal aquifer is the bolson deposits. These deposits consist of sand, clay, and gravel, in mixtures of particle sizes and in irregular beds and lenses with local, imbedded volcanic rock. The bolson fill is primarily of the Tertiary and Quaternary age. The bedrock underlying the basin has not been explored in detail; therefore, the waterbearing capacity of this deeper rock is unknown.

The aquifer is continuous over most of the basin, covering an estimated 5,600 square miles, mostly in the southern portion of the study area. While the deposits range up to 1,000 feet in depth, a more conservative average of 250 feet of thickness has been estimated. Water quality is generally good; however, poor quality water occurs locally.

The basin is generally confined both topographically and structurally with the exception of the extension on several sub-basins south into Mexico.

The principal source of groundwater recharge in the Southwestern Closed Basins is runoff from precipitation and subsequent infiltration into the aquifer through permeable stream beds and alluvial lands where coarse particles permit water to infiltrate easily. Some water may eventually reach the playas in Southern Hidalgo County via the many ephemeral streams; however, this water is usually evaporated before percolation to the water table occurs.

Surface water is a very minor portion of the total available water and is utilized only in the upper reaches of the Mimbres River. It is used primarily in conjunction with groundwater sources for irrigation purposes. Development of the groundwater reservoir began about 1908 in the Deming area. Pumping for large-scale irrigation for other parts of the study area began about 1948 and irrigated agriculture expanded rapidly. Five underground water basins have been declared by the State Engineer in the Southwestern Closed Basins.

The yields of typical irrigation wells range from 200 to over 1,800 gallons per minute. The depth to water in these wells ranges from less than 25 feet to over 400 feet below the surface. The saturated thickness of the aquifer ranges from 40 feet to over 300 feet. The amount of groundwater withdrawn annually exceeds the recharge in most areas; however, water levels are actually rising in some wells due primarily to lateral water movement. The average groundwater decline ranges from less than a foot in some areas to nearly four feet in others.

Land Resources

The study area of the Southwestern Closed Basins comprises some 4.6 million acres. Approximately 47 percent of this acreage lies in Hidalgo County, 41 percent in Luna County, and 11 percent in Grant County. The ownership of land in the study area is approximately 42 percent federal, 22 percent state, and 36 percent private or other miscellaneous public uses, such as roads and towns (Table 1).

Agricultural use accounts for about 97 percent of the total land (Table 2). Included in the agricultural use category are croplands, grazing lands, and commercial timber lands. Crop production accounts for only about 2 percent of the land and commercial timber less than one percent, while grazing uses comprise the balance of 94 percent of the land devoted to agricultural use.

Table 1. Land Ownership in the Southwestern Closed Basins, 1978*

Land	Luna County	Hidalgo County	Grant County	Total
	acres			
Indian Lands	0	11,000	0	11,000
Federal Lands	786,150	882,679	260,320	1,929,149
Forest Service	---	(77,220)	(22,240)	(99,460)
BLM	(783,534)	(805,459)	(238,080)	(1,827,073)
Defense	(2,081)	---	---	(2,081)
Miscellaneous	(535)	---	---	(535)
State Land	534,951	354,431	120,320	1,089,702
Private and Other	571,379	957,970	137,760	1,667,109
Total Area	1,892,480	220,608	518,400	4,616,960

*Only includes those lands in the study area -- all of Luna County, the panhandle of Grant County and that portion of Hidalgo County in the Southwestern Closed Basins.

Source: Adapted from New Mexico State Engineer Office, Land Ownership and Administration by County and Drainage Basin, Open File Report, Santa Fe.

Table 2. Land Use in the Southwestern Closed Basins, 1978*

Land	Luna County	Hidalgo County	Grant County	Total
	acres			
Inland Waters	0	16,074	0	16,074
Urban and Built Up	17,820	10,470	1,426	29,716
Roads	10,451	10,217	2,243	22,911
Crops (total)	67,140	35,230	2,612	104,982
Irrigated	(67,140)	(35,230)	(2,612)	(104,982)
Defense	2,081	0	0	2,081
Parks, fish and wildlife	980	0	0	1,020
Commercial timber	0	11,666	22,625	34,291
Grazing lands (total)	1,794,008	2,122,383	489,494	4,405,885
Non-commercial timber	(17,730)	(210,383)	(137,058)	(365,412)
Range land	(1,776,278)	(1,911,759)	(352,436)	(4,040,473)
Total Area	1,892,480	2,206,080	518,400	4,616,960

*Only includes those lands in the study area -- all of Luna County, the panhandle of Grant County, and that portion of Hidalgo County in the Southwestern Closed Basins.

Source: Adapted from New Mexico State Engineer Office, Land Use by Counties and River Basins, Open File Report, Santa Fe, June 6, 1974.

The irrigated cropland in the Southwestern Closed Basins is located principally on the basin floor (Figure 1). The acreages of the various crops produced are reported in Table 3. The most important crop was cotton at 27 percent, followed by grain sorghum at 12 percent, native pasture at 9 percent and corn and small grains at 7 percent of the total irrigated cropland. Idle and fallow land accounted for 25 percent of the total irrigated cropland of 114,640 acres in 1978.

METHODS AND PROCEDURES

An interdisciplinary approach to the solution of the water resource problems in the Southwestern Closed Basins was made possible by the integration of hydrology with economics. Research procedures developed to carry out this study were closely coordinated by the investigators to achieve the stated

Table 3. Estimated Irrigated Crop Acreage in the Southwestern Closed Basins, New Mexico, 1973-1978, By Crop

ITEM*	1973	1974	1975	1976	1977	1978≠
	(ACRES)					
IRRIGATED CROPS						
CORN	2,770	6,520	5,000	4,500	11,700	7,800
SORGHUM-GRAIN	30,100	33,400	42,000	44,200	21,500	13,700
SORGHUM-ALL OTHER	600	700	--	120	--	200
WHEAT	1,870	2,600	4,550	8,750	4,050	6,200
BARLEY	4,350	3,800	5,500	2,200	2,850	1,300
OTHER SMALL GRAINS	490	400	230	1,020	390	300
COTTON-UPLAND	21,900	22,100	11,500	8,820	26,000	28,500
COTTON-AMERICAN/PIMA	3,405	1,050	830	420	1,200	2,300
PEANUTS	10	--	10	5	10	5
SUGAR BEETS	--	--	50	230	55	--
DRY BEANS	330	1,900	3,200	1,030	640	1,150
ALL OTHER FIELD	120	440	270	210	35	30
POTATOES	--	--	--	--	40	30
LETTUCE	340	540	590	160	370	340
ONIONS	620	620	440	250	350	340
CHILE	655	1,110	810	610	540	650
ALL OTHER VEGETABLES	630	350	180	235	330	205
ORCHARDS AND VINEYARDS	830	850	800	820	820	840
ALFALFA	3,700	4,200	4,100	4,150	5,100	4,850
PLANTED PASTURE	3,260	5,000	3,300	2,420	2,200	2,200
NATIVE PASTURE	10,350	10,350	10,350	10,350	10,350	10,350
SUB-TOTAL ALL CROPS	86,330	95,930	93,710	90,500	88,530	81,290
MULTIPLE-CROPPED	3,050	4,050	4,660	2,700	1,500	1,000
TOTAL ACRES IRRIGATED	83,280	91,880	89,050	87,800	87,030	80,290
CROPLAND ADJUSTMENT PROGRAM (CAP)	220	220	220	220	--	--
DIVERTED-SETASIDE (PLANTED)	(100)	--	--	--	--	--
DIVERTED-SETASIDE (IDLE AND FALLOW)	2,090	--	--	--	--	5,355
PLANTED (NOT IRRIGATED)	--	--	--	--	--	--
IDLE AND FALLOW	22,650	16,460	19,650	23,370	25,890	28,995
TOTAL IRRIGATED CROPLAND	108,240	108,560	108,920	111,390	112,920	114,640

* HYPHENS (--) REPRESENT ZERO.
≠ PRELIMINARY.

objectives. Inputs into the economic model were obtained from separate area studies covering hydrology, crop agriculture, energy price projections, and the cost of farm fuels.

The economic model was designed to represent the cropped agricultural economy of the Southwestern Closed Basins and to obtain the optimal combination of irrigated crop activities (acres), resultant income, water pumpage, and direct agricultural employment under conditions of increasing energy costs and increasing depths to water. It consists primarily of a linear programming (LP) model, with other sub-models determining fuel cost and pumping cost to provide input into the LP model, and with a set of constraints placed upon land, water and energy related resources. These constraints include:

1. Groundwater resources
2. Land resources -- groundwater irrigated cropland
3. Sources of energy for irrigation water pumpage
4. Risk and agronomic considerations

Model Description

An LP model was developed, incorporating crop enterprise cost and returns budgets, a pumping cost model, hydrologic data, and projected energy prices for four sub-areas in the Southwestern Closed Basins. The model incorporates the outputs of each sub-investigation and is utilized to project future water-use patterns and crop agriculture economic activity under alternative energy costs.

An optimal solution of the model for a given set of economic and hydrologic conditions can be obtained by maximizing the model's objective function. The model is designed to maximize regional farm return to land and risk. Each crop contributes to the total farm return according to its level of production, while increased energy costs and declining water table levels impose additional costs on the region's economy.

The model's basic behavioral assumption is that farmers are profit maximizers and that they will adjust their decisions in a weighted time-lag manner, i.e., that the producer's behavior in the current time period is a function of economic groundwater conditions in previous time periods. This behavioral assumption indicates that the farmer's decision-making process is dependent on historical information with the most recent information being the most important.

In summary, the methodology for any year is as follows: First, the effects of an energy price increase on farm machinery fuel prices and irrigation water fuel prices would be determined. Second, the pumping plant efficiency would be determined based upon the time period and engineering data. Third, the total aquifer decline based upon water pumped in previous time periods would be determined by hydrologic relationships. Fourth, the total water horsepower requirements would be estimated for both flood and sprinkler systems. Fifth, the actual fuel cost per acre-foot of water pumped would be determined by considering fuel prices, pumping plant efficiency, and total water decline for both flood and sprinkler systems by fuel type. Sixth, the fuel costs for both farm machinery operation and irrigation water pumping would be moved into the objective function of the LP model. The technical coefficients and the returns in the LP model are based on the crop cost and returns budgets for the Southwestern Closed Basins. At this point, a solution to the model would be obtained. Seventh, the time period would be advanced, the amount of water pumped would be added to that previously pumped, and the process would then be repeated.

A detailed formulation of the LP model as well as the sub-models are presented in Appendix A. The individual sub-region models are also presented in Appendix A.

Model Components

Results and interpretations from the economic model are only as good as the assumptions within the model and the reliability of the basic input data. Consequently, a major portion of the time and effort of this study went into the preparation of the basic hydrologic, agricultural, and economic data. The year 1978 was chosen as the base year for the coefficients in the model.

Hydrologic Data

Economic analysis of irrigated agriculture required the evaluation of the groundwater characteristics and quantification of parameters regarding existing and future conditions. The groundwater and well characteristics of prime interest are: aquifer saturated thickness, depth to water, well yield, and pumping lift. A comprehensive alternative water-use analysis also requires information on the condition and response of the aquifer under various projected stresses. The numerous groundwater and well characteristics vary according to the magnitude of these projected stresses. A sufficient data source of these characteristics under future usage does not exist, and methods of indirect assessment are required. It was assumed that estimates of the rate of decline of the water table and representative well yields provide the necessary input for assessing projected stresses. Historic data on water levels, rates of decline, pumping lift, and well yields were obtained from various publications and open-file reports of the New Mexico State Engineer Office.

Crop Costs and Returns Budgets

Per acre crop costs and returns enterprise budgets were developed for the more important irrigated crops for each of the four sub-regions in the study area; the Mimbres and Uvas Basins in Luna and Grant Counties, the Columbus-Hermanas area in Luna County, the Lordsburg and Animas Valleys in Hidalgo and Grant Counties, and the Playas Basin in Hidalgo County. These budgets were developed for farms that are above-average in both size and management on the basis of soil, water quality, and water quantity conditions. The measure of profit used in constructing the enterprise budgets was net return to land and risk. Net return to land and risk does not include an interest charge on the land investment. However, a charge is made for all purchased inputs such as seed, fertilizers, insecticides, and herbicides. Labor, fuel, repairs for machinery and equipment, fixed machinery equipment costs (depreciation and personal property taxes), overhead expenses (insurance), land taxes, employee benefits, management's interest on operating, and interest on machinery investment are similarly charged against gross income.

The crop cost and returns budgets were developed by a computer-based whole farm cost-and-return budget generator written by the Agricultural Economics and Agricultural Business Department at New Mexico State University. A more detailed description of the budget generator and assumptions for the crop budgets are presented in the crop budget report for Southwestern Closed Basins (Lansford et al., 1980). The crop budgets by sub-basin were adopted from Lansford et al. (1980).

For purposes of this report, "above-average" management of farms, and therefore above-average yields in 1978, were assumed to be the average yields and net returns over the 20 year time horizon of this study. This assumption overstates the expected net returns in the early years of the projections and probably underestimates the expected net returns in the latter years of the 20 year projection. The yields used in the budgets were approximately 20 to 30 percent above those reported in New Mexico Agricultural Statistics for 1978. The upward trend in crop yields over the past 20 years is due primarily to improved crop varieties and better irrigation water management. Therefore, it was felt that by choosing above-average managed farms for 1978, the average farmers should achieve those expected yields in 10 to 15 years. Since average farm size has been increasing over the past 40 to 50 years, it was felt that by using an above-average farm size, increases in farm sizes in the next 10 to 20 years would be adequately reflected.

Energy Price Projections

Because of the emergence of OPEC as a world price leader after the 1973-1974 oil embargo, the projection of possible energy price increases over the next two decades becomes clouded with a high degree of uncertainty. The energy price increase projections for this analysis were based on the United States Department of Energy (DOE) Project Independence Evaluation System (PIES) projection as presented in the 1978 Annual Report to the Congress. The PIES model is the DOE's major mid- to long-term energy forecasting and analysis model. It consists of a number of complex interrelated econometric models and associated data bases which can be used to project the state of the energy market in the years 1980, 1985, and 1990.

The PIES model determines the equilibrium of supply and demand for eight different fuel types in each of the nation's nine Census Regions. Demand estimates are provided separately by log-linear approximations to a collection of econometric models. A variety of techniques are used to develop supply curves for oil, coal and natural gas, and also to develop costs of converting fuels into the energy forms in which they are used by consumers. An elaborate transportation network is included in order to model the transport of fuels and products across the nation. The sum of production, conversion and transportation costs and the price paid for imports is the cost of supplying energy to the nation. At the center of PIES is the Integration Model, which combines the supply and demand sides of the overall model with a linear programming model (McRea, 1977).

The U.S. DOE 1978 Annual Report to the Congress specified five scenarios based on various supply, demand, and world price situations. The lowest scenario indicated almost no real increases in the price of energy, while the highest scenario considered low supplies, high demand, and high world prices for energy resources. Scenario B is probably the most reasonable scenario for estimating real annual increases in the price of energy for the southwestern United States.

Under Scenario B energy prices in the commercial sector (which includes irrigation) were estimated to increase by the following percentages by 1985: electricity 5.18 percent, natural gas 8.27 percent, distillants 6.01 percent, and liquid products by 6.42 percent. The same scenario projected annual real price increases to the year 1990 for the commercial sector to be electricity 3.74 percent, natural gas 4.43 percent, distillants 4.36 percent and liquid products 4.65 percent.

The PIES projections only forecasted prices to 1990. However, the time horizon for this study is to the year 1998. The time factor combined with rapidly escalating energy prices during 1978-1979 led to the decision to develop alternative energy price projections.

In cooperation with Los Alamos Scientific Laboratory personnel, a set of real energy price projections were developed for the years 1979 through 1998 based on PIES scenarios as presented to the Congress in 1978. One price projection is that of no real increase in the price of energy products purchased by farmers in New Mexico during the period 1979-1998. A second energy price projection estimates a low annual real energy price increase (based on Scenario B), a third projection estimates a medium real annual price increase for energy which essentially is 1.5 times the low alternative, and a fourth projection estimates a high real annual increase in energy prices of about two times the low energy alternative.

The impact of increasing energy prices on fertilizer costs were evaluated using secondary data. Two recent studies of the fertilizer industry by Dvoskin and Heady (1976) and Whittlesey and Lee (1975) were the primary sources of data for this evaluation.

Farm Fuel Costs

The base fuel costs for natural gas, electricity, and diesel were developed in the regional crop budgets. The base fuel costs were increased by the energy price alternatives to project fuel costs. The estimate of future fuel costs under the four energy price alternatives were determined by utilizing equations 2 through 8 in Appendix A.

A model was developed to determine the cost per acre-foot of pumping water which incorporated hydrologic information, engineering relationships and information, and energy price projections to compute fuel costs for the pumping irrigation model. Hydrologic information provided the model with depth to water, specific well capacity, and drawdown data. Engineering relationships include the formulas to determine the amount of fuel necessary to pump the required amount of water, and engineering information provided the initial well efficiencies. The energy price projections provided the rate of adjustment of fuel prices in real terms over time. The model was designed to represent a dynamic situation in which several variables may move in the same or different directions at the same time. In keeping with the dynamic nature of the model, farmers were assumed to assimilate present and new technology in their irrigation water pumping systems, which results in more efficient systems.

RESULTS AND IMPLICATIONS

This comprehensive study was made possible through the inclusion of several disciplines and study areas. These disciplinary activities were designed primarily to provide necessary information for the linear programming model. These activities included data collection, analysis, and interpretation. Secondary data were compiled whenever possible. In a number of study areas, more detailed investigations were necessary for incorporation into the model. Some of these activities resulted in additional information beyond the needs of the model and the scope of this report and will be published as separate reports.

Hydrologic Data

An economic analysis of irrigated agriculture required the evaluation of existing groundwater conditions and the projection of future conditions regarding quantity and availability in each particular sub-basin. The principal aquifers have a practical maximum thickness of approximately 250 feet. Saturated thickness will decrease with time in response to groundwater depletion, which is almost entirely due to irrigated agriculture. Availability of groundwater for each subregion was defined in terms of depth to water, drawdown at the pumping well, and well yield.

Mimbres-Uvas Basins

Depth to water ranges from 60 to 170 feet, with a typical value of about 145 feet. Typical irrigation wells in the area yield approximately 800 gpm and well yields range from 100 to 2,000 gpm. The drawdown at the pumping well can be determined from the specific capacity which is the yield in gallons per minute divided by the drawdown. The wells in the Mimbres-Uvas Basins presently have a specific capacity of approximately 27 gpm per foot of drawdown. The present pumping lift of typical wells is 145 feet of static lift plus 30 feet of drawdown, resulting in a lift of 175 feet. The decline in the saturated thickness will vary with location in response to geologic conditions, sources of recharge, and imposed stress. A typical value of 1.6 feet per year decline in saturated thickness was used.

Columbus-Hermanas Area

Depth to water ranges from less than 15 feet to nearly 400 feet, with a typical value for the present depth to water of about 270 feet. The typical irrigation wells in the area yield approximately 1,000 gpm and well yield ranges from 60 to over 2,800 gpm. The wells in the Columbus-Hermanas area presently have a specific capacity of approximately 14.3 gpm per foot of drawdown. The present pumping lift of typical wells is 270 feet of static lift plus 70 feet of drawdown, resulting in a lift of 340 feet. The decline in the saturated thickness will vary with location in response to geologic conditions, sources of recharge, and imposed stress. A typical value of 5.0 feet per year was used for this area.

Lordsburg-Animas Basins

The depth to water in the area ranges from about 20 feet to over 260 feet with a typical value of about 125 feet. Typical irrigation wells yield approximately 900 gpm, and well yield ranges from 200 to nearly 1,900 gpm. The wells in the Lordsburg-Animas Basins presently have a specific capacity of approximately 30 gpm per foot of drawdown. The present pumping lift of typical wells is 125 feet of static lift plus 30 feet of drawdown, resulting in 155 feet of lift. The decline in the saturated thickness will vary with location in response to geologic conditions, sources of recharge, and imposed stress. A typical value of 1.8 feet per year decline in saturated thickness was used for this area.

Playas Basin

Depth to water in the area ranges from as little as 2 feet to as much as 290 feet, with a typical value of about 75 feet. Irrigation wells range in capacity from 200 to over 2,500 gpm. However, there exists a diversity of geohydrologic conditions in the area, and a truly representative well is difficult to identify. A well with a capacity of 2,000 gpm was selected to represent a typical well in the area. Due to the size of operations now existing in the Playas Basin, high capacity wells are commonly utilized. The wells in the Playas Valley presently have specific capacities of approximately 25 gpm per foot of drawdown. The present pumping lift of typical wells is 75 feet of static lift plus 80 feet of drawdown, resulting in 155 feet of lift. The decline in the saturated thickness will vary with location in response to geologic conditions, sources of recharge, and imposed stress. A typical value of 0.3 feet per year decline in saturated thickness was used for the area.

Summary

A comprehensive alternative water-use analysis also requires information on the condition and response of the aquifer under various projected stresses. The numerous groundwater and well characteristics will vary according to the magnitude of these projected stresses. It was assumed that future groundwater response will be comparable to past response. Specifically, it was assumed that the near future decline in water levels can be estimated by a typical decline of 1.6 feet per year in the Mimbres-Uvas Basins, 5.0 feet per year in the Columbus-Hermanas area, 1.8 feet per year in the Lordsburg-Animas Basins, and 0.3 feet per year in the Playas Basin. The water level data was obtained from the State Engineer Office in cooperation with the U. S. Geological Survey.

Crop Costs and Return Budgets

Per-acre crop costs and return enterprise budgets were developed for four sub-regions in the Southwestern Closed Basins of New Mexico: Mimbres and Uvas Basins in Luna and Grant Counties, Columbus-Hermanas Area in Luna County, Lordsburg and Animas Valleys in Hidalgo and Grant Counties, and the Playas Basin in Hidalgo County. Only flood irrigation systems were included in the budgets. Much of the information for the budgets was obtained from local farmers during a series of meetings in the sub-regions during 1978 and 1979. Detailed individual crop budgets can be found in Appendix B. The major items of cost and returns by sub-region are summarized in Table 4. A summary discussion of the budgets for each sub-region follows.

Mimbres-Uvas Basins

Costs and returns per acre were budgeted for production of four major irrigated crops (corn, cotton, grain sorghum, and wheat) for 1978. The flood-irrigated farm was estimated to contain 640 acres, of which 580 acres would be cropped, as follows: about 17 percent corn for grain, 45 percent cotton, 27 percent sorghum, and 10 percent wheat. This farm was estimated to have five irrigation wells producing 800 gpm, each pumping from a depth of 145 feet.

Upland cotton was the most profitable crop budgeted (Table 4). The net operating profit for cotton was calculated to be $312.86 per acre. However, when interest was assessed for the use of operating capital and equipment investment, the net return to land and risk was reduced to $280.73.

Table 4. Summary of costs and returns per acre for corn for grain, upland cotton, grain sorghum, and wheat for grain, by area, Southwestern Closed Basins, 1978

Item	Mimbres-Uvas Basin				Columbus-Hermanas Area			
	Corn for Grain	Upland Cotton	Grain Sorghum	Wheat for Grain	Corn for Grain	Upland Cotton	Grain Sorghum	Wheat for Grain
Yield	160.00 Bu	700.00 Lbs	70.00 cwt	55.00 Bu	160.00 Bu	700.00 Lbs	70.00 cwt	55.00 Bu
Gross Return	400.00	543.80	280.00	189.00	400.00	543.80	280.00	189.00
Costs								
Purchased Inputs	81.35	51.41	47.49	60.64	81.35	51.41	47.49	60.64
Pre-Harvest								
Purchased Inputs	--	12.00	--	--	--	12.00	--	--
Labor	17.62	14.03	14.96	12.92	17.62	14.03	14.96	12.92
Fuel, Oil and Repair	75.07	35.41	58.64	54.40	132.48	54.68	101.30	96.95
Fixed	27.24	16.39	22.35	19.35	32.16	16.46	25.69	23.33
Total Pre-Harvest	119.93	77.83	95.95	86.67	182.26	97.17	141.95	133.20
Harvest								
Purchased Inputs	--	17.50	--	--	--	17.50	--	--
Labor	3.12	5.52	3.12	3.12	3.12	5.52	3.12	3.12
Fuel, Oil and Repair	5.15	6.34	5.15	5.15	5.15	6.34	5.15	5.15
Fixed	8.44	8.74	8.44	8.44	4.39	6.76	4.39	4.39
Total Harvest	16.71	38.10	16.71	16.71	12.66	36.12	12.66	12.66
Overhead	56.72	63.60	49.42	43.73	56.72	63.60	49.42	43.73
Total Operating Expenses	274.71	230.94	209.57	207.75	332.99	248.30	251.52	250.23
Net Operating Profit	125.29	312.86	70.43	-18.75	67.01	295.50	28.48	-61.23
Interest on Operating Capital	9.24	7.48	6.70	6.92	10.68	7.96	7.77	7.98
Interest on Equipment Investment	34.39	24.65	30.23	28.58	34.03	22.67	28.43	26.70
Net Return to Land and Risk	81.66	280.73	33.50	-54.25	22.30	264.87	-7.72	-95.91

Item	Lordsburg Animas Basins				Playas Basin		
	Corn for Grain	Upland Cotton	Grain Sorghum	Wheat for Grain	Corn for Grain	Grain Sorghum	Wheat for Grain
Yield	150.00 Bu	650.00 Lbs	70.00 cwt	55.00 Bu	150.00 Bu	70.00 cwt	55.00 Bu
Gross Return	375.00	492.00	280.00	189.00	375.00	280.00	189.00
Costs							
Purchased Inputs	81.35	51.41	47.49	60.64	81.35	47.49	60.64
Pre-Harvest							
Purchased Inputs	--	12.00	--	--	--	--	--
Labor	17.62	14.03	14.96	12.92	17.62	14.96	12.92
Fuel, Oil and Repair	64.38	30.14	54.34	48.45	53.53	45.51	39.99
Fixed	20.06	11.51	17.26	16.37	9.65	8.79	6.26
Total Pre-Harvest	102.06	67.68	86.56	77.74	80.80	69.26	59.17
Harvest							
Purchased Inputs	--	16.25	--	--	--	--	--
Labor	3.12	5.52	3.12	3.12	3.12	3.12	3.12
Fuel, Oil and Repair	5.15	6.34	5.15	5.15	5.15	5.15	5.15
Fixed	5.58	6.36	5.58	5.58	2.16	2.16	2.16
Total Harvest	13.85	34.47	13.85	13.85	10.43	10.43	10.43
Overhead	53.97	59.51	47.92	42.23	53.97	47.92	42.23
Total Operating Expenses	251.23	213.07	195.82	194.46	226.55	175.10	172.47
Net Operating Profit	123.77	278.93	84.18	-5.46	148.45	104.90	16.53
Interest on Operating Capital	8.84	7.13	6.52	6.70	8.56	6.30	6.49
Interest on Equipment Investment	24.58	17.61	22.16	22.60	11.86	11.08	8.79
Net Return to Land and Risk	90.35	254.19	55.50	-34.76	128.03	87.52	1.25

Corn for grain was the second most profitable crop. The net operating profit was $125.29 per acre and return to land and risk was $81.66 per acre. In terms of net operating profits, grain sorghum was the third most profitable crop, yielding $70.43 per acre. The net return to land and risk for flood-irrigated grain sorghum was $33.50 per acre. Wheat was the least profitable crop with a net operating profit of -$18.75 and a return to land and risk of -$54.25.

Columbus-Hermanas Area

Costs and returns per acre were budgeted for production of four important irrigated crops (corn for grain, upland cotton, grain sorghum, and wheat) for 1978. The flood-irrigated farm was estimated to contain 1,280 acres, of which 1,130 acres would be cropped as follows: about 10 percent wheat, 25 percent grain sorghum, 14 percent corn for grain, 51 percent cotton. This farm was estimated to have eight irrigation wells producing 1,000 gpm, each pumping from a depth of 270 feet.

Cotton was the most profitable crop with $295.50 per acre in net operating profits and $264.87 in returns to land and risk (Table 4). The next most profitable crop was corn for grain with $67.01 per acre in net operating profits and $22.30 in returns to land and risk. Grain sorghum was the third most profitable crop, with $28.48 in net operating profit and returns of -$7.72 to land and risk. Wheat was the least profitable with -$61.23 in net operating profits and -$95.91 in returns to land and risk.

Lordsburg-Animas Basins

Costs and returns per acre were budgeted for production of four major irrigated crops (corn for grain, upland cotton, grain sorghum, and wheat). The flood-irrigated farm was estimated to contain 960 acres, of which 770 acres would be cropped as follows: about 4 percent wheat, 28 percent corn for grain, 26 percent grain sorghum, and 42 percent cotton. This farm was estimated to have seven irrigation wells producing 900 gpm, each pumping from a depth of 125 feet.

Upland cotton was the most profitable crop, with a net operating profit of $278.93 per acre and a return to land and risk of $254.19 (Table 4). Corn for grain was the second most profitable crop with a net operating profit of $123.77 and return to land and risk of $90.35. Grain sorghum returned $84.18 in net operating profit and $55.50 to land and risk. The least profitable crop was wheat, showing a -$5.46 in net operating profit and -$34.76 in returns to land and risk.

Playas Basin

Cost and returns per acre were budgeted for the more important groundwater-irrigated crops in the Playas Basin of Hidalgo County for 1978. Only flood irrigation systems were included in the budgets.

The flood-irrigated farm was estimated to contain 5,000 acres. Of these, 4,000 acres would be cropped as follows: about 15 percent corn for grain, 15 percent grain sorghum, and 70 percent wheat. There would be 19 irrigation wells producing 2,000 gpm each pumping from a depth of 75 feet.

Corn for grain was the most profitable with a net operating profit of $148.45 and a return to land and risk of $128.03 per acre. The second most profitable crop was grain sorghum, returning

$104.90 in net operating profit and $87.52 to land and risk. The least profitable crop in the Playas Basin was wheat, with a net operating profit of $16.53 and a return to land and risk of $1.25 (Table 4).

Energy Prices

Increasing energy costs affect agriculture through increased fertilizer prices, increased fuel costs for pumping irrigation water, and increased fuel costs for operating farm machinery. The magnitude of these impacts will depend upon the rate of the energy price increase. To provide for a wide range of real energy price increases, this study presents the effects under four energy price increases: base, low, medium, and high.

Energy Price Projections

The first energy price alternative (base) assumed that in real terms, energy prices would not increase above the general price level, (energy price increases would move at the same rate as general price inflation). This price alternative was considered in the model as the base alternative and is used for comparison with other alternatives (Table 5).

Table 5. Projected annual real energy price increases (1978 dollars) for the four alternative energy price scenarios by source of energy

Energy Price Alternative	Natural Gas	Electricity	Diesel	LP Gas
	(percent)			
Base	0	0	0	0
Low	4	2	4	4
Medium	6	3	6	6
High	8	4	8	8

Recently, the prices of diesel and LP gas have increased sharply, and are expected by some to increase at a real rate faster than those projected for the general economy. In order to expand the range of relevant real energy price increases, three alternative energy price alternatives were developed. These alternatives are based on the 1978 PIES Scenario B, where prices were based on typical electricity rates for January, 1979; natural gas rates based on the American Gas Association rates for early 1979; and diesel and LP gas prices based on early 1979 heating oil prices. The first real energy price increase projection assumes increases of 4 percent per year for natural gas, diesel, and LP gas, and 2 percent per year for electricity. This alternative is considered the "low alternative" (Table 5). Two additional energy price increase alternatives were developed. They were estimated to be 1.5 times the low alternative (medium) and 2 times the low alternative (high) (Table 5).

Fertilizer Prices

A number of recent studies on the energy impacts on demand for commercial nitrogen fertilizer point to conclusions contrary to intuition. Currently, 87 percent of nitrogen in chemical fertilizer is from ammonia derived from natural gas (USDA, 1974). This is to say, an average of 38,000 cubic feet of natural gas is required to produce a ton of anhydrous ammonia (White, 1974). However, a national simulation study by Dvoskin and Heady (1976) indicated that the energy crisis would definitely cause sharp increases in commercial nitrogen fertilizer prices as well as a sharp reduction in its supply, but the existence of close substitutes from legume crops, carry-over, and manure tended to offset such energy impacts. Under their hypothesized 10 percent energy shortage, doubled energy prices, and energy minimization practices, total nitrogen use declined less than five percent, with a sharp decline in commercial fertilizer usage. Whittlesey and Lee (1975) predicted a similar result: a 100 percent increase in natural gas prices would add about 15 percent to the farm cost of nitrogen fertilizer, which in turn would add about 2 percent to the farmers' cost of producing wheat. As a result of the studies by Dvoskin and Heady and Whittlesey and Lee, fertilizer prices were held at constant 1978 prices in this analysis.

Irrigation Water Fuel Costs

The fuel cost of irrigation water effectively applied to a crop is a function of many factors. A partial list of some of the most important factors would include: efficiency of the pumping plant, depth to water, well output, and pressurization of the irrigation system (if any). The depth to water, as it relates to pumping costs, is composed of two parts, the static water level and drawdown. The static water level was obtained from the State Engineer Deming Office for the sub-regions of the Southwestern Closed Basins. The drawdown was based on the hydrology section of this report for each sub-region.

The base pumping unit efficiencies used in this study were based on a study by Abernathy, (1978). Abernathy conducted well tests in the Southwestern Closed Basins in 1977 and 1978. Tests were conducted on free-discharge irrigation wells powered by natural gas, electricity, diesel and LP gas. The base pumping unit efficiencies for free-discharge natural-gas powered wells ranged from 12.0 percent in the Mimbres Basin to 12.6 percent in the Columbus-Hermanas, Lordsburg-Animas, and Playas areas. The efficiencies for electricity ranged from 57.5 percent in the Mimbres Basin to 60.1 percent in the other three areas. Diesel efficiencies ranged from 17.3 percent in the Mimbres Basin to 18.1 percent in the other areas, and LP gas (propane) ranged from 16.2 percent in the Mimbres Basin to 16.9 percent in the remainder of the study area (Table 6).

The overall efficiencies adapted from Abernathy were below those of a good pumping plant. The reported efficiency of a good natural gas pumping plant is 13.8 percent, 66.1 percent for electric powered plants, 19.9 percent for diesel powered plants, and 18.6 percent for LP-gas powered plants (High Plains Underground Water Conservation District No. 1, 1976).

It was also assumed that the base efficiencies determined above would not be fixed over the 20 year projections of the study. As energy costs increase, it is assumed that farmers would adopt existing and forthcoming technologies in order to survive. Studies such as those done by Abernathy (1978) and Young and Coomer (1979) emphasize the need to maintain good pumping plant efficiencies.

Table 6. Irrigation pumping plant efficiencies by fuel type and sub-region, Southwestern Closed Basins, 1978

Pumping Plant Efficiency	Natural Gas	Electricity	Diesel	LP Gas
Original - Flood				
Mimbres Basin	12.0	57.5	17.3	16.2
Columbus-Hermanas Area	12.6	60.1	18.1	16.9
Lordsburg-Animas Basin	12.6	60.1	18.1	16.9
Playas Basin	12.6	60.1	18.1	16.9
Optimal - Flood	13.8	66.1	19.9	18.6

Current research indicates that technological increases in pumping plant efficiency represent a "cheap" method to reduce fuel consumption. For this study, it was assumed that the pumping plant efficiency would be increased by one-half the difference between present efficiency and good efficiency every two years. Thus, the pumping plant efficiencies increase for all 20 years of the projections, with the greatest increase occurring in the early time periods. The formula for calculation of pumping plant efficiencies is presented in Appendix A.

The pumping fuel cost model is presented in equations 4 through 7 in Appendix A. Equation 4 presents the method used for determining total water decline. The method for calculating water horsepower requirements is presented in equation 5. Equation 6 presents the calculations for determining the fuel cost per hour, and equation 7 converts the fuel cost per hour to fuel cost per acre-foot. The impact of the cost of fuel for pumping irrigation water from the alternative energy price projections are presented in the following sub-regional economic sections.

Farm Machinery Fuel Costs

The increased fuel costs for operating diesel-powered farm machinery will be used as an estimate of the increased fuel costs of all farm machinery. Future fuel costs for farm machinery were obtained by using equation 8 in Appendix A. The impacts of increased diesel fuel prices for the four energy price alternatives are presented in the following sub-regional economic sections.

Impact Projections

The linear programming model was utilized to simulate a 20 year (1978-1998) crop production and irrigation water utilization pattern in the Southwestern Closed Basins of New Mexico under alternative energy price projections. Each simulation process begins with the same basic solution of the model, and continues with biannual changes to satisfy the alternative energy price projections for a period of 20 years. The basic solution used 1978 conditions and closely approximated the actual crop acreages and other resources used in the base year 1978. Differences between the basic solution of the model and the actual production levels in 1978 resulted from the optimization procedures used.

The results of the linear programming model for the 20 year simulation period for the four alternative energy price projections are presented in the following sections.

Base Year - 1978

Approximately 75,700 acres of land were farmed, all under flood irrigation. Cotton accounted for nearly 47 percent of the total irrigated cropland, while corn for grain accounted for 31 percent, sorghum for grain nearly 16 percent, and wheat 6 percent (Table 7). The net return to land and risk for the Southwestern Closed Basins for the base year 1978 was estimated to be nearly $11.4 million (Table 7).

The amount of irrigation water pumped in the Southwestern Closed Basins during the base year was estimated to be approximately 212,000 acre-feet. Approximately 60 percent of the total water pumped was in the Mimbres-Uvas Basin, the Lordsburg-Animas Basins accounted for 20 percent, the Columbus-Hermanas Area 11 percent, and the Playas Basin 9 percent. Electricity was assumed to be used as the pumping plant power source in all areas except the Mimbres-Uvas Basin, which utilized both natural gas (60 percent) and electricity (40 percent). Farm machinery fuel was assumed to be diesel with an annual cost for crop agriculture of slightly more than $1.1 million for over 2.5 million gallons in 1978. Labor requirements of over 580,000 man-hours of labor were estimated to cost $3.8 million for the 1978 crop year. The total annual capital requirements (excluding energy) were estimated at slightly more than $17.3 million.

Base Energy Price Alternative

The acreage farmed under this alternative remained constant over the 20 year projection period (Table 7). Under this alternative, no shifts in the cropping pattern are expected over the next 20 years. The cropping pattern would include 47 percent cotton, 31 percent corn for grain, 16 percent grain sorghum, and 6 percent wheat. The net return to crop agriculture in the Southwestern Closed Basins are expected to increase slightly from the base year level of $11.3 million to $11.7 million in 1984, and then decline to $11.5 million in 1998. This increase in net returns was due to increasing pumping plant efficiencies. Pumping costs are expected to decline from 1978 to 1982 for the Mimbres-Uvas Basins, to 1984 for the Columbus-Hermanas Area, to 1986 for the Lordsburg-Animas Basin, and to 1988 for the Playas Basin. Beyond these years, the cost of pumping irrigation water is expected to increase because of the greater pumping lifts due to the declining water table, which will more than offset gains in efficiency of the pumping plant.

Approximately 212,000 acre-feet of water would be pumped in the base year, and remain constant through 1998. The total water decline over the twenty year period was estimated to range from over 6 feet in the Playas Basin to nearly 127 feet in the Columbus-Hermanas Area (Table 7).

Electricity and natural gas were estimated to be the major sources of energy for the pumping plant for the entire 20 year period in the Mimbres-Uvas Basins. The per acre-foot cost of irrigation water for the 127,500 acre-feet pumped is expected to decrease from 1978 to 1984 for both electric and natural gas powered units, as a result of gains in efficiency of the pumping plant. From an initial pumping plant efficiency of 10.3 percent for natural gas and 48.9 percent for electricity in 1978, the efficiency is expected to increase to 13.4 percent for natural gas and 64 percent for electricity by

Table 7. Impacts of real energy price increases on the crop agriculture sector, Southwestern Closed Basins, New Mexico -- Base energy price projection, 1978-1998

Item	Unit	1978	1980	1982	1984	1986	1998	1990	1992	1994	1996	1998
Cropping Pattern												
Flood Irrigated Crops												
Corn	acres	23,710	23,710	23,710	23,710	23,710	23,710	23,710	23,710	23,710	23,710	23,710
Cotton	acres	35,350	35,350	35,350	35,350	35,350	35,350	35,350	35,350	35,350	35,350	35,350
Grain Sorghum	acres	11,855	11,855	11,855	11,855	11,855	11,855	11,855	11,855	11,855	11,855	11,855
Wheat	acres	4,785	4,785	4,785	4,785	4,785	4,785	4,785	4,785	4,785	4,785	4,785
Total Irrigated Crops	acres	75,700	75,700	75,700	75,700	75,700	75,700	75,700	75,700	75,700	75,700	75,700
Net Returns	dollars	11,358,022	11,637,709	11,713,774	11,727,192	11,716,336	11,688,517	11,654,115	11,616,404	11,573,446	11,533,211	11,492,537
Water Pumped												
Deming-Uvas Basins												
Energy Source	type	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG	NG
Water Pumped	acre-feet	76,454	76,454	76,454	76,454	76,454	76,454	76,454	76,454	76,454	76,454	76,454
Cost	$/ac. ft.	9.23	7.87	7.49	7.39	7.42	7.51	7.63	7.76	7.90	8.05	8.20
Energy Source	type	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL
Water Pumped	acre-feet	50,969	50,969	50,969	50,969	50,969	50,969	50,969	50,969	50,969	50,969	50,969
Cost	$/ac. ft.	11.27	9.62	9.15	9.03	9.06	9.17	9.32	9.47	9.65	9.82	10.00
Total Water Pumped	acre-feet	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423
Total Water Decline	feet	1.9	5.8	9.7	13.5	17.4	21.2	25.1	29.0	32.8	36.7	40.6
Columbus-Hermanas Area												
Energy Source	type	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL
Cost	$/ac. ft.	19.77	18.12	17.85	18.01	18.38	18.84	19.35	19.89	20.44	21.00	21.56
Total Water Pumped	acre-feet	24,102	24,102	24,102	24,102	24,102	24,102	24,102	24,102	24,102	24,102	24,102
Total Water Decline	feet	6.0	18.1	30.2	42.2	54.3	66.4	78.4	90.5	102.6	114.6	126.7
Lordsburg-Animas Basins												
Energy Source	type	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL
Cost	$/ac. ft.	8.99	8.15	7.92	7.89	7.67	7.98	8.11	8.24	8.48	8.63	8.78
Total Water Pumped	acre-feet	41,981	41,981	41,981	41,981	41,981	41,981	41,981	41,981	41,981	41,981	41,981
Total Water Decline	feet	1.6	4.9	8.2	11.4	14.7	17.9	21.2	24.4	27.7	30.9	34.2
Playas Basin												
Energy Source	type	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL
Cost	$/ac. ft.	8.91	8.01	7.66	7.52	7.46	7.45	7.46	7.48	7.51	7.53	7.56
Total Water Pumped	acre-feet	18,550	18,550	18,550	18,550	18,550	18,550	18,550	18,550	18,550	18,550	18,550
Total Water Decline	feet	0.3	1.0	1.7	2.3	3.0	3.6	4.3	5.0	5.6	6.3	7.0
Farm Machinery Fuel Cost	dollars	1,136,554	1,136,554	1,136,554	1,136,554	1,136,554	1,136,554	1,136,554	1,136,554	1,136,554	1,136,554	1,136,554
Labor and Management												
Hours	man hours	581,221	581,221	581,221	581,221	581,221	581,221	581,221	581,221	581,221	581,221	581,221
Cost	dollars	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501
Capital Requirements												
Operating Capital	dollars	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756
Fixed Capital	dollars	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372
Sunk Capital	dollars	294,107	294,107	294,107	294,107	294,107	294,107	294,107	294,107	294,107	294,107	294,107

1984. The cost per acre-foot of water will decline from $9.23 to $7.39 for natural gas-powered units and from $11.27 to $9.03 for electrically powered units. Since optimal efficiency for a natural gas pumping plant has been estimated to be 13.8 percent, and 66.1 percent for an electric pumping plant, it is evident that the majority of the projected efficiency increases would be realized by 1984. Small gains in efficiency would be realized from 1986 to 1998, but these would be outweighed by increases in lift of nearly two feet per year, (about 41 feet for the total period), resulting in increases in the fuel cost for pumping irrigation water from $7.39 per acre-foot in 1986 to $8.20 in 1998 for natural gas units and from $9.03 to $10.00 for electrically powered units (Table 7).

The cost of irrigation water in the Columbus-Hermanas Area is expected to decrease from 1978 through 1982. The initial decrease in water costs is due to a gain in efficiency for the electrically powered plant from 54.1 percent to 63.1 percent. The cost per acre-foot is expected to decrease from $19.77 in 1978 to $17.85 in 1982 then rise to $21.56 by 1998 for the 24,000 acre-feet of water pumped annually. The gains in efficiency of the pumping plant are expected to be relatively small after 1982, rising only about three percent by 1998. The increase in water cost from 1982 to 1998 was due primarily to an average yearly decline in the water table of over six feet, resulting in increasing lifts. The total water decline by 1998 for the Columbus-Hermanas Area was estimated to be over 126 feet.

The Lordsburg-Animas Basin utilized electricity as the principal pumping plant energy source to pump 42,000 acre-feet of water annually. The per-acre-foot cost of water is expected to decrease from $8.99 in 1978 to $7.67 in 1986, then increase through 1998 to a level of $8.78. The water cost decrease is due to a gain in efficiency from 54.1 percent to 65.4 percent. After 1986 any gains in efficiency would be less significant than the increased lift due to increased depth to water, resulting in gradual increases in water cost. The average yearly decline in the water table for the area was anticipated to be nearly 2 feet for a total decline of over 34 feet.

Irrigation water cost approximately $8.91 per acre-foot in the Playas Basin in 1978. By 1988, the cost is expected to decrease to $7.45 per acre-foot. This is due to an anticipated gain in efficiency for the electrically powered pumping plant from 54.1 to 65.7 percent. Since good efficiency for this type of plant is 66.1 percent, most of the efficiency gain would have been realized by 1988. The water level would decline at a rate of approximately 0.4 feet per year, resulting in a decrease of only 7 feet for the entire period, which would account for a gradual rise in water cost to $7.56 in 1998.

Farm machinery fuel cost for crop agriculture was estimated to be slightly more than $1.1 million for 2.5 million gallons of diesel fuel in 1978. The cost of diesel fuel and quantity used for the farm machinery remained constant throughout the study period.

The man-hours of labor required under the base alternative were slightly greater than 580,000 for 1978 and remained at this level through 1998. Labor and management cost was nearly $3.9 million per period throughout the 20 year study (Table 7).

The capital requirement for cropped agriculture in the Southwestern Closed Basins was divided into three components: operating capital, fixed capital, and sunk capital. Operating capital consisted of all purchased inputs, labor, repairs, and interest on operating capital. Fixed capital was composed of the depreciation and taxes on farm machinery and equipment, one-half the depreciation and taxes on irrigation equipment, and the interest on equipment investment. Sunk capital was assumed to be one-half the depreciation and taxes on irrigation equipment. It was estimated that operating capital required in 1978 would be $13.5 million; fixed capital $3.8 million; and sunk capital over $294,000. Capital requirements remained constant over the study period.

Low Energy Price Alternative

Neither the cropping pattern nor the acreage farmed under this alternative is expected to change from the base alternative. The net return to crop agriculture in the Southwestern Closed Basins is expected to decrease from the base year level of nearly $11.4 million to $8.7 million in 1998, for a net decrease of 23 percent (Table 8). This decrease in net return was due primarily to increases in farm machinery fuel, and secondly to increases in energy costs for irrigation water pumping plants.

Approximately 212,000 acre-feet of water would be pumped for crop agriculture in the four areas in 1978 (Table 8). The primary energy sources utilized for pumping irrigation water were natural gas and electricity. All areas were anticipated to use electricity except the Mimbres-Uvas Basins, which used natural gas to power 60 percent of the pumping plants and electricity for the other 40 percent. Beginning in 1988 all water was expected to be pumped using electricity as the primary power source.

The cost of pumping irrigation water in the Mimbres-Uvas Basins in 1978 was estimated at $9.23 per acre-foot for the 76,500 acre feet pumped with natural gas and $11.27 for the 51,000 acre-feet pumped with electricity. Water pumped using natural gas as a fuel increased in cost to $10.99 per acre-foot in 1986. After 1988, all water was expected to be pumped with electricity, which increased steadily in cost to $15.46 per acre-foot in 1998. Under this alternative the increasing cost of energy had a greater impact on the cost of water than increased pumping plant efficiencies, resulting in an increased cost per acre-foot of water. The decline in the water table of about 41 feet by 1998 (approximately 2 feet per year) also increased the cost of water due to greater pumping lifts (Table 8).

The Columbus-Hermanas Area utilized electricity exclusively for a pumping plant power source. The cost per acre-foot for the 24,000 acre-feet pumped was $19.77 (estimated in 1978) and is expected to increase to to $33.33 by 1998. After an initial decrease in water cost in 1980, which was due to increases in pumping plant efficiency, water costs are expected to rise steadily through 1998. The cost of pumping irrigation water increased not only due to a price increase, but also to an average increase in pumping lift of over 6 feet per year, for a total water decline of over 126 feet.

Approximately 42,000 acre-feet of water were used yearly for irrigation purposes in the Lordsburg-Animas Basin. The cost of water in 1978 was estimated to be $8.99 per acre-foot. The cost would decrease in 1980 due to expected increases in pumping plant efficiency, then rise to $13.57 per acre-foot by 1998. The increased cost of water was due to the anticipated increases in the cost of electricity, decreasing gains in pumping plant efficiency, and an expected average yearly increase in depth to water of nearly 2 feet per year or over 34 feet by 1998.

The average amount of water pumped yearly in the Playas Basin was estimated to be nearly 18,600 acre-feet. The primary source of energy for the pumping plant was electricity. Water cost was esti-

Table 8. Impacts of real energy price increases on the crop agriculture sector, Southwestern Closed Basins, New Mexico -- Low energy price projection, 1978-1998

	Unit	1978	1980	1982	1984	1986	1988	1990	1992	1994	1996	1998
Cropping Pattern												
Flood Irrigated Crops												
Corn	acres	23,710	23,710	23,710	23,710	23,710	23,710	23,710	23,710	23,710	23,710	23,710
Cotton	acres	35,350	35,350	35,350	35,350	35,350	35,350	35,350	35,350	35,350	35,350	35,350
Grain Sorghum	acres	11,855	11,855	11,855	11,855	11,855	11,855	11,855	11,855	11,855	11,855	11,855
Wheat	acres	4,785	4,785	4,785	4,785	4,785	4,785	4,785	4,785	4,785	4,785	4,785
Total Irrigated Crops	acres	75,700	75,700	75,700	75,700	75,700	75,700	75,700	75,700	75,700	75,700	75,700
Net Returns	dollars	11,358,022	11,325,870	11,195,906	10,983,024	10,724,059	10,454,050	10,161,412	9,844,524	9,498,648	9,133,667	8,743,464
Water Pumped												
Deming-Uvas Basins												
Energy Source	type	NG	NG	NG	NG	NG						
Water Pumped	acre-feet	76,454	76,454	76,454	76,454	76,454						
Cost	$/acre-foot	9.23	9.21	9.48	10.12	10.99						
Energy Source	type	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL
Water Pumped	acre-feet	50,969	50,969	50,969	50,969	50,969	127,423	127,423	127,423	127,423	127,423	127,423
Cost	$/acre-foot	11.27	10.42	10.30	10.58	11.04	11.63	12.29	13.01	13.78	14.59	15.46
Total Water Pumped	acre-feet	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423
Total Water Decline	feet	1.9	5.8	9.7	13.5	17.4	21.2	25.1	29.0	32.8	36.7	40.6
Columbus-Hermanas												
Energy Source	type	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL
Cost	$/acre-foot	19.77	19.61	20.10	21.11	22.40	23.90	25.54	27.31	29.20	31.21	33.33
Total Water Pumped	acre-feet	24,102	24,102	24,102	24,102	24,102	24,102	24,102	24,102	24,102	24,102	24,102
Total Water Decline	feet	6.0	18.1	30.2	42.2	54.3	66.4	78.4	90.5	102.6	114.6	126.7
Lordsburg - Animas												
Energy Source	type	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL
Cost	$/acre-foot	8.99	8.82	8.92	9.24	9.59	10.12	10.70	11.32	12.11	12.82	13.57
Total Water Pumped	acre-feet	41,981	41,981	41,981	41,981	41,981	41,981	41,981	41,981	41,981	41,981	41,981
Total Water Decline	feet	1.6	4.9	8.2	11.4	14.7	17.9	21.2	24.4	27.7	30.9	34.2
Playas Basin												
Energy Source	type	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL
Cost	$/acre-foot	8.91	8.67	8.63	8.81	9.10	9.45	9.84	10.27	10.72	11.20	11.70
Total Water Pumped	acre-feet	18,550	18,550	18,550	18,550	18,550	18,550	18,550	18,550	18,550	18,550	18,550
Total Water Decline	feet	0.3	1.0	1.7	2.3	3.0	3.6	4.3	5.0	5.6	6.3	7.0
Farm Machinery Fuel Cost	dollars	1,136,554	1,229,297	1,329,541	1,438,082	1,555,488	1,682,327	1,819,623	1,968,057	2,128,766	2,302,431	2,490,303
Labor/ Management												
Hours	man-hours	581,221	581,221	581,221	581,221	581,221	581,221	581,221	581,221	581,221	581,221	581,221
Cost	dollars	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501
Capital Requirements												
Operating Capital	dollars	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756
Fixed Capital	dollars	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372
Sunk Capital	dollars	294,107	294,107	294,107	294,107	294,107	294,107	294,107	294,107	294,107	294,107	294,107

mated at $8.91 per acre-foot in 1978, and was expected to increase to $11.70 in 1998. The cost of pumping water would decrease from the 1978 level through 1982, after which it is expected to rise continuously until 1998. The increase in cost would be due principally to increased energy costs, while other less important factors (decreasing gains in efficiency of the pumping plant and the expected average water level decline of .4 feet per year) would result in increased pumping lifts. The total water decline was estimated to be only 7 feet over the 20 year period.

Farm machinery fuel costs were estimated to be slightly more than $1.1 million for over 2.5 million gallons of diesel for the base year. The yearly increase of 4 percent in the price of diesel fuel would result in a total fuel cost of nearly $2.5 million in 1998, or a yearly increase of over 2 percent. Neither the man-hours of labor, the total cost of labor and management, nor the capital requirements changed from the base alternative (Table 8).

Medium Energy Price Alternative

The net return to crop agriculture in the Southwestern Closed Basins decreased from the base year level of nearly $11.4 million to $6.7 million in 1998 even though the acreage farmed and the cropping pattern remained unchanged from that of the base year (Table 9). This represented a reduction in net returns of nearly two percent per year. Rapid escalation of the price of diesel fuel utilized in farm machinery, increases in the cost of energy to power the pumping plant, and increasing depths to water were the primary reasons for the decrease in net returns. Diesel fuel and natural gas prices were expected to increase at an annual rate of 6 percent per year. The cost of electricity, which would be used as the principal source of power for the pumping plant, increased at a rate of 3 percent annually. The effect of these rising energy prices is readily seen in the anticipated 40 percent reduction of net returns to crop agriculture.

The major energy sources for pumping irrigation water were expected to be electricity and natural gas. All areas were assumed to use electricity exclusively, with the exception of the Mimbres-Uvas Basins, which used a combination of 60 percent natural gas and 40 percent electricity. An expected increase in the cost per acre-foot of irrigation water throughout the 20 year time period in all areas illustrates the impact of energy price increases, even while the pumping plant was assumed to progress from original to good efficiency.

Approximately 127,500 acre-feet of water would be pumped for irrigation purposes in the Mimbres-Uvas Basins in 1978. Natural gas would be used through 1982 to pump approximately 60 percent of this total. The cost of water pumped with natural gas would rise from a 1978 level of $9.23 per acre foot to $10.62 in 1982. After 1982, all water would be pumped with electricity as an energy source. The cost per acre-foot of water pumped with electricity was projected to rise from $11.27 in 1978 to $19.16 in 1998. An initial decrease in the cost of pumping with electricity, from 1978 to 1982, due to increases in efficiency of the pumping plant would be realized. The yearly volume of water pumped was expected to remain constant throughout the study period. The increased costs of pumping water were due to increasing energy costs and increased pumping lifts due to an expected average water table decrease of nearly 2 feet per year for a total decline of over 40 feet.

The major source of energy for pumping water in the Columbus-Hermanas Area was expected to be electricity. The amount of water pumped for irrigation purposes would be approximately 24,000 acre-

Table 9. Impacts of real energy price increases on the crop agriculture sector, Southwestern Closed Basins, New Mexico -- Medium energy price projection, 1978-1998

Item	Unit	1978	1980	1982	1984	1986	1988	1990	1992	1994	1996	1998
Cropping Pattern												
Flood Irrigated Crops												
Corn	acres	23,710	23,710	23,710	23,710	23,710	23,710	23,710	23,710	23,710	23,710	23,710
Cotton	acres	35,350	35,350	35,350	35,350	35,350	35,350	35,350	35,350	35,350	35,350	35,350
Grain Sorghum	acres	11,855	11,855	11,855	11,855	11,855	11,855	11,855	11,855	11,855	11,855	11,855
Wheat	acres	4,785	4,785	4,785	4,785	4,785	4,785	4,785	4,785	4,785	4,785	4,785
Total Irrigated Crops	acres	75,700	75,700	75,700	75,700	75,700	75,700	75,700	75,700	75,700	75,700	75,700
Net Returns	dollars	11,358,022	11,161,316	10,909,855	10,578,539	10,205,690	9,770,964	9,282,501	8,739,292	8,132,337	7,468,546	6,736,380
Water Pumped												
Deming/Uvas Basins												
Energy Source	type	NG	NG	NG								
Water Pumped	acre-feet	76,454	76,454	76,454								
Cost	$/acre-foot	9.23	9.94	10.62								
Energy Source	type	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL
Water Pumped	acre-feet	50,969	50,969	50,969	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423
Cost	$/acre-foot	11.27	10.83	10.92	11.43	12.18	13.07	14.09	15.20	16.42	17.74	19.16
Total Water Pumped	acre-feet	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423
Total Water Decline	feet	1.9	5.8	9.7	13.5	17.4	21.2	25.1	29.0	32.8	36.7	40.6
Columbus-Hermanas												
Energy Source	type	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL
Cost	$/acre-foot	19.77	20.39	21.31	22.82	24.70	26.86	29.27	31.92	34.80	37.93	41.31
Total Water Pumped	acre-feet	24,102	24,102	24,102	24,102	24,102	24,102	24,102	24,102	24,102	24,102	24,102
Total Water Decline	feet	6.0	18.1	30.2	42.2	54.3	66.4	78.4	90.5	102.6	114.6	126.7
Lordsburg-Animas												
Energy Source	type	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL
Cost	$/acre-foot	8.99	9.17	9.45	10.00	10.57	11.37	12.26	13.23	14.43	15.58	16.82
Total Water Pumped	acre-feet	41,981	41,981	41,981	41,981	41,981	41,981	41,981	41,981	41,981	41,981	41,981
Total Water Decline	feet	1.6	4.9	8.2	11.4	14.7	17.9	21.2	24.4	27.7	30.9	34.2
Playas Basin												
Energy Source	type	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL
Cost	$/acre-foot	8.91	9.02	9.15	9.52	10.03	10.62	11.29	12.01	12.78	13.61	14.50
Total Water Pumped	acre-feet	18,550	18,550	18,550	18,550	18,550	18,550	18,550	18,550	18,550	18,550	18,550
Total Water Decline	feet	0.3	1.0	1.7	2.3	3.0	3.6	4.3	5.0	5.6	6.3	7.0
Farm Machinery Fuel Cost	dollars	1,136,554	1,277,032	1,434,786	1,612,202	1,811,440	2,035,340	2,286,860	2,569,635	2,887,188	3,244,066	3,645,042
Labor/Management												
Hours	man-hours	581,221	581,221	581,221	581,221	581,221	581,221	581,221	581,221	581,221	581,221	581,221
Cost	dollars	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501
Capital Requirements												
Operating Capital	dollars	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756
Fixed Capital	dollars	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372
Sunk Capital	dollars	294,107	294,107	294,107	294,107	294,107	294,107	294,107	294,107	294,107	294,107	294,107

feet per year. The cost per acre-foot of pumping water was expected to more than double from $19.77 in 1978 to $41.31 in 1998. A projected decline in the water table of over six feet per year for the 20 years of the study period resulted in a total water table decline of approximately 120 feet. The efficiency of the pumping plant was assumed to increase from 1978 to 1998; however, the increases in efficiency were smaller than increases in energy costs, resulting in increased water costs.

Electricity was the major source of energy used for pumping irrigation water in the Lordsburg-Animas Basins. Nearly 42,000 acre-feet of water would be pumped each year in the area. Water costs were projected to increase approximately 87 percent from 1978 to 1998, from $8.99 to $16.82 per acre-foot. The expected increases in the efficiency of the pumping plant were offset by projected increases in fuel prices, resulting in increased water costs. The total water decline was expected to be equal to that of the previous alternative (34 feet), for an average decline of nearly 2 feet per year.

The Playas Basin was also expected to utilize electricity as the primary source of energy for pumping the 18,600 acre-feet of irrigation water used annually. As with the other areas considered, water costs were expected to rise throughout the study period. From $8.91 per acre-foot in 1978, the cost of water rose nearly 63 percent to $14.50 by 1998. Efficiency increases in the pumping plant were smaller than price increases, resulting in the steadily increasing cost of water. The expected decline in the water table for this area did not change from the previous alternative level of 0.4 feet per year which resulted in a total decline of only 7 feet.

The farm machinery fuel cost for crop agriculture in the Southwestern Closed Basins was estimated to be over $3.6 million by 1998. This represents a rise of over 185 percent from the 1978 level. This increase was due to the increasing price of diesel fuel. Labor requirements and capital requirements (other than for fuel) did not change from the base projection (Table 9).

<u>High Energy Price Alternative</u>

The net return to crop agriculture under this alternative is expected to decrease nearly 62 percent from $11.4 million in the base year to $4.4 million in 1998. The cropping pattern and acreage farmed is expected to remain unchanged from the base energy price scenario through 1994 when irrigation is expected to cease in the Columbus-Hermanas Area and in 1996 for the Playas Basin. The decrease in net returns was due primarily to the higher prices paid for diesel fuel, natural gas, and electricity. Of greatest importance was diesel fuel, which increased eight percent per year. The pumping plant fuels, principally electricity, as well as a small amount of natural gas, increased four percent and eight percent per year, respectively. Once again, the price increase in these fuels was expected to cancel any savings due to increases in pumping plant efficiency, resulting in higher water pumping costs and lower returns (Table 10).

The Mimbres-Uvas Basins were expected to use electricity as a primary energy source for pumping plants. However, natural gas was used as the energy source to pump nearly 60 percent of the water from 1978 to 1980, after which electricity was expected to be used exclusively. The cost of water pumped with natural gas increased from approximately $9.23 in 1978 to an estimated $10.71 per acre-foot in 1980. The cost of water pumped with electricity increased about 110 percent from the 1978 level of $11.27 per acre-foot to an expected value of $23.70 in 1998. The estimated gains in efficiency of the pumping plant were generally less than energy price increases resulting in increasing

Table 10. Impacts of real energy price increases on the crop agriculture sector, Southwestern Closed Basins, New Mexico -- High energy price projection, 1978-1998

Item	Unit	1978	1980	1982	1984	1986	1988	1990	1992	1994	1996	1998
Cropping Pattern												
Flood Irrigated Crops												
Corn	acres	23,710	23,710	23,710	23,710	23,710	23,710	23,710	23,710	23,710	21,130	18,630
Cotton	acres	35,350	35,350	35,350	35,350	35,350	35,350	35,350	35,350	35,350	51,050	31,050
Grain Sorghum	acres	11,855	11,855	11,855	11,855	11,855	11,855	11,855	11,855	11,855	10,565	9,315
Wheat	acres	4,785	4,785	4,785	4,785	4,785	4,785	4,785	4,785	4,785	4,355	3,105
Total Irrigated Crops	acres	75,700	75,700	75,700	75,700	75,700	75,700	75,700	75,700	75,700	67,100	62,100
Net Returns	dollars	11,358,022	10,990,809	10,628,164	10,178,061	10,205,690	8,985,329	8,240,354	7,388,110	6,408,843	5,383,781	4,362,028
Water Pumped												
Deming-Uvas Basins												
Energy Source	type	NG	NG									
Water Pumped	acre-feet	76,454	76,454									
Cost	$/ac. ft.	9.23	10.71									
Energy Source	type	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL
Water Pumped	acre-feet	50,969	50,969	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423
Cost	$/ac. ft.	11.27	11.26	11.57	12.35	12.18	14.68	16.13	17.75	19.54	21.52	23.70
Total Water Pumped	acre-feet	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423	127,423
Total Water Decline	feet	1.9	5.8	9.7	13.5	17.4	21.2	25.1	29.0	32.8	36.7	40.6
Columbus-Hermanas Area												
Energy Source	type	EL	EL	EL	EL	EL	EL	EL	EL	EL		
Cost	$/ac. ft.	19.77	21.19	22.59	24.65	24.70	30.17	33.51	37.26	41.41		
Total Water Pumped	acre-feet	24,102	24,102	24,102	24,102	24,102	24,102	24,102	24,102	24,102		
Total Water Decline	feet	6.0	18.1	30.2	42.2	54.3	66.4	78.4	90.5	102.6	102.6	102.6
Lordsburg-Animas Basins												
Energy Source	type	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL
Cost	$/ac. ft	8.99	9.53	10.02	10.80	10.57	12.77	14.04	15.45	17.18	18.91	20.81
Total Water Pumped	acre-feet	41,981	41,981	41,981	41,981	41,981	41,981	41,981	41,981	41,981	41,981	41,981
Total Water Decline	feet	1.6	4.9	8.2	11.4	14.7	17.9	21.2	24.4	27.7	30.9	34.2
Playas Basin												
Energy Source	type	EL	EL	EL	EL	EL	EL	EL	EL	EL	EL	
Cost	$/ac. ft.	8.91	9.37	9.70	10.29	10.03	11.93	12.92	14.01	15.21	16.51	
Total Water Pumped	acre-feet	18,550	18,550	18,550	18,550	18,550	18,550	18,550	18,550	18,550	18,550	
Total Water Decline	feet	0.3	1.0	1.7	2.3	3.0	3.6	4.3	5.0	5.6	6.3	6.3
Farm Machinery Fuel Cost	dollars	1,136,554	1,325,677	1,546,168	1,803,484	1,811,440	2,453,706	2,861,957	3,338,173	3,893,720	3,861,403	4,191,283
Labor and Management												
Hours	man hours	581,221	581,221	581,221	581,221	581,221	581,221	581,221	581,221	581,221	514,988	478,263
Cost	dollars	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,855,501	3,409,798	3,190,693
Capital Requirements												
Operating Capital	dollars	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	13,454,756	11,843,899	11,079,111
Fixed Capital	dollars	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,771,372	3,327,418	3,215,093
Sunk Capital	dollars	294,107	294,107	294,107	294,107	294,107	294,107	294,107	294,107	294,107	242,542	236,655

pumping costs. A very small decrease in cost was expected from 1978 to 1980, when utilizing electricity as the energy source, due to the increase in efficiency of the pumping plant. The expected decline in the water table averaged slightly more than 2 feet per year over the study period resulting in a total decline of over 40 feet over the 20 year period.

Electricity was expected to be the major pumping plant energy source for the 24,000 acre-feet of water pumped in the Columbus-Hermanas area through 1994, when irrigation would cease in the area. The projected cost of pumping water rose from $19.77 per acre-foot in the base year to $41.41 in 1994, for an increase of 109 percent. Even though pumping plant efficiency would increase at a rapid rate, energy cost was expected to increase even more rapidly, resulting in the higher water costs. The water decline for the area would be over 6 feet per year through the year 1994 of the study. Since irrigated agriculture was expected to cease in 1994, the total water decline would be only 103 feet.

In the Lordsburg-Animas Basins, the major source of fuel for pumping plants was expected to be electricity. Nearly 42,000 acre-feet of water would be pumped each year for the 20 years of the study. The water cost per acre-foot ranged from $8.99 in 1978 to $20.81 in 1998, for an increase of 131 percent. This cost was estimated to increase steadily over the 20 year study, indicating that efficiency gains in the pumping plant were smaller than energy price increases. The total decline in the water table in the area was over 34 feet for an average of nearly 2 feet per year.

The Playas Basin would also use electricity as the principal pumping plant's fuel source through 1996, when irrigated acreage would fall to zero. Approximately 18,600 acre-feet of water would be pumped yearly for irrigation purposes. Water cost per acre-foot was expected to rise over 85 percent from 1978 to 1996, from $8.91 to $16.51. The constantly increasing water cost indicates that fuel price increases were greater than yearly gain in pumping plant efficiencies. The water table was estimated to decline slightly less than 0.4 feet each year through 1996, when the total decline of over 6 feet was reached.

Farm machinery fuel costs for agriculture in the Southwestern Closed Basins were estimated to increase 269 percent (to $4.2 million) by 1998. Farm machinery fuel cost would account for most of the reduction in net returns due to the change in the price of diesel fuel (Table 10).

Labor hours required under this projection were identical to the requirement for the previous projections through 1994 after which they would decline as the irrigated acreage declined. The cost of labor was the same as in previous energy price alternatives through 1994 when it would fall due to decreased acreages. Capital requirements did not change from the levels stated in the base, low, and medium projections, until 1996 and 1998 when they declined due to the reductions in acreage farmed (Table 10).

Implications

The impact of increasing energy costs and increasing pumping lifts on the cropped agriculture in the Southwestern Closed Basins of New Mexico may be generally characterized by stable acreages and declining per-acre net returns to land and risk, if energy prices increase faster than the general price level.

The region-wide decline in net returns to land and risk indicates that farmers will be forced to maintain present levels, or obtain increased capital for both operating and machinery purposes under lowered per-acre profit margins. This may cause farmers to have increased difficulty in obtaining operating and machinery capital in the long-run. This also has the potential effect of increasing the attrition rate among farm owners. Since there were no general declines in labor requirements, a probable shift is toward larger farms with increased hired labor.

The declining per-acre returns to land and risk on the low, medium, and high energy price alternatives resulted from increased farm machinery fuel costs, increasing irrigation fuel costs, and increasing pumping lifts. Under the base energy price alternative, there was an increase in net returns of over 1 percent which was due to increased pumping plant efficiency and constant fuel costs. The low energy price increase resulted in per-acre declines in returns to land and risk of 23 percent. The medium energy price alternative resulted in the decline in per-acre returns of 41 percent. The decline in per-acre returns to land and risk were 62 percent in 1998 under the high alternative. This constant decline in returns to land and risk indicates that farmers will be forced to acquire increased capital for both operating and machinery purposes under lowered per-acre profit margins. This may cause farmers to have increased difficulty in obtaining operating and machinery capital over the long run.

The impacts of increasing energy costs on the water resource of the Mimbres-Uvas Basins were minimal. The total water table declines by 1998 were estimated to be 40.6 feet for all energy price alternatives. This indicated that the relative profitability of the crops grown and associated water utilization would not change. Since the water declines were the same under all energy price projections, the aquifer life is not expected to be extended due to reduced withdrawals. In the 20 years examined in this study, there were no expected problems with water availability.

The impacts of increasing energy costs on the water resource were minimal in the Columbus-Hermanas Area. The total water table declines by 1998 were estimated to be 126.7 feet for the base, low, and medium energy price alternatives, and 102.6 feet for the high energy price alternative. This resulted in a reduction in the water level decline of 24.1 feet under the high energy price alternative. Since the water declines were less under the high energy price projection, the aquifer life is expected to be extended due to reduced withdrawals only if irrigation ceases. In the 20 years covered by the study, no problems with water availability were expected.

The impacts of increasing energy costs on the water resource of the Lordsburg-Animas Basins were minimal. The total water table declines by 1998 were estimated to be 34.2 feet for all energy price alternatives. This indicated that the relative profitability of the crops grown and associated water utilization did not change. Since the water declines were the same under all energy price projections, the aquifer life is not expected to be extended due to reduced withdrawals. In the twenty years examined in this study, there were no expected problems with water availability.

The impacts on the water resource of increasing energy costs were minimal in the Playas Basin. The total water table declines by 1998 were estimated to be 7.0 feet for the base, low, and medium energy price alternatives and 6.3 feet for the high energy price alternative. This resulted in a reduction in the water level decline of .7 feet under the high energy price alternative. Since the water declines were less under the high energy price projection, the aquifer life is expected to be extended due to reduced withdrawals only if irrigation ceases. There were no expected problems with water availability for the 20 year study period.

The return to risk for the Southwestern Closed Basins, after imposing a charge for the use of irrigated cropland valued at an average of $800 per acre, was $69 per acre in the base year (1978). The returns to risk became even smaller under the low ($34) and medium ($8) price alternatives. Under the high alternative, the regional returns to risk were estimated to be a negative $19 per acre in 1998. Under the base price alternative, the regional net returns to risk were estimated to be $70 per acre in 1998.

The return to risk in the Mimbres-Uvas Basins, after imposing a charge for irrigated land based on a land value of $1,000 per acre, was $60 per acre in the base year. The per-acre return to risk in 1998 increased slightly under the base alternative to $63. However, there were significant declines in the per-acre returns to risk under the low ($27), medium ($2), and high (negative $31) energy alternatives.

The decline in returns to risk was greatest in the Columbus-Hermanas Area of the Southwestern Closed Basins, where, a charge for the use of irrigated land was based on a land value of $450 per-acre. In the base year, the returns to risk were $78 per acre. The per-acre returns to risk declined under the base energy price alternative to $73 in 1998, and were $16 under low, negative $26 under medium, and all agriculture had ceased under the high energy price alternative by 1998. Under the high alternative, the returns to risk were negative $30 per acre by 1994.

The returns to risk declined significantly in the Playas Basins over the study period. The land charge was based on land valued at $400 per acre. In the base year, the returns to risk were $42 per acre. In 1998, the per-acre returns to risk were $46 for base, $15 for low, negative $9 for medium, and all agriculture ceased by 1998 under the high alternative. In 1996, under the high alternative, the returns to risk were negative $35 per acre.

In the Lordsburg-Animas Basins, the declines in returns to risk were large, but the returns were positive in 1998. The land charge in the Lordsburg-Animas Basins was based on a land valuation of $600 per acre. The per-acre returns to risk were $97 for the base year. In 1998, the per-acre returns to risk were $97 for base, $68 for low, $46 for medium, and $15 for the high energy price alternative.

The negative returns in some areas of the Southwestern Closed Basins under the high price alternative indicate that the land prices, if they hold at their present level, are higher than irrigated agriculture can support in the long run. The land prices utilized were due not only to the value of the land for agricultural purposes, but also the value of the water rights, mineral rights, and inflationary expectations. In some areas of the Southwestern Closed Basins, the value of the water rights and other rights, and land must decline in the long run under the high energy price alternative, or force out irrigated agriculture, if the prices for agricultural outputs do not increase at a rate faster than the general price level.

SUMMARY

The primary purpose of this study was to evaluate the economic impacts of alternative energy prices and declining groundwater levels on the irrigated agricultural sector in the Southwestern Closed Basins for the period 1979 to 1998.

The comprehensiveness of the study was made possible through the inclusion of a wide range of disciplines and area studies. These interdisciplinary activities were designed primarily to provide necessary information for the linear programming model. These activities included data collection, analysis, and interpretation. Secondary data were compiled whenever possible.

Economic Model

A linear programming (LP) model was developed, incorporating crop enterprise cost and returns budgets, a pumping cost model, hydrologic data, and projected energy prices for the Southwestern Closed Basins. The LP model incorporated the outputs of each sub-investigation and was utilized to project future water-use patterns and irrigated agriculture economic activity under alternative energy costs. The model was designed to maximize regional farm return to land and risk. Each crop contributes to the total farm return according to its level of production, while increased energy costs and declining water table levels impose additional costs on the economy of the region.

Hydrologic Data

Economic analysis of irrigated agriculture required the evaluation of the groundwater characteristics and quantification of parameters regarding existing and future conditions. Historic data on water levels, rates of decline, pumping lift, and well yield were obtained from various publications and open-file reports of the New Mexico State Engineer Office for use in this analysis. The principal aquifers in the Southwestern Closed Basins have a practical maximum thickness of 250 feet. A saturated thickness of 20 feet was selected as the minimum value which would yield sufficient water to support irrigated agriculture. Typical irrigation wells in the Southwestern Closed Basins yield from less than 800 gpm to over 2,000 gpm. Average pumping lifts range from less than 75 feet to nearly 400 feet. The near-future declines in water level were estimated from typical declines that ranged from less than a foot per year in the Playas Basin to as much as 5 feet per year in the Columbus-Hermanas Area.

Cost and Returns Budgets

Per-acre crop cost and returns enterprise budgets were developed for the more important irrigated crops for the Southwestern Closed Basins for farms that were above-average in both size and management. Much of the information for the budgets was obtained from local farmers during a series of meetings in 1979 and 1980. These budgets were developed on the basis of soil, water quality and water quantity conditions. The measure of profit used in constructing the enterprise budgets was net return to land and risk. Costs and returns per acre were budgeted for production of four major irrigated crops (corn for grain, cotton, grain sorghum and wheat). Only flood irrigation systems were included in the budgets.

Energy Price Projections

Increasing energy costs affect agriculture through increased fertilizer prices, increased fuel costs for pumping irrigation water, and increased fuel costs for operating farm machinery. The magnitude of these impacts will depend upon the rate of the energy price increase. To provide for a wide range of real energy price increases, this study presents the effects under four energy price increases: base, low, medium, and high. The base energy price projection assumed no real increase in the price of energy products purchased by farmers in New Mexico during the period 1979-1998. A low energy price projection estimated a low annual real energy increase, a third projection estimated a medium real annual price increase for energy which essentially was 1.5 times the low alternative, and the high projection estimated a high real annual increase in energy prices of about 2 times the low energy alternative.

Impact Projections

The LP model was utilized to simulate a 20 year period (1979-1998) crop production and irrigation water utilization pattern in the Southwestern Closed Basins under alternative energy price projections. Each simulation process begins with the same basic solution of the model, and continued with biannual changes to satisfy the alternative energy price projections for the 20 year period. The basic solution used 1978 conditions and closely approximated the actual crop acreages and other resources used in the base year 1978.

The results of the LP model for the 20 year simulation period for the 4 alternative energy price projection follows.

Base Year - 1978

Approximately 75,700 acres of land would be farmed, all flood irrigated (Table 11). The net return to land and risk for the Southwestern Closed Basins for the base year 1978 was estimated to be nearly $11.4 million. The amount of irrigation water pumped in the Southwestern Closed Basins during the base year was estimated to be approximately 212,000 acre-feet. Annual declines in the water table were about 2 feet in the Mimbres-Uvas Basin, 6 feet in the Columbus-Hermanas Area, 2 feet in the Lordsburg-Animas Basins, and less than 1 foot in the Playas Basin. The primary source of energy for pumping 212,000 acre-feet of irrigation water was electricity, with natural gas being the energy source for the remainder. Farm machinery fuel was assumed to be diesel with an annual cost for crop agriculture of slightly more than $1.1 million. The annual labor requirements were over 581,000 man-hours of labor and estimated to cost over $3.8 million annually.

The capital requirement for cropped agriculture in the Southwestern Closed Basins was divided into three components: operating capital, fixed capital, and sunk capital. Operating capital consisted of all purchased inputs, labor, repairs, and interest on operating capital. Fixed capital was composed of the depreciation and taxes on farm machinery and equipment, one-half the depreciation and taxes on irrigation equipment, and the interest on equipment investment. Sunk capital was comprised of only one item, one-half of the depreciation and taxes on irrigation equipment. The annual operating capital requirements (excluding energy costs) were estimated at more than $13 million. Fixed capital requirements were estimated at approximately $3.8 million, and sunk capital was estimated to be over $294,000.

Base Energy Price Alternative

The acreage farmed under this alternative remained constant at 75,700 acres with no shifts in the cropping pattern over the 20 year projection period (Table 11). The net return to crop agriculture in the Southwestern Closed Basins increased from the base year level of $11.4 million to $11.5 million in 1998. This rise in net return was due to reduced costs by the increased efficiency of the pumping plant. Approximately 212,000 acre-feet of water would be pumped in 1998. Electricity would be the primary source of energy for the pumping plants for the entire 20 year period, pumping 64 percent, with natural gas pumping the remainder. Average pumping costs for the Southwestern Closed Basins declined from 1978 to 1998; however, in some areas, the cost increased because of the greater pumping depths due to the declining water table, which more than offset gains in efficiency of the pumping plant. Total water decline for the base energy price alternative ranged from 7 feet for the Playas Basin to over 126 feet for the Columbus-Hermanas Area. Declines were over 34 feet in the Lordsburg-Animas Basins, and over 40 feet in the Mimbres-Uvas Basins (Table 11).

Farm machinery fuel cost for crop agriculture was estimated to be over $1.1 million for nearly 2.5 million gallons of diesel fuel in 1998. The man-hours of labor, labor and management costs, and capital requirements did not change from the base year levels.

Low Energy Price Alternative

Neither the cropping pattern nor the acreage farmed under this alternative changed from the base energy price alternative. The net return to crop agriculture in the Southwestern Closed Basins decreased $2.8 million from the base year level to $8.7 million in 1998 (Table 11). Approximately 212,000 acre-feet of water would be pumped in 1998, the primary energy source being electricity. The average cost of pumping water for the Southwestern Closed Basins increased about 55 percent from 1978 to 1998 (Table 11). Since the amount of water pumped was the same, the total water declines were the same as the base energy price alternative. Farm machinery fuel costs were estimated to be slightly less than $2.5 million in 1998, or a yearly increase of about 6 percent. Neither the man-hours of labor, the total cost of labor and management, nor capital requirements changed from the base energy price alternative.

Medium Energy Price Alternative

The net return to crop agriculture in the Southwestern Closed Basins decreased from the base year level of $11.4 million to $6.7 million in 1998 or nearly 2 percent per year (Table 11). The primary reasons for the decrease in the net returns were the rapid escalation of the price of diesel fuel, pumping plant fuel, and increasing depths to water as acreage remained constant. The effects of these rising energy prices are readily seen in the 41 percent reduction of net returns to crop agriculture.

The average cost of pumping irrigation water increased to $20.81 per acre-foot for the Southwestern Closed Basins, while in some areas the cost was over $41 per acre-foot (Table 11). The water

Table 11. Comparisons of the Impacts Resulting from the Four Energy Price Projections on the Crop Agricultural Sector, Southwestern Closed Basins, New Mexico, 1978-1998

Item	Units	Base Year 1978	Energy Price Projection Base	Low	Medium	High
Acres Irrigated	acres	75,700	75,700	75,700	75,700	62,100
Net Returns to Land and Risk						
Southwest Closed Basin	dollars	11,358,022	11,492,537	8,743,461	6,736,380	4,362,028
	$/acre	150.04	151.82	115.50	88.99	70.24
Mimbres-Uvas Basins	dollars	7,287,315	7,431,287	5,804,348	4,656,114	3,110,281
	$/acre	160.16	163.32	127.57	102.33	68.36
Columbus-Hermanas Area	dollars	1,059,750	1,016,530	530,034	164,732	0[a]
	$/acre	123.23	118.20	61.63	19.15	0[a]
Lordsburg-Animas Basins	dollars	2,602,324	2,611,200	2,131,864	1,758,226	1,251,736
	$/acre	156.77	157.30	128.43	105.92	75.41
Playas Basin	dollars	408,633	433,519	277,217	157,307	0[b]
	$/acre	81.73	86.70	55.44	31.46	0[b]
Net Returns to Risk[c]						
Southwest Closed Basin	dollars	5,225,022	5,359,537	2,610,461	603,380	-1,183,972
	$/acre	69.02	70.80	34.48	7.97	-19.07
Mimbres-Uvas Basins	dollars	2,737,315	2,881,287	1,254,348	106,114	-1,439,709
	$/acre	60.16	63.32	27.27	2.33	-31.64
Columbus-Hermanas Area	dollars	672,750	629,530	143,034	-222,268	0[a]
	$/acre	78.23	73.20	16.63	-25.85	0[a]
Lordsburg-Animas Basins	dollars	1,606,324	1,615,200	1,135,864	762,226	255,736
	$/acre	96.77	97.30	68.43	45.92	15.41
Playas Basin	dollars	208,633	233,519	77,217	-42,693	0[b]
	$/acre	41.73	46.70	15.44	-8.54	0[b]
Water Pumped and Cost						
Southwest Closed Basin	ac. ft.	212,056	212,056	212,056	212,056	169,404
	$/ac. ft.[d]	10.85	10.21	16.79	20.81	22.98
Mimbres-Uvas Basins	ac. ft.	127,423	127,423	127,423	127,423	127,423
	$/ac. ft.[e]	10.05	8.92	15.46	19.16	23.70
Columbus-Hermanas Area	ac. ft.	24,102	24,102	24,102	24,102	0
	$/ac. ft.	19.77	21.56	33.33	41.31	0
Lordsburg-Animas Basins	ac. ft.	41,981	41,981	41,981	41,981	41,981
	$/ac. ft.	8.99	8.78	13.57	16.82	20.81
Playas Basin	ac. ft.	18,550	18,550	18,550	18,550	0
	$/ac. ft.	8.91	7.56	11.70	14.50	0
Total Water Decline						
Mimbres-Uvas Basins	feet	1.9	40.6	40.6	40.6	40.6
Columbus-Hermanas Area	feet	6.0	126.7	126.7	126.7	102.6
Lordsburg-Animas Basins	feet	1.6	34.2	34.2	34.2	34.2
Playas Basin	feet	0.3	7.0	7.0	7.0	6.3
Farm Machinery Fuel Cost	dollars	1,136,554	1,136,554	2,490,303	3,645,042	4,191,283
	$/acre	15.01	15.01	32.90	48.15	67.49
Labor and Management	hours	581,221	581,221	581,221	581,221	478,263
	dollars	3,855,501	3,855,501	3,855,501	3,855,501	3,190,693
Capital Requirements						
Operating Capital	dollars	13,454,756	13,454,756	13,454,756	13,454,756	11,072,111
Fixed Capital	dollars	3,771,372	3,771,372	3,771,372	3,771,372	3,215,093
Sunk Capital	dollars	294,107	294,107	294,107	294,107	236,655

a The last year in which irrigated agriculture occured in the Columbus-Hermanas Area under the high price alternative was 1994.

b The last year in which irrigated agriculture occured in the Playas Basin under the high price alternative was 1996.

c Net Returns to Risk = net return to land and risk - (10% x acres irrigated x land value per acre).

d Weighted average from all areas.

e Weighted average by fuel.

pumped remained at over 212,000 acre-feet and the total water declines were the same as the base and low alternatives.

The farm machinery fuel cost for crop agriculture was estimated to be over $3.6 million by 1998 which is over 220 percent above the 1978 level. This increase was due to the increased price of diesel. Labor requirements and capital requirements (other than for fuel) did not change from the base and low energy price projections.

High Energy Price Alternative

The net return to crop agriculture decreased from $11.4 million in the base year to $4.4 million in 1998, a decline of about 62 percent (Table 11). This decrease was due to the higher prices paid for diesel fuel, electricity and increasing depths to water. Of importance was diesel fuel, which increased 8 percent per year. The pumping plant fuels, primarily electricity, increased 4 percent per year. The acreage farmed declined from 75,700 acres in 1978 to 62,100 acres in 1998, with the change caused by areas of irrigated land going out of production in 1994 and 1996.

The average cost of pumping water increased 112 percent in the Southwestern Closed Basins from 1978 to 1998. The amount of water pumped, and associated water declines, was the same as in the previous energy price alternatives in the Mimbres-Uvas Basin and the Lordsburg-Animas Basins. In the Columbus-Hermanas Area, all agriculture ceased in 1994 which resulted in a total water decline of about 103 feet. In the Playas Basin all agriculture ceased in 1996 which resulted in a total water decline of over 6 feet. The discontinuance of all agriculture in 2 areas by 1998 resulted in a total pumpage in the Southwestern Closed Basins of slightly more than 169,000 acre-feet, a 20 percent decline (Table 11).

Farm machinery fuel costs for agriculture were estimated to increase 269 percent (to $4.2 million) by 1998. Labor hours and capital under this projection were identical to the requirement for the previous projections through 1994, then decreased as the acres irrigated declined in 1998.

Returns to Risk

The return to risk for the Southwestern Closed Basins, after imposing a charge for the use of irrigated cropland valued at an average of $800 per acre, was $69 per acre in the base year (1978), then increased to $71 in the base price alternative. The returns to risk became even smaller under the low ($34) and medium ($8) price alternatives. Under the high alternative, the regional returns to risk were estimated to be a negative $19 per acre in 1998. Under the base price alternative, the regional net returns to risk were estimated to be $70 per acre in 1998 (Table 11). The negative returns in some areas of the Southwestern Closed Basins under the high price alternative indicate that the land prices, if they hold at their present level, are higher than irrigated agriculture can support in the long run. In some areas of the Southwestern Closed Basins, the value of the water rights and other rights, and land, must decline in the long run under the high energy price alternative, or force out irrigated agriculture, if the prices for agricultural outputs do not increase at a rate faster than the general price level.

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APPENDIX A: LINEAR PROGRAMMING MODEL

APPENDIX A: LINEAR PROGRAMMING MODEL

The basic economic model is a linear programming (LP) model. The other models (fuel costs, pumping cost) provide input into the LP model. The objective function for the model (regional returns to land and risk) can be represented by the following equation:

$$\text{Maximize } \sum_c \sum_j \sum_k R_{cikt} X_{cikt} - (FCAF_{ijkt} WP_{jkt}) - MFC_{it} - OC_{ckt} - FC_{ckt} - SC_{ckt} \quad [1]$$

where:

R_{cikt} = Gross crop returns in dollars per acre for crop c under energy price increase i, under well type k, in time period t

X_{cikt} = Acres of crop c given an energy price increase i, under well type k, in time period t

$FCAF_{ijkt}$ = Fuel cost per acre-foot of water pumped under energy price increase i, fuel type j, well type k, in time period t

WP_{jkt} = Water pumped with fuel j, under well type k in time period t

MFC_{it} = Regional machinery fuel cost (diesel cost) under energy price increase i, in time period t

OC_{ckt} = Operating capital (purchased inputs, labor and management, repairs, and interest on operating capital) for crop c, under well type k, in time period t

FC_{ckt} = Fixed capital (depreciation and taxes on machinery and equipment, one-half the depreciation and taxes on irrigation equipment, and interest on equipment investment) for crop c, under well type k, in time period t

SC_{ckt} = Sunk capital (one-half the depreciation and taxes on irrigation equipment) on crop c, under well type k, in time period t

Pumping Cost Model

The fuel cost per acre-foot of water effectively applied to a crop is a function of many factors. Some of the most important factors include: efficiency of the distribution and application system, base fuel costs, pumping unit efficiency, depth to water, well output and pressurization (if any).

The efficiency of the distribution and application system in this study refers to how efficiently the water is applied to crops after leaving the well. The more efficient the distribution and application system the fewer gallons of water that must be pumped to meet crop's needs plus losses. The assumed average efficiencies for the distribution and application system were derived from the crop budgets for the region by Lansford, et al. (1980).

The base fuel costs for natural gas, electricity, and diesel were those reported by Lansford, et al. (1980), in the regional crop budgets. The base fuel costs were increased by the real energy price increases presented in Table 5 to project fuel costs. The estimate of future fuel costs were determined by equation 2:

$$FC_{ijt} = BC_j \times (1 + EPI_{ij})^t \quad [2]$$

where: FC_{ijt} = Fuel cost for fuel type j, in time period t, under energy price increase i

j = Fuel type; natural gas, electricity, diesel, or LP gas

i = Energy price increase

t = Time period where 1978 is the base year to 1998 for a 20 year period beyond the base year

BC_j = Base cost of fuel j in 1978

EPI_{ij} = Energy price increase for fuel j, for energy price i, in constant 1978 dollars as a percent per year

The base pumping unit efficiencies were based on a study by Abernathy (1978), presented in Table 6 and discussed earlier in this report. In this study it was assumed that the pumping plant efficiency would be increased by one-half the difference between present efficiency and good efficiency every two years. Thus, the pumping plant efficiencies increase for all 20 years of the projections, with the greatest increase occuring in the early time periods. The method of increasing pumping plant efficiencies is presented in equation 3:

$$E_{jkt} = E_{jk(t-2)} + [(GE_j - E_{jk(t-2)}) \div 2] \qquad [3]$$

where: E_{jkt} = Pumping plant efficiency for fuel type j, well type k in time period t

k = Well type: flood

t = Time period where 1978 is the base year and 1998 for a 20 year period beyond the base

GE_j = Good efficiency for a pumping plant utilizing fuel j

The depth to water as it relates to pumping costs is composed of two parts, the static water level and the drawdown. The static water level was determined for the region from the crop budgets by Lansford, et al. (1980). The drawdown was based on the hydrology section of this report for each region. The original depth to water is presented in Table A-1. The well output was determined from the crop budgets by Lansford, et al. (1980), and is also presented in Table A-1.

Table A-1. Assumptions for pumping cost model for the Southwestern Closed Basin, New Mexico, 1978

Item	Unit	Mimbres-Uvas Basins	Columbus-Hermanas Area	Lordsburg-Animas Basins	Playas Basin
Water Decline*	ft/yr	1.6	5	1.8	0.3
Water Pumped in 1977	ac-ft	105,556	19,974	46,405	16,800
Original Depth to Water**					
Flood	feet	175	340	155	155
Gallons per Minute Pumped					
Flood	gallons	800	1,000	900	2,000

* From Results section dealing with hydrology
** Depth to water includes the static water table and average drawdown for the area
*** Includes the pressurization equivalent of 116 feet of head

The pumping fuel cost model is presented in equations 4 through 7. Equation 4 presents the method used for determining total water decline. The method for calculating water horsepower requirements are presented in equation 5. Equation 6 presents the calculations for determining the fuel cost per hour. Equation 7 converts the fuel cost per hour to fuel cost per acre foot.

$$TD_t = WP_{(t-n)} \; (WD \div WP_{1977}) \qquad [4]$$

where: TD_t = Total decline in water table in year t

$WP_{(t-n)}$ = Total water pumped in each of the previous time periods (t-n)

WD = Water decline based on historical data (Table A-1)

WP_{1977} = Water pumped in 1977 (Table A-1)

$(WD \div WP_{1977})$ = Decline of water table in feet per year per acre foot of water pumped for crops in 1977

n = A time period greater than one and less than t

$$WHP_k = ((TD_t + D_k + P_k) \times GPM_k) \div 3960 \qquad [5]$$

where: WHP_k = Water horsepower for well type (k)

TD_t = Total decline in water table (from equation 4)

D_k = Depth to water for well type k (Table A-1)

P_k = Pressurization required for well type k (sprinkler is 50 psi which equals 116 feet of static head; flood is 0 psi included in depth to water in Table A-1).

GPM_k = Gallons per minute pumped from well type k (Table A-1)

3960 = BTU's required to lift one gallon one foot

$$FCH_{ijkt} = (WHP_k \times FR_j) \times FC_{ijt} \qquad [6]$$

where: FCH_{ijkt} = Fuel cost per hour for fuel type j under energy price increase i, and well type k in time period t

WHP_k = Water horsepower for well type k (from equation 5)

FR_j = Quantity of fuel required to develop one water horsepower for fuel type j (High Plains Underground Water Conservation District Number 1, 1976)

FC_{ijt} = Fuel cost for fuel j under energy price i in time period t (from equation 2)

$$FCAF_{ijkt} = E_{jkt} \times FCH_{ijkt} \times 325{,}851/(GPM_k \times 60) \qquad [7]$$

where: $FCAF_{ijkt}$ = Fuel cost per acre-foot of water pumped under energy price increase i, fuel type j, well type k, in time period t

GE_j = Good pumping plant efficiency for pumping plants using fuel j

E_{jkt} = Present pumping plant efficiency for fuel type j and pumping plant (well) type k in time period t (from equation 3)

FCH_{ijkt} = Fuel cost per hour for fuel type j, under energy price increase i, well type k, in time period t (from equation 6)

325,851 = Gallons per acre-foot

GPM_k = Gallons per minute pumped from well type k

60 = Minutes per hour

The fuel cost per acre-foot of water pumped was then included directly in the LP model.

Base fuel costs for tractors and harvesting equipment were obtained from the crop budgets by Lansford, et al. (1980). In the study by Lansford, all farm machinery was assumed to be diesel powered. The fuel costs were based on $0.45 per gallon diesel fuel and fuel consumption rates from the 1978 Nebraska Tractor Test Data.

In this study the increased fuel costs for operating diesel powered farm machinery was used as an estimate of the increased fuel costs of all farm machinery. Future fuel costs for farm machinery were obtained from the following equation:

$$MFC_{it} = BC \times (1 + EPI_i)^t \qquad [8]$$

where: MFC_{it} = Machinery fuel cost (diesel fuel cost) in time period t under energy price increase i

t = Time period where 1978 is the base year and 1998 is 20 years beyond the base year

i = Energy price increase scenerio

BC = Base cost of diesel fuel in 1978

EPI = Energy price increase i in constant 1978 dollars in percent per year

Resource Constraints

The objective function, equation 1, was maximized subject to regional resource availability. The resource constraints also consider "typical" farming practices such as crop rotation and risk diversification. The general constraints were as follows:

1. The summation of all irrigated cropping activity levels cannot exceed the total irrigable land.

$$\sum_c \sum_k I_{cikt} < TI$$

2. For rotational practices and risk and uncertainty diversification, each single irrigated crop activity level was assumed to not exceed a percentage of the total irrigated cropland.

$$\sum_k I_{cikt} < Y_c \, TI$$

In addition, for crop rotational practices it was necessary to include a minimum acreage for some crops in the subregions.

$$\sum_k I_{cikt} > Q_c \, TI$$

3. Counting rows were included in the model to sum the different capital requirements to subtract from the objective function and for informational purposes. They are:

   a. Operating capital requirements,

$$\sum_c \sum_k o_{cikt} = Or$$

   b. Fixed capital requirements,

$$\sum_c \sum_k f_{cikt} = Fr$$

   c. Sunk capital requirements,

$$\sum_c \sum_k s_{cikt} = Sr$$

   d. Labor hours,

$$\sum_c \sum_k lh_{cikt} = Lh$$

   e. Labor and supervision and management cost,

$$\sum_c \sum_k lc_{cikt} = Lc$$

   f. Fuel cost,

$$\sum_c \sum_k fc_{cikt} = BC$$

where:

I = Acres of irrigated crops

TI = Total irrigated land available

Y_c = Maximum percentage of total irrigated land that can be planted in crop c

Q_c = Minimum percentage of total irrigated land that must be planted in crop c

Or = Total operating capital requirements

Fr = Total fixed capital requirements

Sr = Total sunk capital requirements

Lh = Total hours of labor required

Lc = Total cost of labor, supervision and management

BC = Total base fuel cost

c = Type of crop

i = Energy price increase

k = Well type

t = Time period

o_{cikt} = Operating capital requirements (purchased inputs, labor and management, repairs, and interest on operating capital)

f_{cikt} = Fixed capital requirements (depreciation and taxes on machinery and equipment, one-half the depreciation and taxes on irrigation equipment, and interest on equipment investment)

s_{cikt} = Sunk capital requirements (one-half the depreciation and taxes on irrigation equipment)

lh_{cikt} = Labor hours required

lc_{cikt} = Labor supervision and management cost

fc_{cikt} = Dollars of fuel used by crop c

Southwestern Closed Basins

The specific resource constraints in the Southwestern Closed Basins, by sub-basin were as follows:

Mimbres-Uvas Basin

$$\sum_c \sum_k I_{ckit} \leq 45{,}500 \text{ acres}$$

$$\sum_k I_{ckit} \leq Y_c \, TI \text{ and } \sum_k I_{ckit} \geq Q_c \, TI$$

Columbus-Hermanas Area

$$\sum_c \sum_k I_{ckit} \leq 8{,}600 \text{ acres}$$

$$\sum_k I_{ckit} \leq Y_c \, TI \text{ and } \sum_k I_{ckit} \geq Q_c \, TI$$

Lordsburg-Animas Basins

$$\sum_c \sum_k I_{ckit} \quad I \leq 16{,}600 \text{ acres}$$

$$\sum_k I_{ckit} \leq Y_c \, TI_k \text{ and } \sum_k I_{ckit} \geq Q_c \, TI$$

Playas Basin

$$\sum_c \sum_k I_{ckit} \leq 5{,}000 \text{ acres}$$

$$\sum_k I_{ckit} \leq Y_c \, TI \text{ and } \sum_k I_{ckit} \geq Q_c \, TI$$

where the values Y_c and Q_c are given below for each crop in each sub-basin:

	Corn	Cotton	Sorghum	Wheat
Mimbres-Uvas Basins				
y_c	0.30	0.50	0.30	0.15
Q_c				0.05
Columbus-Hermanas Areas				
Y_c	0.30	0.50	0.30	0.15
Q_c				0.05

	Corn	Cotton	Sorghum	Wheat
Lordsburg-Animas Basins				
Y_c	0.30	0.50	0.30	0.15
Q_c				0.05
Playas Basin				
Y_c	0.50		0.50	0.50
Q_c				0.25

APPENDIX B: BUDGET GENERATOR

APPENDIX B: BUDGET GENERATOR

A computer-based crop cost and returns budget generator, developed by the Agricultural Economics and Agricultural Business Department at New Mexico State University was used to compile the crop budgets. With an engineering cost approach, the budget generator develops costs per acre for each operation performed for each crop. The budget tables present the cost per acre of purchased inputs (materials such as seed and fertilizer); the labor, fuel and repairs, and fixed costs associated with pre-harvest and harvest operations; as well as overhead costs such as taxes, insurance and interest cost for a particular crop.

The budget generator provides estimates of per acre machinery cost, based on a prorated share of the total farm variable and fixed cost of owning and operating the required farm machinery.

The budgets are developed in a two-step process. The first step involves the determination of the machinery and equipment costs for the particular farm size and cropping pattern. The second step involves the determination of the cost and returns per acre for each crop. For each item of equipment, the size, number per farm, value per item of equipment, and annual use is reported. Also reported for equipment are the variable costs, which include fuel, oil and lubricants, repairs, and total variable costs per hour of annual use. Fixed costs included annual depreciation, taxes on equipment, and total fixed costs per hour of annual use.

Annual crop production costs are divided into four major categories. These are purchased inputs, pre-harvest costs, harvest costs, and overhead costs. The purchased inputs include costs for such items as seed, fertilizer, insecticides, and baling wire. Quantities and costs per acre are reported for each. The second category of annual costs is the pre-harvest operations. Pre-harvest costs for fertilizer application, land preparation, cultural operations, irrigation water and insecticide applications are reported per acre. These costs include labor, fuel, oil and repair; and fixed costs per acre for this phase of production. Harvest operations are reported in hours of use per acre for each item of equipment and associated labor, fuel, oil and repairs, fixed costs and total costs per acre. Overhead expenses include other purchased inputs, insurance, labor downtime, employee benefits, supervision costs, land taxes, and other overhead expenses per acre.

Farm Characteristics

Construction of the budgets required compilation of information typical of farms that were above-average in both size and management. The information included farm size, irrigation water source and application rates, cropping patterns, yields, and equipment requirements. The farm characteristics for each sub-basin used in this study are presented in Table B-1.

Irrigation Water

Typical flood irrigation water application rates are presented in Table B-1.

Table B-1. Farm and Crop Characteristics of the Southwestern Closed Basins, 1978

Item	Unit	Mimbres	Hermanas	Playas	Lordsburg Animas
Farm Size	acres	640	1,280	5,000	960
Crop Acreage:					
Corn	acres	90	160	600	215
Cotton	acres	290	580	--	325
Grain Sorghum	acres	145	280	600	200
Wheat	acres	55	110	2,800	30
Idle and Fallow	acres	60	150	1,000	190
Total	acres	640	1,280	5,000	960
Well Characteristics:					
Number	number	5	8	19	7
Depth to Water	feet	145	270	75	125
Yield	gpm	800	1,000	2,000	900
Fuel	type	NG	EL	EL	EL
Water Application:					
Corn	ac-in	54.5	54.5	49.5	49.5
Cotton	ac-in	18.3	18.3	--	15.0
Grain Sorghum	ac-in	40.5	40.5	40.3	40.3
Wheat	ac-in	40.4	40.4	38.6	38.6
Crop Yields:					
Corn	bu	160	160	150	150
Cotton - lint	lbs	700	700	--	650
Cotton - seed	lbs	1,130	1,130	--	1,050
Grain Sorghum	cwt	70	70	70	70
Wheat	bu	55	55	55	55
	acre grazing	1	1	1	1
Crop Prices:					
Corn	$/bu	2.50	2.50	2.50	2.50
Cotton - lint	¢/lb	.68	.68	--	.66
Cotton - seed	¢/lb	.06	.06	--	.06
Grain Sorghum	$/cwt	4.00	4.00	4.00	4.00
Wheat	$/bu	3.00	3.00	3.00	3.00
	$/acre grazing	24.00	24.00	24.00	24.00

Crop Yields and Prices

Crop yields, estimated for above-average farms, are higher than the county average yields. The prices farms received for crops were those typically received for the 1978 crop year. Crop yields and prices are presented in Table B-1.

Returns

Returns were defined as the net return to land and risk. They were based on gross returns from the sale of the crop, less total operating expenses, which yields net operating profit. From net operating profit, an interest charge for the use of capital (operating and machinery) was subtracted to obtain net return to land and risk. An interest charge was not assessed for land investment. Return to risk is defined as the residual return after an additional charge is specified for the land investment. The interest charge on operating and machinery capital was viewed as an opportunity cost for the use of the capital whether owned or borrowed.

Costs

Production costs were categorized as variable, fixed, or overhead. Variable costs differ with the quantity of use. Fixed costs do not vary with the quantity of use but are fixed at the farm level. Overhead costs cover items not directly associated with production, such as insurance and taxes. The basic cost data used in preparing the crop budgets are presented in Table B-2.

Variable Costs

Labor Costs. On the cost and return budgets, labor was valued at $3.00 per hour for equipment operators and $2.75 per hour for irrigators and other general farm labor.

Materials and Other Purchased Inputs. Fertilizer, seed, wire, and other purchased input costs were developed from 1978 prices typically paid by farmers in the sub-regions. The unit prices are reported in Table B-2.

Fuel, Oil, Lubricants, and Repair Costs. Fuel consumption rates were determined from the Nebraska Tractor Tests (1978) for the typical size and type of tractors found in the area. The specific fuel prices utilized are reported in Table B-2. Oil costs were estimated to be 15 percent of the hourly fuel costs. Lubrication costs were calculated as a percentage of current value of the machine and adjusted for the annual hours of use. Repairs and maintenance costs are calculated as a percentage of the price of the new machinery and adjusted for the annual use and remaining expected life. Repair costs are adjusted for used machinery by assuming that the ratio of the price of used machinery to the price of new machinery is a measure of the percentage of remaining expected life of the used machinery.

Fixed Costs

Fixed costs included annual depreciation expenses and personal property taxes. Annual depreciation expenses were calculated as one-third of current equipment value times the tax rate in the

Table B-2. Basic Farm Information for the Southwestern Closed Basins, 1978

Item	Unit	Mimbres-Uvas Basin	Columbus-Hermanas Area	Lordsburg-Animas Basins	Playas Basin
Labor Wage Rate					
Equipment operators	$/hour	3.00	3.00	3.00	3.00
General and irrigators	$/hour	2.75	2.75	2.75	2.75
Purchased Inputs:					
Anhydrous ammonia	$/lb	0.06	0.06	0.06	0.06
16-20-0	$/lb	0.07	0.07	0.07	0.07
Seed:					
Corn	$/lb	0.87	0.87	0.87	0.87
Grain sorghum	$/lb	0.04	0.04	0.04	0.04
Cotton	$/lb	0.07	0.07	0.07	--
Wheat	$/lb	0.20	0.20	0.20	0.20
Herbicide:					
Corn	$/acre	2.75	2.75	2.75	2.75
Cotton	$/acre	3.00	3.00	3.00	--
Grain sorghum	$/acre	3.00	3.00	3.00	3.00
Insecticide:					
Corn	$/acre	0.75	0.75	0.75	0.75
Wheat	$/acre	0.75	0.75	0.75	0.75
Gasoline	$/gal	0.50	0.50	0.50	0.50
Diesel fuel	$/gal	0.45	0.45	0.45	0.45
Natural gas	$/MFC	1.72	--	--	--
Electricity	¢/KWH	3.02	3.02	3.02	3.02
Farm Insurance	$/acre	4.00	4.00	2.50	2.50
Employee Liability Insurance Rate	$/$1000 wages	15.00	15.00	15.00	15.00
Labor Downtime	percent of direct time	25	25	25	25
Interest on Operating Capital	percent	10	10	10	10
Interest Rate on Equipment	percent	10	10	10	10
Land Taxes	$/acre	2.00	2.00	2.00	2.00
Personal Property Tax Rate	$/$1000 AV	24.00	24.00	25.00	24.00
Supervision Factors*					
Field crop--irrigation	$/labor hour	0.90	0.90	0.90	0.90
Field crop--equipment and general	$/labor hour	0.45	0.45	0.45	0.45
Management Rate	percent of gross returns	5	5	5	5
Non-productive Machine Adjustment Factor**	percent of machine hours	25	25	25	25
Employee Benefits	percent of total labor cost	15	15	15	15
Other Expenses	$/acre	20	20	20	20

*See Appendix Equation 7 for further explanation.

**Allowance for machine hour accumulations not directly associated with crop operations such as travel to and from fields and general farm clean-up operations.

area. The annual depreciation and tax expense for each item of equipment was based on the aggregate annual hours of use for each item. These costs per hour were then prorated according to the crop requirements.

Overhead Expenses

Overhead expenses included insurance, labor downtime, land taxes, supervision and management, and other overhead expenses. These overhead expense rates are presented in Table B-2.

Insurance. Farm liability and property insurance costs were estimated to be $4.00 per acre for the Mimbres-Uvas Basins and the Columbus-Hermanas Area. It was estimated to be $2.50 per acre for the Lordsburg-Animas Basins and Playas Basin. Employee liability insurance was estimated to cost $15.00 per $1,000 of wages paid per acre.

Labor Downtime. Labor downtime was based on 25 percent of the direct labor time involved in machine operations at the respective wage rates. This was an allowance for getting to and from the fields and other non-productive labor time.

Employee Benefits. Employee benefits were calculated at 15 percent of total labor costs. These included social security taxes, unemployment compensation taxes, and other fringe benefits.

Land Taxes. Land taxes were estimated to be $2.00 per acre for the Southwestern Closed Basins based on local tax rates and assessed valuations (Table B-2).

Management and Supervision Costs. Management costs were calculated at five percent of the gross returns. Supervision costs were based on the type of labor involved per acre from information developed by Sweetzer (1975).

Other. Other overhead expenses include such items as the farm share of the telephone, other utilities, farm pick-up, buildings, accounting fees, etc. The other overhead expenses were estimated at $20.00 per acre.

Interest on Operating Capital

The opportunity cost in the use of operating capital was calculated at 10 percent. The purchased inputs were charged for six months, variable costs of pre-harvest operations for three months, and variable costs of harvest operations for one month.

Interest on Machinery Investment

The opportunity cost in the use of capital invested in machinery and equipment was calculated on the average investment, at an interest rate of 10 percent.