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Part II

IRRIGATION WATER REQUIREMENTS FOR CROP PRODUCTION ROSWELL ARTESIAN BASIN

AN ECONOMIC ANALYSIS AND BASIC DATA

by

ROBERT R. LANSFORD, Assistant Professor

BOBBY J. CREEL, Water Research Aide

WATER RESOURCES RESEARCH INSTITUTE

in cooperation with

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Department of Agricultural Economics and Agricultural Business

New Mexico State University

Las Cruces, New Mexico

The project Water Requirements for Crop Production in the Roswell Artesian Basin (Water Resources Research Institute Report 4) was published in four parts.

Parts I, II, and III contain the analysis and basic data for the subsections. Part IV is the overall project analysis and summary. These were published by multilith in limited numbers to be used as work copies and for reference and file copies. The four parts are as follows:

Water Requirements for Crop Production
in the Roswell Artesian Basin

Part I - An Agronomic Analysis and Basic Data

Part II - An Economic Analysis and Basic Data

Part III - An Engineering Analysis and Basic Data

Part IV - Project Analysis and Summary

The Project Analysis and Summary of the entire project was printed as Water Resources Research Institute Report No. 5 and is available for general distribution.

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The Department of Agricultural Economics and Agricultural Business conducted this part of the interdisciplinary research project (An Analysis of Water Requirements for Crop Production in the Roswell Underground Water Basin).

The principal investigators for this section were Robert R. Lansford and Bobby J. Creel, agricultural economists, New Mexico State University. The other sections of the research were: agronomic, conducted by Carl E. Barnes, superintendent, Southeastern Branch Station, New Mexico Agricultural Experiment Station, Artesia, New Mexico; agricultural engineering, conducted by Evan Carroon, consulting agricultural engineer, Alamogordo, New Mexico; and soils, conducted by Harold Dregne, soil scientist, New Mexico State University. H. R. Stucky, Director, New Mexico Water Resources Research Institute, New Mexico State University, was coordinator of this project.

In addition to these, other groups and individuals aided in the study. Special appreciation is expressed to the following: U. S. Soil Conservation Service, especially work-unit personnel in Roswell, Hagerman, and Artesia, New Mexico; State Engineer Office; Agricultural Stabilization and Conservation Service personnel, and the Agricultural Extension County Agents in Chaves and Eddy Counties; and finally to the farmers who participated in this study.

ABSTRACT

This study describes adjustments to farm organizations which farmers in the Roswell Artesian Basin of New Mexico might profitably make with limited quantities of irrigation water.

The case study method was used to obtain detailed information on production requirements, costs, and returns for the principal crops produced in the Roswell Artesian Basin. Twelve study farms were selected. Enterprise and whole farm budgets were constructed and compared with optimal farm organizations determined by the linear programming method. Three linear programming models were used: one model (model A) described the maximum net farm return that could be obtained with seven quantities of irrigation water (2.50, 2.75, 3.00, 3.25, 3.50, 3.75, and 4.00 acre-feet per water-right acre); a second model (model B) described the maximum net farm return that could be obtained with a 5 percent increase in farm irrigation efficiency with seven quantities of irrigation water (2.50, 2.75, 3.00, 3.25, 3.50, 3.75, and 4.00 acre-feet per water-right acre); and the third model described, for the specific quantities of irrigation water, the farm organization and returns with an assumed crop rotation of about 30 percent of the water-right acres devoted to the production of alfalfa.

Comparisons of the optimal farm enterprise organizations with the actual organizations indicated: 1) that net farm returns are not maximized under existing farm organizations, and 2) that the diversion of 2.75 to 3.00 acre-feet of irrigation water per water-right acre would be required to maximize net farm returns in models A and B. In model C, the optimum quantity of irrigation water diversion would be between 3.75 and 4.00 acre-feet per water-right acre.

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IRRIGATION WATER REQUIREMENTS FOR CROP PRODUCTION IN THE ROSWELL ARTESIAN BASIN, NEW MEXICO

by Robert R. Lansford and Bobby J. Creel[1]

INTRODUCTION

Farmers in the Roswell Artesian Basin, as in other areas of New Mexico, are continually faced with the problems of adjusting to changing economic conditions. Some of the reasons for these problems are changes in resource and product prices, changes in technology, changes in enterprise alternatives, and changes in institutional factors. In addition, many farmers in this area are faced with the need for rapid adjustment of their farming operations to comply with a legal restriction placed on the quantity of ground water diverted for irrigation. To make this adjustment, farmers must have current information about resource requirements, production costs, and profit-maximizing enterprise combinations for various farm situations.

To supply current information on the above mentioned problems a three-year study was undertaken by the New Mexico Water Resources Research Institute in cooperation with the New Mexico Agricultural Experiment Station. This study was designed to obtain information on crops grown, yields, soil quality, water quality, types of irrigation systems, methods of irrigation, and amounts of water consumed by alfalfa and cotton, and to analyze these factors as they relate to the water requirements for crop production. A team composed of agronomists, agricultural engineers, agricultural economists, and soil specialists was selected to conduct the research. This is a report of the agricultural economics phase of the project. A similar report is available on the agronomic, agricultural engineering, and soils phases. These reports were summarized, with recommendations and conclusions, and have been published in an overall report of the project which is available for general distribution. The sectional reports have been published in limited numbers for reference use and data storage.

The several reports include the results obtained through carefully designed experimental procedures for the conditions found in the Roswell Artesian Basin during the period of the project, calendar years 1966, 1967, and 1968. These results may serve administrators, farmers, and other decision-makers to establish the specific water use allowable, types of farm rotations, and water management practices for the farmers in the area and for the basin as a whole.

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1. Assistant Professor and Water Research Aide, respectively, Department of Agricultural Economics and Agricultural Business, New Mexico State University.

HISTORICAL DESCRIPTION

Overexpansion in the use of ground water for irrigation has been a basic problem in the Roswell Artesian Basin since the beginning of major ground water development, about 1900. After 1916, the level of artesian water began to decline rapidly, but provisions for legal restraints on the development of ground water were not enacted until 1931 (25, p. 71).

On August 21, 1931, the Roswell Artesian Basin was declared by the New Mexico State Engineer to facilitate the orderly development of the area and to insure the protection of existing rights. After the declaration of the basin, new artesian wells could be drilled only after a permit was obtained from the state engineer. In addition, the reasonable annual diversion of ground water withdrawal was set by the state engineer at three acre-feet per acre (36, p. 5). However, this provision was not enforced until 1967.

Initially, shallow water wells were permitted by the state engineer. Shallow water aquifers soon became a major source of irrigation water supply. On August 1, 1937, the basin was also closed to further development of shallow water (21, p. 2). Eight extensions in the area of the basin have been made since 1931.

Water levels have, nevertheless, continued to decline. Since the beginning of major irrigation development, water levels in the southern part of the basin have declined more than 200 feet. This has resulted in noticeable effects such as decreases in artesian and surface flows, increased pumping lifts, and intrusion of salt water into fresh water aquifers (3).

The seriousness of these problems led to adjudication of ground water rights. In 1956 the state engineer and the Pecos Valley Artesian Conservancy District jointly filed suit in the District Court of Chaves County to obtain a judicial determination of water rights, both artesian and shallow aquifers, in the Roswell Artesian Basin. A companion suit was filed in the fall of 1958 to determine the rate of approaching exhaustion of economically recoverable water for irrigation from the shallow aquifers in those locations. During the hearings it was found that about 142,000 acres of land were irrigated, of which approximately 130,000 acres had valid rights (25, p. 72). Irrigation of the other 12,000 acres was declared illegal and eventually this land was removed from production. The court, on January 10, 1966, filed a partial final judgment and decree which further defines water rights in the Roswell Artesian Basin. The order called for water meters to be placed on all irrigation wells by January 1, 1967. It also set an annual duty of water--three acre-feet per acre per annum--to be exceeded only if the total amount of water diverted in any period of five consecutive years does not exceed 15 acre-feet. The order further provided for the appointment of a watermaster to enforce the provisions of the decree.[2]

Many farmers historically have diverted more irrigation water than the current annual allotment of three acre-feet per water-right acre. The rate at which use exceeds recharge into the Roswell Artesian Basin is indicated as follows: the natural recharge of ground water aquifers is about 265,000 acre-feet, of which about 115,000 acre-feet are naturally discharged. A balance of 150,000 acre-feet remains available for consumptive use (25, p. 80). The total pumpage from this area was estimated for the 1960-1964 period to be between 400,000 and 430,000 acre-feet per year, of which about 270,000 acre-feet are consumed and the remainder is returned to the underground aquifers. The consumptive use exceeds available recharge by about 120,000 acre-feet annually (26, p. 80). Total metered water diverted in 1967 was 387,361.5 acre-feet and 339,124.5 acre-feet in 1968 (12).

Part of the higher water diversion per water-right acre has resulted from changes in the cropping pattern. Lansford and Simkins, in 1966, concluded from an analysis of 60 sample farms in the basin for the years 1948 to 1966, that the percentage of all crops except cotton and alfalfa remained fairly constant during the preceding 20 years (17). Cotton acreage, however, decreased as a consequence of acreage allotments under the government cotton program while the acreage of alfalfa increased. Because alfalfa has a higher water requirement than cotton, many farmers are faced with the need to adjust their cropping patterns to comply with the reduced quantity of irrigation water for a total of 15 acre-feet per acre pumped in any period of five consecutive years.

OBJECTIVES OF THE STUDY

The objectives of the overall project as stated in the agreement between the Pecos Valley Artesian Conservancy District and the New Mexico Water Resources Research Institute were:

1. To assemble and analyze existing cropping patterns, water use, water quality, soil quality, and crop yields for the Roswell Underground Water Basin.

2. To determine the water requirements of crops, of farms, and of the basin under various irrigation methods, efficiencies, and cropping patterns.

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2. State of New Mexico, et al. L. T. Lewis, Hagerman Canal Company, et al. (Consolidated Number 14945, District Court of Chaves County, State of New Mexico), Partial Final Judgment and Decree (mimeo, 6 99.), 1966.

3. To determine farm and basin income effects from various irrigation methods, efficiencies, and cropping patterns.

The specific objectives of the agricultural economics phase of the study were:

1. To determine the present cropping system, management practices, and income patterns of the farms in the basin.

2. To evaluate the economic effects of alternative cropping systems and management practices under varying amounts of irrigation water, with specific emphasis on three acre-feet of irrigation water per acre.

DEFINITION OF TERMS

To avoid frequent lengthy descriptions, certain terms are used throughout this study. Reference to the following definitions may facilitate a better understanding of the discussion.

Irrigated cropland: Land on which water is artificially applied for the production of agricultural products and/or on which the owner has the physical facilities and legal right to do so.

Water-right acres: Land on which the owner has the legal right to apply irrigation water as defined by adjudication and permit.

Cultivated land: Land to which cultural practices were actively applied during the preceding two years including the years in which this study was conducted (includes cropped, fallow, and diverted land).

Cropped acreage: Land on which crops were growing at the time of the study.

Out of production: Land on which cultural practices were not applied during the two years preceding the study.

Diverted: Land devoted to conservation uses for a period of time as specified in the provisions of the 1966, 1967, and 1968 Upland Cotton Programs.

Net returns to land and management: The compensation for farm capital in land and for management of the operator employed in the production of a given crop enterprise (32, p. 374).

Net farm returns to land and management: The compensation for farm capital in land and management of the operator employed in the production of all crop enterprises.

Underground pipeline: A covered pipeline used to convey irrigation water from a well or storage reservoir to another water conveyance device or to the site of application.

Concrete-lined ditch: An open concrete-lined irrigation ditch used to convey irrigation water from the well or storage reservoir to another irrigation water conveyance device or to the site of application.

Earthen primary and secondary laterals: Earthen ditches commonly used to convey irrigation water from some intermediate point in the irrigation conveyance system to the site of application. Secondary earthen laterals commonly subdivide an irrigation site or field.

Farm irrigation efficiency: The percentage of irrigation water pumped or diverted, that is stored in the soil and which is available for consumptive use.

Typical: The modal average during the three years of this study, 1966, 1967, and 1968.

DESCRIPTION OF THE BASIN

Location

The Roswell Artesian Basin lies within the Pecos River Valley in southeastern New Mexico (figure 1). The natural boundaries of the basin extend from near Vaughn on the north to Seven Rivers Hills on the south, and from the summit of the Sacramento Mountains on the west to a few miles east of the Pecos River on the east. For administrative purposes the New Mexico State Engineer has established definite boundaries for the basin that are considerably smaller than the natural boundaries. The declared basin lies mainly along the west side of the Pecos River in Chaves and northern Eddy Counties; the remainder is in eastern Lincoln and Otero Counties. It ranges in width from approximately 4 to 66 miles, and extends about 100 miles from north to south. The northern boundary is about 24 miles north of Roswell, and the southern boundary is about 24 miles south of Artesia.

At present, the declared basin encompasses an area of about 4,280 square miles. However, only a small part of this area is irrigated cropland. The principal irrigated area is west of the Pecos River (figure 2). It extends from 24 miles north of Roswell to 24 miles south of Artesia and ranges from 6 to 8 miles in width. In the vicinity of the tributaries of the Pecos River, the irrigated area extends westward from the Pecos River as much as 20 miles.

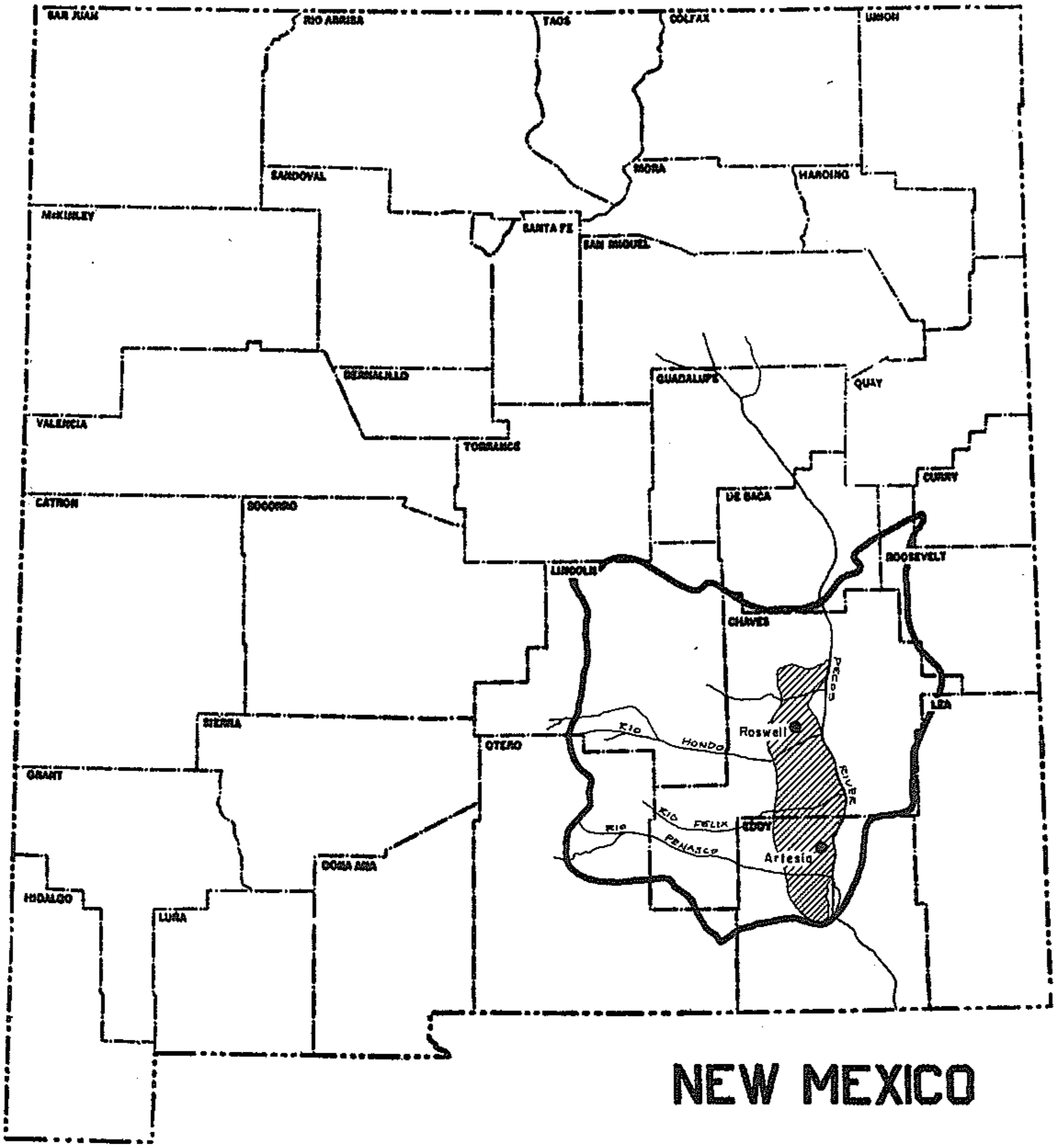


Figure 1. Location of study area.

 Study area - Roswell Artesian Basin

Drainage area for Pecos River in the Roswell Artesian Basin

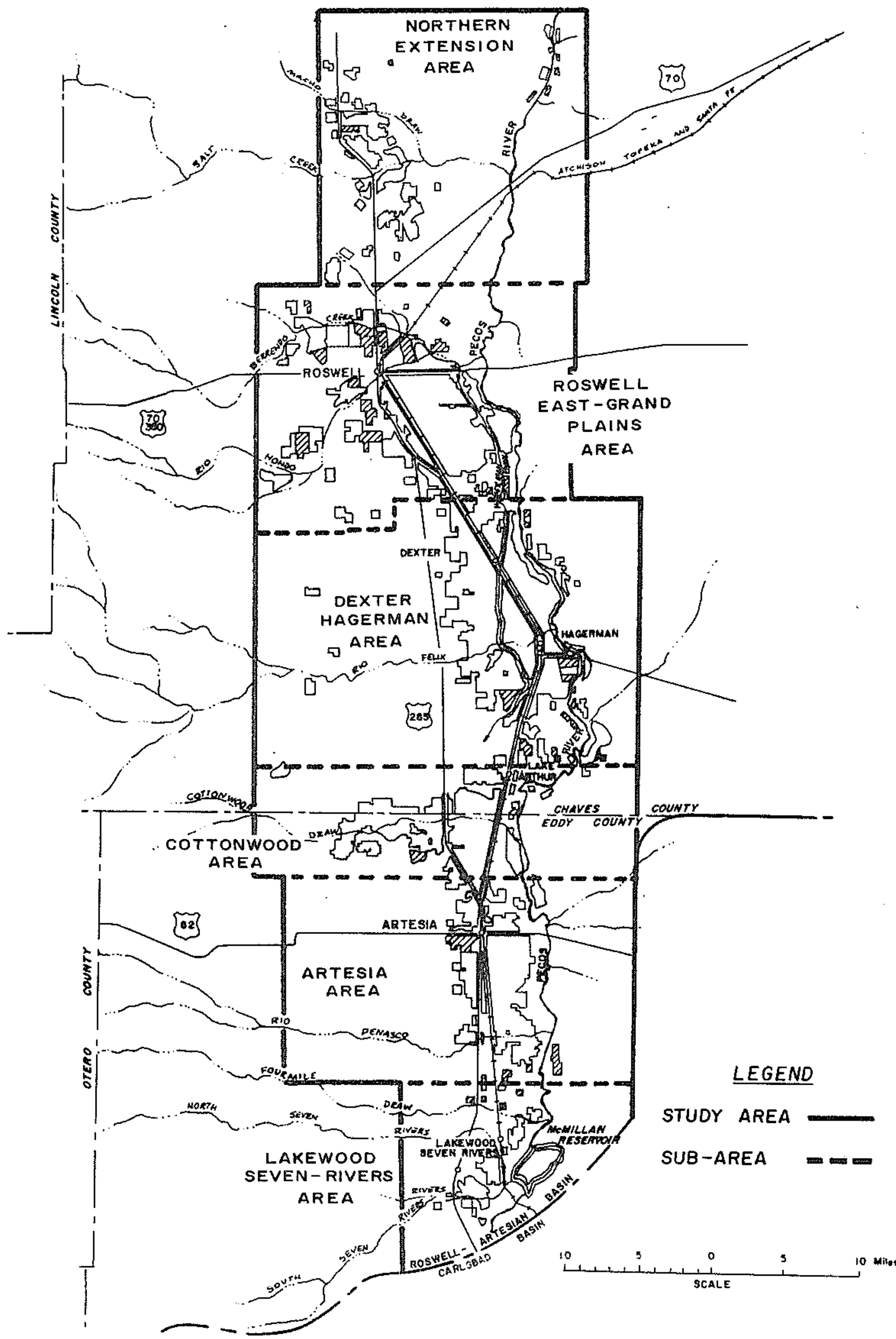


Figure 2. Location of irrigated cropland by sub-areas in the Roswell Artesian Basin, New Mexico.

Climate

The climate is semiarid with low average annual precipitation, low relative humidity, high temperatures, and persistent wind movement. Winters are usually mild and dry but heavy snows and extremely low temperatures have been experienced. The average annual precipitation (1931-1968) was 11.18 and 10.73 inches at Roswell and Artesia respectively, and the average temperature was 57.6° F and 61° F for Roswell and Artesia (table 1) (16, 28, 37).

Table 1. Precipitation, temperature, and growing season for 1966, 1967, and 1968, and long-time average at Roswell and Artesia, New Mexico.

	1966	1967	1968	Average[1]
Precipitation:				
Annual total (inches)				
Roswell	9.68	11.06	15.84	11.18
Artesia	10.68[2]	4.90[2]	9.66	10.73
Temperature				
Average annual (°F)				
Roswell	58.8	59.8	57.6	57.6
Artesia	58.9[2]	59.7[2]	58.8	61.0
Growing Season:				
Date of last spring frost:				
Roswell	April 20	May 2	April 30	April 8
Artesia	April 6	May 2	April 29	April 7
Date of first fall frost:				
Roswell	Oct. 15	Oct. 17	Oct. 17	Oct. 28
Artesia	Oct. 14	Oct. 18	Sept. 28	Nov. 1
Number of frost-free days:				
Roswell	178	168	169	203
Artesia	191[2]	169[2]	152	208

1. Average for years 1931-1968.
2. Source: Weather Records kept by Southeastern Experiment Branch Station, New Mexico State University, Artesia, New Mexico, 1966, 1967.

Source for all other data: Weather Bureau, Climatological Data, New Mexico (Annual Summaries) Vols. 34-72, 1931-1968.
Decennial Census of United States Climate--Monthly Normals of Temperature, Precipitation, and Heating Degree Days, New Mexico, Climatography of U. S. No. 81-25, U. S. Government Printing Office, Washington, D. C.

At Roswell, in the northern portion of the basin, the annual precipitation for 1966, 1967, and 1968 was 9.68, 11.06, and 15.84 inches respectively (table 1). In 1966 precipitation was 1.5 inches below the normal average, 1967 was about normal, and 1968 was 4.66 inches above normal.

At Artesia the annual rainfall for the same years was 10.68, 4.90, and 9.66 inches respectively (table 1). In 1966, rainfall was about normal, 1967 was considerably below normal (5.83 inches), and 1968 was one inch below normal.

The average annual temperature at Roswell was 58.8, 59.8, and 57.6° F for 1966, 1967, and 1968 respectively. Two of the three years, 1966 and 1967, were above the normal average while 1968 was normal. At Artesia the average annual temperature for these years was 58.9, 59.7, and 58.8° F respectively, which was slightly above normal.

The growing season or number of frost-free days for the three years was below normal for both Roswell and Artesia. Roswell's frost-free period was 178, 168, and 169 days, and Artesia's was 191, 169, and 152 days for the same period. At Roswell the average date for the last spring frost is April 8, and for the first fall frost, October 28. At Artesia the last spring frost averages April 7, and the first fall frost averages November 1 (table 1). For 1966, 1967, and 1968 at both Roswell and Artesia the last spring frost occurred in late April or early May. This reduced the growing season by approximately two weeks. The first fall frost typically occurs about the first of November; however, during the three-year study period, the average was about two weeks early with the first frost occurring as early as September 28. The end result was a loss of approximately one month of growing season.

Other climatic hazards to agriculture in the area are high-velocity winds and droughts. The droughts cause drops in the recharge of water into underground aquifers and also increase the need for more frequent irrigations. Winds cause the soil to dry out more rapidly, and blowing soil may cause severe plant damage and losses in crop production. Crop damage in the area often results from severe rainstorms and hail. The hailstorms follow no predictable pattern and usually occur in localized areas.

Soils

The soils are alluvial in origin. Those on the uplands were developed from materials washed down from the Sacramento Mountains, while the soil mantle covering the flood plains has been transported by the Pecos River as sediments from the Permian formations on the upper drainage basin. Soils of this area are deep, highly calcareous loams and clay loams with a high content of fine sand, and are characterized by an almost structureless profile. They are usually low in organic matter, available phosphorous, and nitrogen. Predominant are the Reagan series on the uplands and the Reeves soils at lower benches. The major difference is in organic content, which is much higher in the Reagan soils. The Arno soils are the important series in the stream valleys (36, p. 4).

Irrigation Water Resources

There are two basic sources of diversion of irrigation water in the Roswell Artesian Basin--surface and ground. Surface water was first diverted for irrigation in the basin in the early 1870's from tributaries of the Pecos River, such as North Spring, South Spring, and Berrendo Creeks, which were fed by large artesian springs in the vicinity of Roswell. In the early 1900's, drilling of artesian wells for expanded irrigation reduced the artesian flow of the springs until it was no longer economically feasible to maintain the diversion ditches used to irrigate from these tributaries (2, p. 20). At present only about 5 percent of the irrigation water supply is from surface water sources. For the most part, this is diverted from the Pecos River or it is return flow resulting from loss during application of ground water.

The Hagerman Canal supplies a major portion of the surface water in the basin. It has been in use since 1879 and has a decreed right of 9,026 acres. The canal receives water from a combination of return flow from irrigation, water from the Berrendo Creek, North Spring, Rio Hondo, and South Spring Creeks, as well as supplemental water from four artesian wells, five shallow wells, and several tile drainage systems. In addition, 56 percent (5,055 acres) of the land irrigated from the Hagerman Canal receives supplemental water from other sources, principally shallow wells (21, p. 26).

An additional 3,760 acres have surface irrigation rights from the Pecos River. This water is diverted directly from the Pecos River by means of pumps.

Ground water pumped from wells supplies all municipal and industrial requirements and about 95 percent of the irrigation requirement in the basin. The principal water-yielding formations are the San Andres limestone (artesian aquifer), which is the deeper formation, and the Quarternary alluvium (shallow aquifer or valley fill). However, aquifers in the lower part of the Chalk Bluff formation in the southern part of the basin yield sufficient quantities of water for irrigation.

Geology and Hydrology

The geology of the underground water supplies as explained by Mower (21, p. 117--118) is summarized as follows. The Yeso, Glorieta, San Andres, and Chalk Bluff formations of the Permian Age, and the alluvial deposits (valley fill) of the Quarternary Age constitute the major geologic formations in the hydrologic regime of the basin. The Glorieta sandstone overlies the Yeso and underlies the San Andres and ranges from 15 to 90 feet thick. The Yeso formation is as thick as 2,100 feet and yields only small quantities of water that is probably highly saline. The San Andres formation overlies the Glorieta sandstone and ranges in thickness from 1,000 to 1,200 feet in the farming area. The depth to the top of the San Andres ranges from less than 400 feet northeast of Roswell to more than 1,200 feet near Lakewood. The Chalk Bluff formation overlies the San Andres and forms a semipermeable layer between the San Andres and the alluvium, except in the vicinity of Roswell and northward. There the valley fill lies directly on the San Andres formation. The alluvial deposits range in thickness from 0 to more than 350 feet with the thickest deposits occurring parallel to and approximately 4 miles west of the Pecos River. The alluvium forms the storage reservoir for the shallow ground water in the basin (figure 3).

About 60 percent of the ground water used for irrigation is diverted from the artesian aquifer (12). Artesian water in the northern part of the basin occurs in cracks, crevices, solution channels and cavernous zones, principally in the San Andres limestone. In the southern part of the basin the same type of openings in the San Andres and the lower part of the Chalk Bluff formation and its equivalent, the Grayburg formation, yield the artesian water (figure 3). The water is confined under pressure where the full section of the San Andres is saturated and dips beneath overlying confining beds of the Chalk Bluff formation. Water in the lower part of the artesian aquifer is saline south of Artesia because of poor circulation. A section of the artesian aquifer east and northeast of Roswell is saturated with saline water (20, p. 28).

Wells finished in the artesian aquifer range in depth from 300 to 1,200 feet. The average depth in the Roswell-East Grand Plains Area is about 600 feet and that in the Dexter-Hagerman Area is about 1,000 feet. Wells in the Artesia Area are deeper, and have a lower supply of water and a higher seasonal drawdown than those in areas to the north where the depth of artesian wells is about 1,050 feet (21). The pumping lifts range from 100 to 270 feet (20).

The specific yield from an artesian well varies with the transmissibility of the artesian aquifer. As explained by Mower (21, p. 81), "the transmissibility of the artesian aquifer is higher and more uniform between the recharge area and the northern part of the pumped

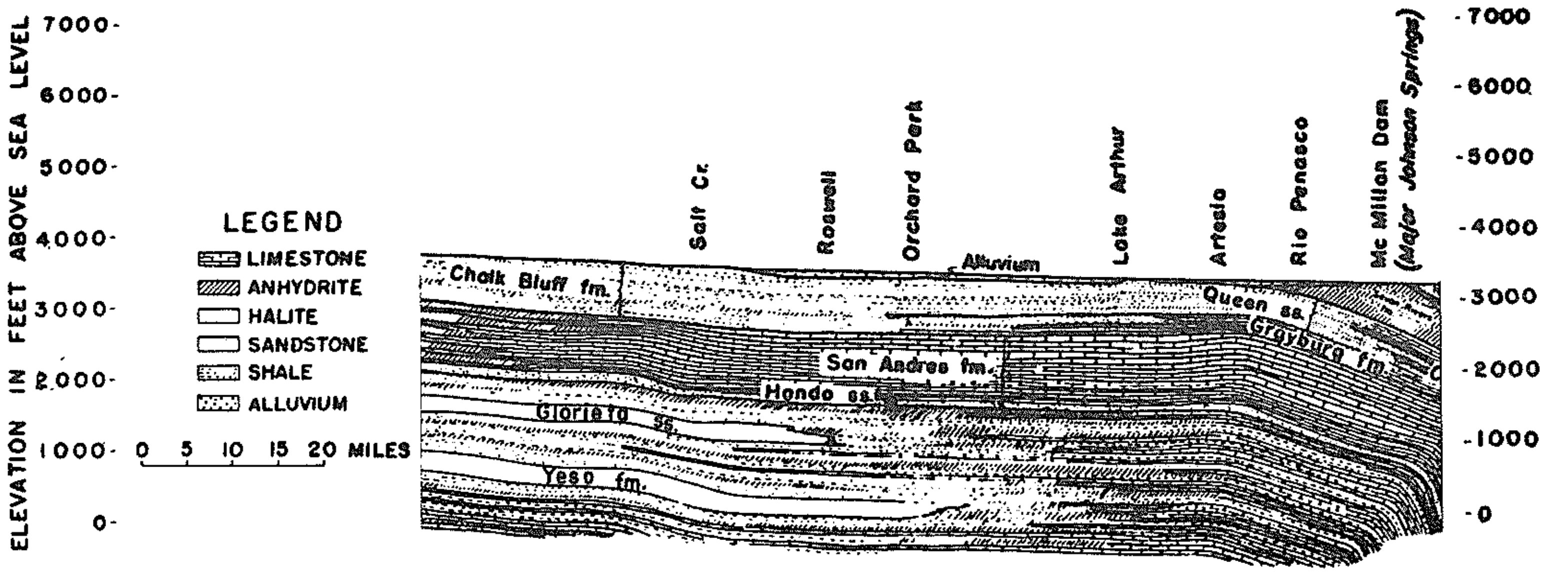
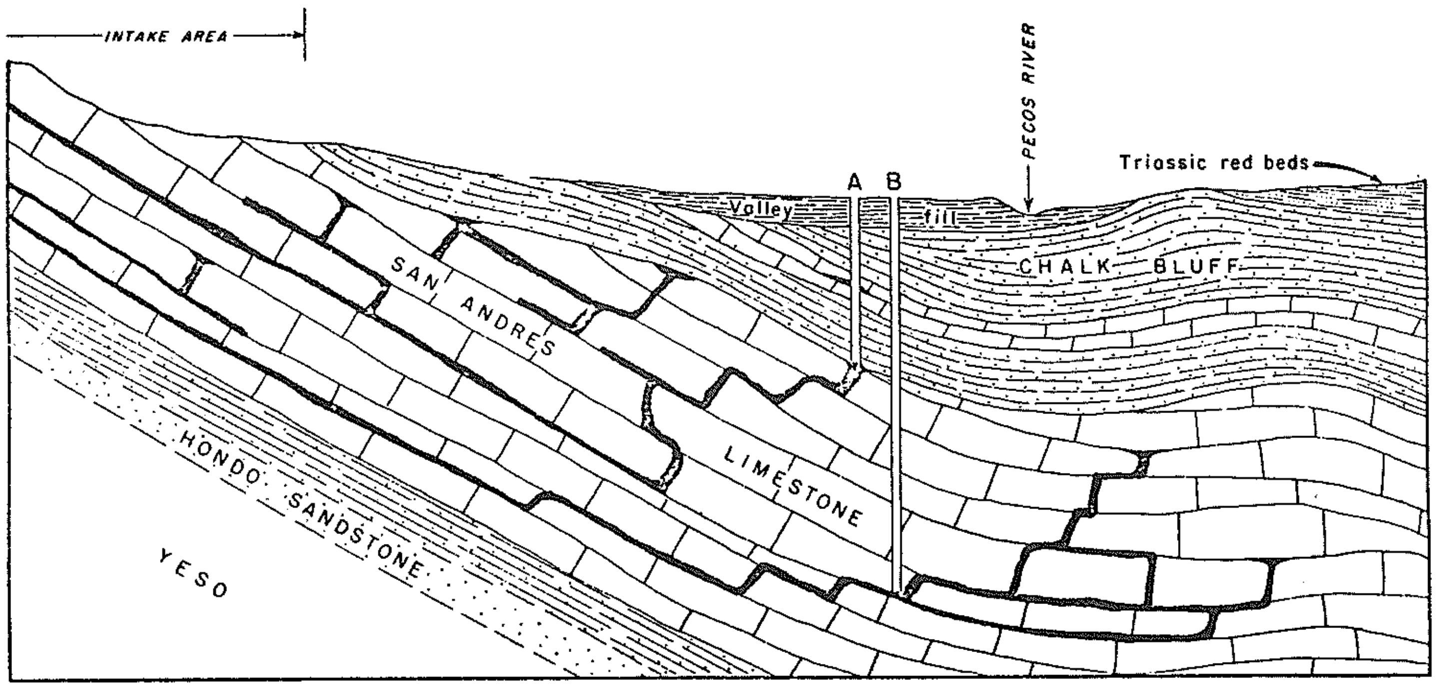


Figure 3. Geologic cross section along the Pecos River, Roswell Artesian Basin, New Mexico.

Source: National Resources Planning Board, Pecos River Joint Investigation, (Report of the Participating Agencies), Washington, D. C., June, 1942.



The abrupt change in ground-water conditions in the artesian aquifers within short distances is illustrated by the hypothetical wells at "A" and "B". The well at "A" encounters some artesian water in the Chalk Bluff formation where it intercepts a solution channel. On drilling deeper it encounters another cavernous zone in the San Andres Limestone which will probably supply more water at a greater pressure head.

Well "B" does not encounter a solution channel in the Chalk Bluff although it may obtain a small amount of water under a low head from joints or fractures in this formation. On passing into the San Andres Limestone it intercepts a solution channel which will probably yield an abundant supply of water at a high pressure head. Well "B" however encounters a solution channel at a lower horizon in the San Andres Limestone than does well "A" because of the unsystematic distribution of solution channels and cavernous zones in the formation.

Figure 4. Idealized section of artesian aquifer, Roswell Artesian Basin, New Mexico.

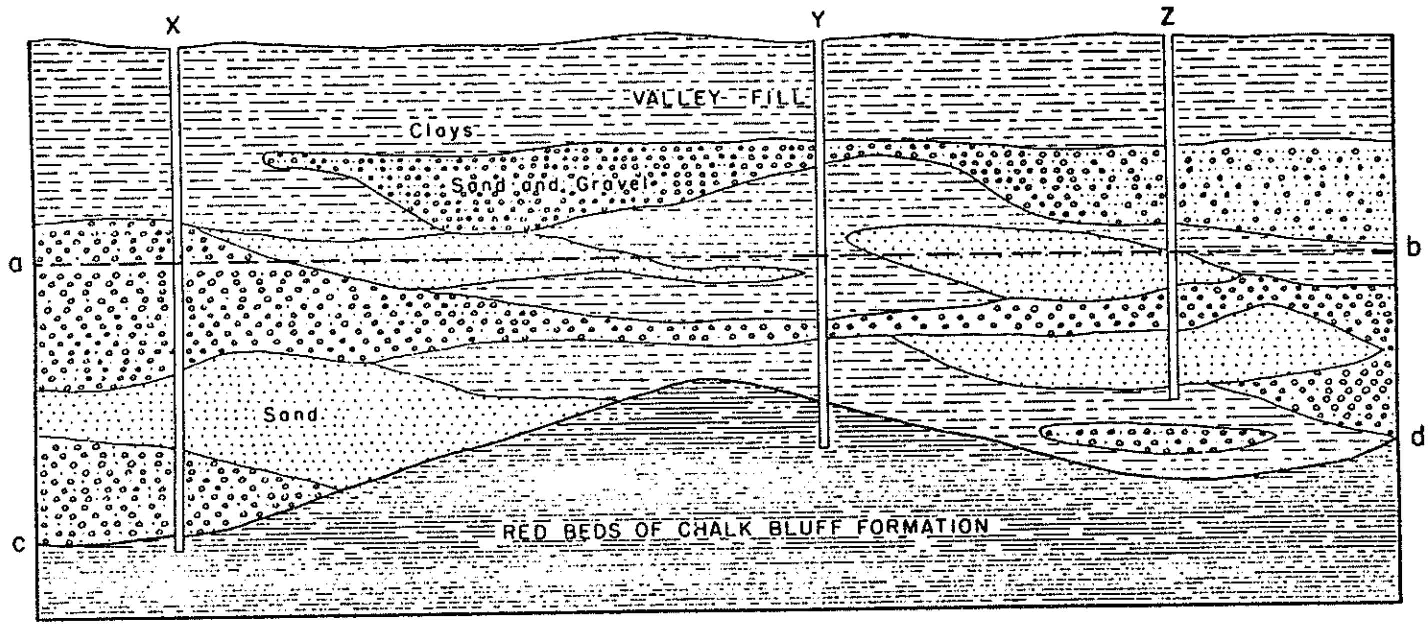
Source: National Resources Planning Board, Pecos River Joint Investigation, (Report of the Participating Agencies), Washington, D. C., June, 1942.

area than between the recharge area and the southern part of the pumped area. The solution cavities and channels are larger, better connected, and apparently more extensive in the vicinity of Roswell than elsewhere in the basin, and water moves from the recharge area to the wells near Roswell with relatively little loss of head." Mower also notes that a belt of closely spaced piezometric-surface contour lines extending southwestward from the vicinity of Lake Arthur, "probably indicates an area of relatively low transmissibility as compared with areas to the north and south. This belt of low transmissibility lies between much of the recharge area and the southern part of the basin, and acts as a partial barrier to the movement of water through the artesian aquifer system to wells in the southern part of the basin. Consequently, the rate of recharge to the artesian aquifer with relation to the rate of pumpage is less in the southern area than in the vicinity of Roswell."

Figure 4 shows an idealized section of the artesian aquifer and illustrates the reason for variation in depth of wells finished in this formation. Wells drilled in the artesian aquifer near Roswell have been tested at rates as high as 9,225 gallons per minute (gpm), but the average yield of such wells is usually considered to be between 2,000 and 3,000 gpm (20, p. 43).

About 40 percent of the ground water used for irrigation in the basin is pumped from the alluvium or shallow aquifer. Hood, et al. (13, p. 30) described the recharge into the aquifer as coming from five sources: 1) interformational leakage from the San Andres through the Chalk Bluff; 2) streamflow across the alluvium; 3) percolation losses from irrigated fields; 4) direct precipitation upon the alluvium; and 5) leakage from faulty artesian wells. The latter two are considered to be minor sources of recharge. In areas of concentrated pumping and low permeability of the aquifer, water level decline may be severe. A cone of depression forms in the water table around a discharging well. Grouping of wells causes these cones to intersect to form one large cone and continual water level decline exists (21, p. 85). In the Dexter-Hagerman Area such a continuation of decline has resulted in fairly large acreages of farm land going out of production due to the approaching exhaustion of economically recoverable water for irrigation.

Wells drilled in the shallow aquifer range from 84 to 440 feet deep, with an average depth of 217 feet. Pumping lifts average about 150 feet, and have an average yield of about 1,168 gpm (20, p. 43). This yield may be reduced as low as 100 gpm in areas of severe water table decline. Figure 5 shows the erratic character of the valley fill (shallow aquifer).



Erratic character and distribution of aquifers in the valley fill and variation in thickness of the valley fill is due to irregularities in the old erosion surface (c–d) upon which it was deposited. The abrupt change in ground-water conditions within short distances is shown by hypothetical wells at X, Y, and Z. A well at X encounters a large amount of coarse sand and gravel below the water table (a–b) and has a large yield. At Y there is little permeable material below the water table and a well there yields very little water. At Z there is considerable permeable material below the water table but not so much as at X.

Figure 5. Erratic character of valley fill (aquifer containing shallow ground water), Roswell Artesian Basin, New Mexico.

Source: National Resources Planning Board, Pecos River Joint Investigation, (Report of the Participating Agencies), Washington, D. C., June, 1942.

Water Quality

Quality of irrigation water is as important as the amount available for irrigation to some farmers in the Roswell Artesian Basin. When water of inferior quality is used for irrigation, crop selection is restricted either to salt-tolerant crops such as cotton and barley or to moderately salt-sensitive crops such as alfalfa and most vegetables, with frequent heavy irrigations (7, p. 98). In either case, certain inefficiencies may exist that directly affect income expectancies under such circumstances.

Irrigation Water Diversions

Prior to 1967 only estimates were available as to the amount of water diverted in the Roswell Artesian Basin. In 1967 the total metered water diverted was 397,618.3 acre-feet, of which 376,001.7 acre-feet were diverted from wells, and 21,616.8 acre-feet were diverted primarily from the Hagerman Canal (table 2).

Of the total of 376,001.7 acre-feet diverted from wells, 243,488.3 acre-feet were diverted from the artesian source and 132,513.4 acre-feet from the shallow source as classified by the Roswell Basin Watermaster. The diversion for irrigation purposes was 381,507.4 acre-feet; for municipal purposes, 14,528.3 acre-feet; and for commercial, industrial, and other sanitary and miscellaneous uses, 1,582.6 acre-feet.

In 1968, the total metered water diverted was 350,109.5 acre-feet, of which 327,753.0 acre-feet were diverted from wells and 22,356.5 acre-feet were in the form of surface water diverted primarily from the Hagerman Canal. The total diverted water for 1968 was 11.95 percent less than that diverted in 1967, which was the lowest diverted since 1946 compared with estimates of diversions for previous years. Of the total of 327,753.0 acre-feet diverted from wells, 213,285.7 acre-feet were diverted from the artesian source and 114,467.3 acre-feet from the shallow source as classified by the Roswell Basin Watermaster. The use for irrigation purposes was 334,902.1 acre-feet; for municipal purposes, was 13,596.3 acre-feet; and for commercial, industrial, and other sanitary, and miscellaneous uses, 1,611.1 acre-feet. Irrigation diversion accounted for 95.5 percent of the total diversion.

Table 2. Tabulation of water diverted by areas, Roswell Artesian Basin, New Mexico, 1967 and 1968.

Area	1967[1] Diversion by Sources[2] Surface (ac.-ft.)	1967 Shallow (ac.-ft.)	1967 Artesian (ac.-ft.)	1967 All Source (ac.-ft.)	1967 Water-Right Acres (acres)	1967 Average Diversion per Acre (ac.-ft.)	1968 Diversion by Sources[2] Surface[3] (ac.-ft.)	1968 Shallow[4] (ac.-ft.)	1968 Artesian[4] (ac.-ft.)	1968 All Source (ac.-ft.)	1968 Water-Right Acres (acres)	1968 Average Diversion per Acre (ac.-ft.)
Northern Extension	221.8	984.6	19,839.1	21,045.5	10,610	1.98	311.5	761.3	16,996.5	18,069.3	10,810	1.67
Roswell-East Grand Plains	719.8	27,083.9	70,364.9	98,168.6	36,930	2.66	271.8	24,167.7	63,442.1	87,881.6	37,400	2.35
Dexter-Hagerman	18,212.4	51,342.2	47,758.1	117,312.7	41,560	2.83	19,323.3	44,689.9	36,924.0	100,937.2	40,080	2.52
Cottonwood	2,461.8	23,860.9	46,860.2	73,182.9	22,220	3.29	2,449.9	19,136.3	42,575.5	64,161.7	22,710	2.83
Artesia	.8	21,708.1	36,361.9	58,070.8	18,510	3.14	---	19,031.0	33,595.5	52,626.5	18,970	2.77
Lakewood-Seven Rivers	---	7,324.9	6,402.0	13,726.9	4,010	3.42	---	6,343.8	4,882.0	11,225.8	4,010	2.80
Total for basin[5]	21,616.6	132,304.6	227,586.2	381,507.4	133,840	2.85	22,356.5	114,130.0	198,415.6	334,902.1	133,980	2.50
Additional Diversion												
Municipal		15.5	14,512.8	14,528.3				203.5	13,392.8	13,596.3		
Commercial and Industrial		193.3	1,389.3	1,582.6				133.8	1,477.3	1,611.1		
Total	21,616.6	132,513.4	243,488.3	397,618.3			22,356.5	114,467.3	213,285.7	350,109.5		

1. Garnett, Edwin T., "Economic Classification of the Irrigated Cropland in the Roswell Artesian Basin, New Mexico," (Unpublished Master's Dissertation, Department of Agricultural Economics and Agricultural Business, New Mexico State University, 1968), 171 pp.
2. Sources classified by adjudication and analysis.
3. Banta, E. H., Tabulation of Water Diverted, Pecos Valley Surface Water District, (Memorandum Report to S. E. Reynolds), New Mexico State Engineer Office, Santa Fe, New Mexico, 1968, 4 pp.
4. Henninghausen, Fred H., and Wayne K. L. Lampert, Metered Use of Water in the Roswell Basin for 1967, 1968, (Memorandum Reports to S. E. Reynolds, State Engineer Office, Santa Fe, New Mexico, February 16, 1968, and February 4, 1969, 4 pp. each.
5. Does not include Upper Rio Felix Area.

PROCEDURES

In the spring of 1966 ten case-study farms were selected following a visit to each farm. In 1967 two additional case-study farms were selected by the principal investigators to make the sample more representative of all farms in the basin with respect to type of farming enterprise. Farms were selected by the project research group with the assistance of the county agricultural agent and Soil Conservation Service personnel in both Chaves and Eddy Counties, using the following criteria:

1. Willingness of the farmer to keep the necessary records.
2. Irrigation water quality and quantity.
3. Type of crops grown.
4. Type of irrigation systems.
5. Soil type.
6. Geographic location.

Three farms were selected in Eddy County and nine farms were selected in Chaves County. Each of these farms was selected from a different geographic location in the basin. One farm was located in the Northern Extension, four were in the Roswell-East Grand Plains Area, three in the Dexter-Hagerman Area, one in the Cottonwood Area, and three in the Artesia Area. No farm was selected in the Lakewood-Seven Rivers Area (figure 2). The major reasons for the selection of particular case farms were:

Case Farm A - All irrigation ditches were earthen and there was a slowly permeable silty soil.

Case Farm B - Much of the irrigation conveyance system consisted of underground pipeline or concrete-lined ditch and the farm was located near Case Farm C in a salt-water encroachment area.

Case Farm C - The irrigation water was high in salinity.

Case Farm D - A cattle feedlot operation was on the farm, much of the cropland was unleveled, and there was a reported history of high irrigation water diversion.

Case Farm E - There was a grain sorghum enterprise on the farm and good-quality irrigation water.

Case Farm F - A relatively low quantity of irrigation water had historically been pumped on the farm.

Case Farm G - There was a low volume of irrigation water pumpage, and most of the irrigation ditches were earthen.

Case Farm H - There were no underground water rights on the farm (all irrigation water was pumped from the Pecos River).

Case Farm I - The irrigation conveyance system consisted almost entirely of underground pipeline.

Case Farm J - Unusually short lengths of irrigation water run for alfalfa fields on the farm.

Case Farm K - About one-half of the irrigation conveyance system was concrete-lined and the other half earthen, and the cropland was not leveled.

Case Farm L - A reservoir was not included in the irrigation system.

Nature of the Sample

The 12 farms do not, of course, represent a random sample of farms in the Roswell Artesian Basin. Therefore statistical inferences made concerning relationships of these farms to the whole basin cannot be made without qualification.

However, in comparing the 12 case-study farms with the basin they appeared to be typical of the basin (table 3). The average cropping program and irrigation water use for the 12 case-study farms was apparently representative of the average for all farms in the Roswell Artesian Basin, the major difference in 1967 being in the production of alfalfa and forage sorghums (table 3). Alfalfa was produced on 6.2 percent more cultivated acres for all farms in the basin than was produced on the 12 case farms. Forage sorghums, however, were produced on 4.1 percent more cultivated acres on the case-study farms than on all farms in the basin.

In 1967 the average irrigation water use for the Roswell Artesian Basin was about the same as the average irrigation water use on the 12 case-study farms (table 3). The average irrigation water use for the basin included 2.85 acre-feet per water-right acre, 3.13 acre-feet per cultivated acre, and 3.58 acre-feet per cropped acre. The average irrigation water use for the 12 case-study farms included 3.05 acre-feet per water-right acre, 3.08 acre-feet per cultivated acre, and 3.69 acre-feet per cropped acre (table 3) (9). The lower per-water-right-acre irrigation water diversion in the basin resulted primarily from a greater percentage of the total water-right acreage in the basin being out of production compared with the 12 case-study farms.

Table 3. Comparison of land and irrigation water diversion between the Roswell Artesian Basin and the case-study farms, 1967.

Item	Roswell Artesian Basin[1]	Twelve Case-Study Farms[2]
Land Use	Percent	Percent
Cotton	25.4	26.4
Alfalfa	43.4	37.2
Grain sorghum	3.8	3.8
Small grains	7.0	8.6
Forage	5.4	9.5
Fallow and diverted	12.1	14.5
Other[3]	2.9	0.0
Total	100.0	100.0
Irrigation Water Use	Acre-feet	Acre-feet
Per water-right acre	2.85	3.05
Per cultivated acre	3.13	3.08
Per cropped acre	3.58	3.69

1. Source: Garnett, Edwin T., "Economic Classification of the Irrigated Cropland in the Roswell Artesian Basin, New Mexico," (Unpublished Master's Thesis, Department of Agricultural Economics and Agricultural Business, New Mexico State University, 1968), 171 pp.
2. Source: Simpkins, Arthur R., "An Economic Analysis of Irrigation Water Requirements for Crop Production in the Roswell Artesian Basin, New Mexico," (Unpublished Master's Thesis, Department of Agricultural Economics and Agricultural Business, New Mexico State University, 1968), 205 pp.
3. Includes pasture, pecans, fruits and vegetables, castor beans, and soybeans.

Case-Study Method

The case-study method was designed to obtain information on production requirements, costs, and returns on individual study farms. This method was selected primarily because so few farmers had detailed records on irrigation water diversion for the different crops grown in the Roswell Artesian Basin.

The type of records to be kept were determined and forms were designed to obtain the needed information on physical requirements, costs, and returns for each crop grown on individual study farms. Record forms were then delivered to the farm cooperators and details of the various entries were explained. The record of irrigation water diversion for each case farm crop was to be completed by the farmer after each irrigation and mailed to the Southeastern Branch Station, where the records were compiled and tabulated in 1966 and 1967. During 1968 the irrigation records were sent to the Department of Agricultural Economics and Agricultural Business at New Mexico State University for compilation and tabulation. The records of other physical requirements, as well as costs and returns data, were maintained by the farmer cooperator.

Several personal visits were made to each farm during each year to insure that all records were kept up to date. All farmer cooperator records were assembled at the end of the year and summarized. Ten farmers agreed to participate in the study for the 1966 crop year, 12 farmers in 1967, and 10 for the 1968 crop year. One of the original 10 farms changed management at the end of the 1967 crop year, and the new farmer did not want to cooperate in the study. Another of the original 10 farms was also dropped on the desire of the farmer. Results are reported for three years on eight farms and for two years on four farms.

Irrigation Water Quality

For purposes of this study irrigation water has been categorized into three classes based on total soluble salts (18):

Class 1 - EC X 10^6 of less 750 millimhos. Water of this class is suitable for use for most crops under most conditions.

Class 2 - EC X 10^6 between 750 to 2,250 millimhos. Water of this class can be used with good management and favorable soil drainage conditions for most crops if care is taken to prevent accumulation of soluble salts.

Class 3 - EC X 10^6 greater than 2,250 millimhos. Water of this class is generally unsatisfactory for crop production. It may be used as a supplemental source of water if the primary source of water is of Class 1 or 2.

Irrigation Efficiency

Farm irrigation efficiency is used as a measure of efficiency in this report. Irrigation efficiency was determined by dividing the consumptive irrigation requirement as calculated by Barnes (2) by the amount of irrigation water pumped per crop. The typical irrigation efficiencies by crops are reported for each case study in a later section and for the individual crops by years in appendix C.

Budgeting

Both enterprise and whole farm budgets were employed in the analysis of each case farm studied. Enterprise budgets were used in preparing whole farm budgets and in the derivation of coefficients for a linear programming model. Whole farm budgets were computed for individual farms to compare with results of linear programming solutions to determine the economic effect of restricting the diversion of irrigation water at seven different levels.

Procedures in preparing enterprise budgets for each case-study farm involved the following five steps:

1. Determining the cultural and harvest operations involved.

2. Determining the physical quantities per acre for all inputs, including services such as labor and machinery hours, plus seed, fertilizer, irrigation water, and other materials.

3. Determining per-acre yields.

4. Applying relevant cost rates and prices to express all per-acre inputs and yields in monetary values.

5. Summing fixed and variable costs, and subtracting from gross returns in order to obtain net returns per acre to land and management for each crop.

Labor

Labor cost was determined by using the same assumed wage rate for each case farm studied. No price distinction was made between operator labor and hired labor. Labor cost for equipment operation and service was assumed to be $1.25 per hour, with irrigation and hoeing labor assumed at $1.15 per hour.

Machinery Operation

Except for the variable expenses of labor, all variable costs, as well as the fixed costs of machinery operation, were computed through the adjustment of secondary data developed by Dawson (5). Ten percent of the total labor hours per acre for any cultural or harvesting operation was assumed to be the time required for machinery service. Thus the actual machinery cost for an operation was obtained by decreasing the labor hours per acre by 10 percent and multiplying the result times the values from the secondary source for the fixed and variable cost per hour of operation for the machine(s) involved.

Other costs computed from secondary data included those of irrigation water and of lining irrigation ditches (19, 10).

Materials and Services

Costs of materials and services used in the production and harvesting of crop enterprises were obtained from the farmer cooperators.

Product Prices

Product prices used in the computation of both enterprise and whole-farm budgets are presented in table 4. These prices are assumed to represent the average prices received on each case farm during the three-year period. In arriving at these prices, no attempt was made to segregate grades received.

Alfalfa Hay

Alfalfa hay is normally established during the fall of the year and remains in production for the next five years. The enterprise budgets for alfalfa include a pro-rated cost of establishment at $8 per acre for all farms.

The alfalfa hay yield for the first year of the five-year production period is normally low. The hay yields on each farm were adjusted to allow for the low yield in the first production year. This was accomplished through the use of a weighted average. An estimate of the alfalfa hay yield for the first year of production was obtained from each of the cooperators and averaged with the actual yield for the four other years. The per-acre water diversion for alfalfa hay was assumed to be the amount that would be diverted for each of the five production years divided by five. All alfalfa hay was assumed to be sold in the field.

Grain Sorghum

Three of the 12 farms studied had grain sorghum enterprises; however, under current commodity programs none of the case farms was eligible for government support payments for grain sorghum. Government support payments were not included in the grain sorghum enterprise budgets.

Castor Beans

Although castor beans were not produced on any of the case farms, they were budgeted as an alternative enterprise. Budgets were computed under the assumption that castor beans were solid-planted with a base yield of 2,800 pounds. Input-output data for these budgets were obtained from a study conducted by Lansford in 1967 (17).

Table 4. Product prices used in preparing crop enterprise and whole farm budgets on case study farms, Roswell Artesian Basin, New Mexico.

Item	Units	Price 1966 (dollars)	1967 (dollars)	1968 (dollars)	Typical (dollars)
Cotton					
Lint	lb.	0.30	0.34	0.25	0.30
Seed	ton	60.00	60.00	72.00	72.00
Price support payment	lb.	0.0942	0.1153	0.1224	0.1106
Diversion payment	lb.	0.1050	0.1078	0.1076	0.1070
Alfalfa					
Baled hay	ton	25.00	28.00	25.00	25.00
Hay sold in windrow	ton	23.00	23.00	23.00	23.00
Seed	lb.	0.50	0.75	0.90	0.75
Pasture	a.u.m.[1]	2.70	2.70	2.70	2.70
Barley					
Hay	ton	23.00	23.00	23.00	23.00
Seed	bu.	0.90	1.00	0.90	0.95
Sorghum					
Grain	cwt.	1.80	1.80	1.90	1.80
Silage[2]	ton	7.20	7.20	7.20	7.20
Corn					
Silage[2]	ton	7.20	7.20	7.20	7.20
Hegari[3]	ton	4.50	4.50	4.50	4.50
Sudex[3]	ton	4.00	4.00	4.00	4.00
Oats					
Hay	ton	20.00	20.00	20.00	20.00
Seed (certified)	cwt.	7.50	7.50	7.50	7.50
Grain	cwt.	4.40	4.40	4.40	4.40

1. Animal unit month (a.u.m.) is defined as the amount of forage that will support a cow and her calf, or animal equivalents, for one month.
2. Delivered to pit.
3. Sold standing in field.

Linear Programming Model

A parametric linear programming model was used in this study to analyze the effects of different quantities of irrigation water on the net farm return of 12 case farms. This method was selected rather than the budgeting technique because an electronic computer was available to accomplish the large number of calculations involved in such an analysis. All linear programming problems were solved on an International Business Machines Corporation (IBM) 1130 computer at New Mexico State University. The computer program was written by IBM (14).

Mathematical Model

$$Z = \Sigma aijXi + Qt$$

subject to the following constraints

$$\Sigma a_1 jX_1 \leq L$$

$$\Sigma a_2 jX_2 \leq C$$

$$\Sigma a_3 jX_3 \leq W$$

and in Model C

$$\Sigma a_4 jX_4 \geq A$$

Where: Z = net farm return to land and management

aij is a coefficient (constant) for the "i"th row and "j"th column

Xi is the "i" crop enterprise

Q is a constant vector

t is the changeable irrigation water parameter equal to 2.50, 2.75, 3.00, 3.25, 3.50, 3.75, and 4.00 acre-feet per acre respectively

L is the water-right acres in a given case farm

C is the cotton allotment associated with each case farm

W is the irrigation water restriction

A is a minimum restriction of about one-third of the water-right acres producing alfalfa

The parametric programming program used in this study may print out any or all of the following: the values of t at basis where changes occur, the new basic set at each change, the optional levels of the basic and dual variable at each change, and the rate of change of each basic variable (with respect to t) between the current t and its value at the next basic change.

Three linear programming models were developed for each case farm studied. These models were developed to ascertain the effect of seven different quantities of irrigation water on the net farm return to land and management of each case farm under two levels of irrigation water efficiency. Coefficients for the equations used in the programming models were derived from enterprise budgets of individual case farms and from secondary data. All coefficients, except those for cotton and alfalfa, were taken directly from the enterprise budgets.

The size of each case farm was restricted to the farm's adjudicated water-rights acreage. However, it should be noted that because of fences, ditches, turnrows, and the like, the total acres on which crops were planted is smaller than the water-rights acreage. As there was only a slight difference on the case farms studied, no allownaces were made for the actual acres of cropland. Provisions for crop rotation were not included in models A and B, but model C included a crop rotation program with a minimum of approximately 30 to 33 percent alfalfa. Thus, for each farm the solutions for models A and B represent the maximum annual net farm return that could be obtained from each of the seven quantities of irrigation water based on production requirements, costs, and returns for each crop used in this study.

The coefficients for the net returns and water use per acre of cotton allotment for each case farm varied with the different diversion levels of the Upland Cotton Program (34). Three cotton diversion plans were included in the programming models of a case farm, to comply with the assumption of constant parameters in the linear programming model. These plans were designated in the tables for linear programming solutions as cotton (65%), cotton (80%), and cotton (95%). The plans correspond to the 35 and 20 percent diversion plans of the 1966 and 1967 Upland Cotton Program, respectively. Each plan assumes that a small part of the diverted cotton acreage was included in the acreage for ditches and turnrows of planted cotton. Government payments for all three plans were based on an average of the 1966, 1967, and 1968 Upland Cotton Programs (34).

The quantities of irrigation water considered in the models were 2.50, 2.75, 3.00, 3.25, 3.50, 3.75, and 4.00 acre-feet per acre, times the adjudicated water-rights acreage of the individual case farm. The irrigation water efficiency levels were 1) the actual measured efficiencies, and 2) an overall increase in irrigation efficiency of 5 percent.

The coefficient for water use per acre of cotton allotment was obtained by averaging the water use per acre of planted cotton allotment with an assumed zero water use per acre of diverted cotton allotment.

The coefficients for the net returns and water use per acre for alfalfa hay (A), alfalfa hay and pasture (B), were taken directly from the enterprise budgets for each case farm. Alternative alfalfa hay enterprises, alfalfa hay (C) and alfalfa hay (D), were included in the programming models for all of the case farms The coefficients for alfalfa C and D were derived from data developed by Barnes (3) and Dregne (9) The alfalfa hay (C) enterprise diverted 5.33 acre-feet of irrigation water per acre and the alfalfa hay (D) enterprise diverted 6 00 acre-feet per acre in models A and C and 5.06 and 5.70 acre-feet per acre respectively in model B.

Other alternative crop enterprises were included in the programming models for almost all case farms studied. The coefficients for the alternative enterprises were obtained either from adjusted budgets for other case farms with similar economic and agronomic characteristics, or from secondary data. The crops considered in the models for all farms are reported in appendix B.

The solutions from the linear programming problems also provide estimates of the marginal value products (shallow prices) for irrigation water. These values are the amount by which net farm return to land and management would change as a result of an increase in irrigation water by one acre-foot. Maximum profit for a farm is attained when the marginal value product or shallow price is equal to the marginal or added factor cost of pumping an additional acre-foot of irrigation water.

CASE FARM A

GENERAL DESCRIPTION

Case Farm A was a rented farm with 232.0 acres of artesian water rights. This farm was part of a 740-acre farming operation located in the Northern Extension (figure 2).

Soils

The major soils on Case Farm A were Reagan Silty Clay Loam, comprising about 81.6 percent of the irrigated cropland, and Unnamed Silt Loam comprising the remaining 18.4 percent. The location of the soils is shown in figure 6. Both soils were SCS Capability Class II and are further described in appendix A.

Irrigation Water

Case Farm A had one artesian well, producing about 1,072 gallons per minute. The irrigation well was developed to approximately 700 feet, but had a pumping lift of less than 200 feet. Average total soluble salt content of the water from this well was 3,580 millimhos and the average sodium adsorption ratio was about 5.90 for the three year period (2). The quality classification of this water was Class 3.

Irrigation System

The artesian well on Farm A was pumped directly into a reservoir. This reservoir had three outlets which drained into a total of approximately 21,120 feet of earthen primary and secondary lateral ditches (figure 6).

Almost all of the cropland on Farm A sloped less than 1 percent. However, 25.4 acres of Farm A could not be irrigated with the existing irrigation system because this acreage lay at a higher elevation than the reservoir. The irrigable cropland on Farm A had been reduced to 206.6 acres. The 25.4 acres that could not be irrigated are shown as land out of production in figure 6. The approximate length of irrigation water runs for the different fields is reported in table 5. Borders were employed in the irrigation of all alfalfa fields.

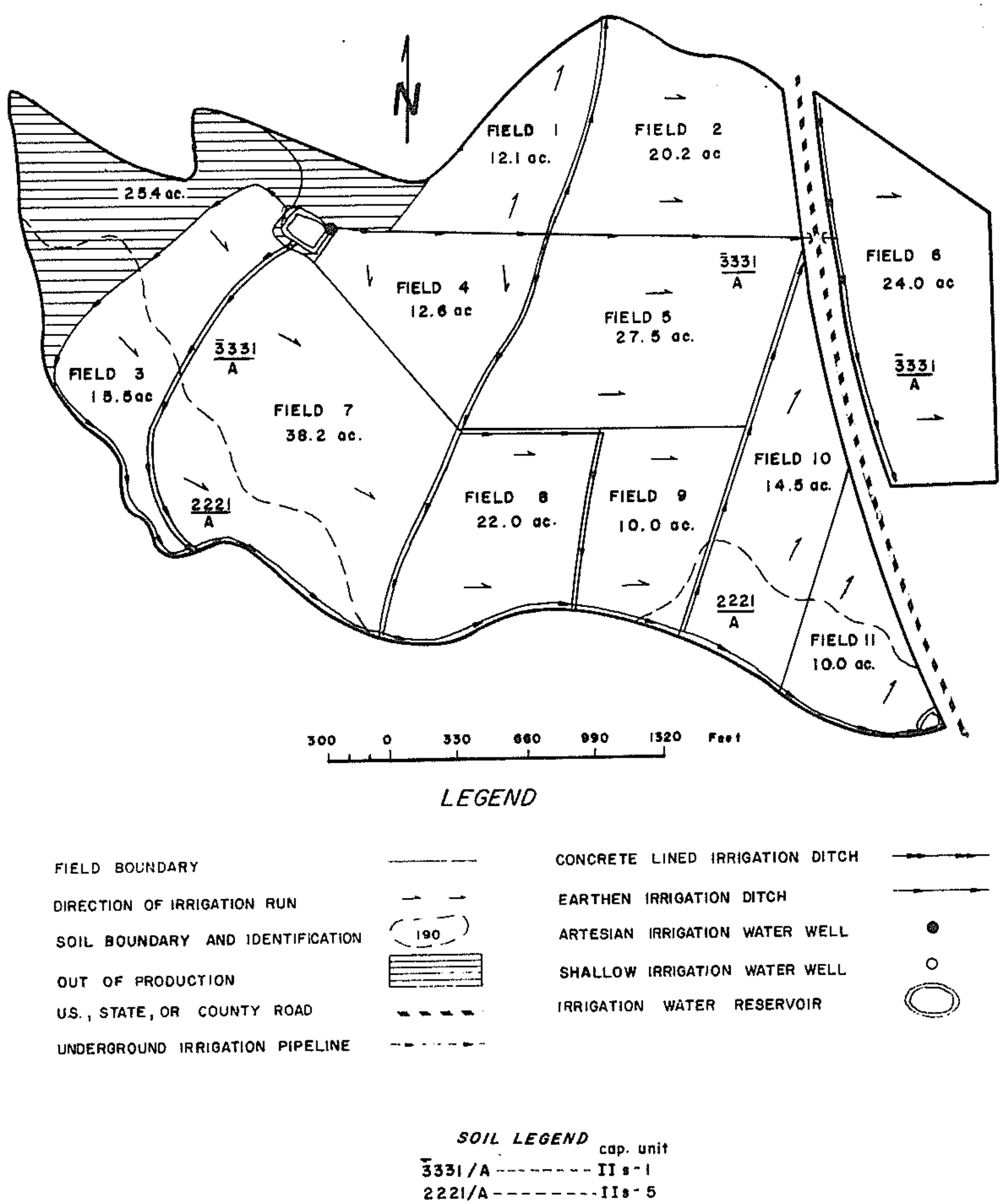


Figure 6. Map of Case Farm A.

Table 5. Case Farm A: Crops planted and approximate lengths of irrigation water runs by fields, Roswell Artesian Basin, New Mexico.

Field Number	Crop Planted 1966	1967	1968	Length of Run (feet)
1	Barley Diverted Barley	Cotton	Cotton	320-1,050
2	Barley Diverted Barley	Cotton	Cotton Diverted Barley	320-1,190
3	Alfalfa	Alfalfa	Alfalfa	370- 580
4	Barley Diverted Barley	Diverted Alfalfa	Alfalfa	420- 800
5	Cotton	Cotton	Cotton	1,190-1,370
6	Alfalfa	Alfalfa	Alfalfa	260- 720
7	Cotton Diverted	Cotton	Cotton Diverted Barley	1,240-1,480
8	Cotton	Diverted Barley	Cotton	690- 790
9	Cotton	Diverted Alfalfa	Alfalfa	530- 660
10	Alfalfa	Alfalfa	Alfalfa	1,056-1,640
11	Alfalfa	Alfalfa	Alfalfa	260-1,056

Crops Produced

The crops produced on Case Farm A were cotton, alfalfa, and barley for the three years. The farm had a 136.9-acre cotton allotment in 1966, and a 140-acre allotment in 1967 and 1968. The reason for the unusually large cotton allotment was consolidation of the cotton allotment from another farm with this one. Under provisions of the Government Upland Cotton Program, 65 percent of the cotton allotment was planted in 1966 and 1967, and 95 percent of the allotment was planted in 1968. However, in 1968 approximately 20 acres of the cotton allotment were moved to another farm. Cotton yield per acre was 805, 865, and 450 pounds for 1966, 1967, and 1968, respectively (table 6). Projected cotton yields by ASC for the three years were 910, 935, and 905 pounds, respectively.

Table 6. Case Farm A: Crops and yields per acre, Roswell Artesian Basin, New Mexico.

Crops	Unit	Yield per Acre 1966	1967	1968	Average
Cotton planted					
Lint	lb.	805.00	865.00	450.80	706.90
Seed	ton	0.60	0.64	0.37	0.54
Alfalfa					
Hay	ton	3.9	3.1	6.0	4.33
Pasture	a.u.m.	15.0	16.67	2.0	11.22
Barley					
Pasture	a.u.m.	12.0	12.0	4.0	9.33

The acreage planted to each crop by years is reported in table 7. Alfalfa was produced on 64.0 acres in 1966, and 86.6 acres in 1967 and 1968 (table 7). In 1966, 10.0 acres of the 64.0 acres were seeded in the fall (field 11), and 22.6 acres were fall planted in 1967 (fields 4 and 9). Alfalfa was used partially as pasture in 1966 and 1967, and to lesser extent in 1968. Yields were adjusted to allow for the lower yield that is obtained in the first year of the assumed five-year production period. Barley was produced primarily as pasture and cover crop for alfalfa.

Irrigation Water Pumped

Pumpage for the three years 1966, 1967, and 1968 was 634.65, 648.34, and 731.70 acre-feet, respectively (table 7). Diversions per acre remained fairly stable for the three-year period at 2.74, 2.79, and 3.15 acre-feet respectively. The average per-acre diversion for cotton for the three-year period was 2.55 acre-feet per acre. Alfalfa received an average of 5.24 acre-feet per acre on the established stand. The seedling alfalfa received an average of 1.28 acre-feet per acre. The barley received an average of 1.04 acre-feet per acre.

Table 4. Case Farm A: Crop acreages and irrigation water pumpage, Roswell Artesian Basin, New Mexico

	Acres				Irrigation Water Pumped							
					Per Crop				Per Acre			
Crop	1966	1967	1968	Average	1966	1967	1968	Average	1966	1967	1968	Average
					(acre-feet)				(acre-feet)			
Cotton	94.7	98.0	115.0	102.6	225.69	331.10	228.15	261.65	2.38	3.64	1.93	2.55
Diverted	47.9	44.6	5.0	32.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alfalfa	54.0	64.0	86.6	68.2	299.16	272.64	500.55	357.45	5.54	4.26	5.78	5.24
Seedling alfalfa	10.0[1]	22.6[2]	0.0	10.9[3]	42.00	22.60	0.00	21.53	4.20	1.00	0.00	1.28
Barley[2]	44.9	22.0	5.0	24.0	67.80	22.00	3.00	30.93	1.51	1.00	0.60	1.04
Out of production	25.4	25.4	25.4	25.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	232.0	232.0	232.0	232.0	634.65	648.34	731.70	671.56	2.74	2.79	3.15	2.89

1. Spring planted.
2. Not included in total acreage, was diverted acreage.
3. Not included in total, 7.6 acres.

In 1967 the average quantity of irrigation water diverted on Case Farm A was higher than the average quantity of irrigation water used on farms in the Northern Extension of the Roswell Artesian Basin. The average irrigation water diversion on Case Farm A included 2.79 acre-feet per water-right acre, 3.14 acre-feet per cultivated acre, and 4.00 acre-feet per cropped acre. The average irrigation water diversion for all farms in the Northern Extension was 1.98 acre-feet per water-right acre, 2.67 acre-feet per cultivated acre, and 3.79 acre-feet per cropped acre (10, p. 130). In 1968 the average irrigation water diversion was 3.15 acre-feet per water-right acre, 1.48 acre-feet per acre more than the average for the Northern Extension (12).

Irrigation Efficiency

The typical irrigation water efficiency by crops is reported in table 8 and yearly estimates in table C1. Irrigation efficiency on cotton ranged from 44.30 to 79.10 with an average of 59.12 percent; on alfalfa from 38.54 to 60.64 with an average of 47.03 percent; on barley from 110.70 to 187.50 with an average of 118.97 percent (table C1).

Table 8. Case Farm A: Typical consumptive irrigation requirement, irrigation water applied, and farm irrigation efficiency.

Crop	Consumptive Irrigation Requirement (acre-inches)	Irrigation Water Applied (acre-inches)	Farm Irrigation Efficiency (percent)
Cotton	18.80	31.80	59.12
Alfalfa	29.31	62.32	47.03
Barley	14.80	12.44	118.97

ECONOMIC ANALYSIS

Financial Summary

The typical per-acre net returns by crops are reported in table 9. The yearly per-acre net returns to land and management are reported in table D1. The net farm return for the three years was $27,192.34, $32,492.93, and $20,076.55, respectively (table E1). (As used hereafter, the term "net farm return" is synonymous with "net farm return to land and management.") Primary reasons for the large variations in net returns were the favorable prices and yields for cotton and alfalfa in 1967, and the unfavorable price and yield for cotton in 1968 (table 9).

Table 9. Case Farm A: Typical per-acre returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns per Acre (dollars)	Gross Expenses per Acre (dollars)	Net Returns to Land and Management per Acre (dollars)
Cotton planted	347.86	156.85	191.01
Cotton diverted	97.91	13.06	84.85
Alfalfa	141.74	84.53	57.21
Barley	25.20	24.52	.68
Weighted average	212.80	99.88	112.92

Because of these wide variations in yields, prices, acreage, and net farm returns, a typical whole farm budget was computed using typical yields, prices, acreage, and costs (table 10). This typical whole farm budget will be used to compare with the linear programming solutions to determine the effect of different levels of irrigation water diversion on net farm returns. The annual whole farm budgets are presented in appendix E (table E1).

Table 10. Case Farm A: Typical whole farm returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
Cotton planted	102.6	35,690.44	16,092.81	19,597.63
Cotton diverted	32.5	3,182.08	424.45	2,757.63
Alfalfa	79.1	11,211.63	6,686.32	4,525.31
Barley	24.0	604.80	588.48	16.32
Total	238.2	50,688.95	23,792.06	26,896.89

Linear Programming Solutions--Model A

The coefficients and constraints for model A are presented below:

$1X_1 + 1X_2 + 1X_3 + 1X_4 + 1X_5 + 1X_6 + 1X_7 + 1X_8 + 1X_9 \leq 232.0$ acres

$1X_1 + 1X_2 + 1X_3 + 0X_4 + 0X_5 + 0X_6 + 0X_7 + 0X_8 + 0X_9 \leq 140$ acres of cotton

$1.66X_1 + 2.04X_2 + 2.42X_3 + 4.71X_4 + 5.24X_5 + 5.33X_6 + 6.00X_7 + 2.56X_8$

$+ 1.04X_9 \leq 580$ acre-feet of irrigation water

The X variables are identified in table 11.

The parameter changes in irrigation water diversion (Qt), where Q = 580.0 acre-feet of irrigation water and t = 58.0 acre-feet, result in the following irrigation water constraints:

2.75 acre-feet per water-right acre = 638.0 acre-feet
3.00 acre-feet per water-right acre = 696.0 acre-feet
3.25 acre-feet per water-right acre = 754.0 acre-feet
3.50 acre-feet per water-right acre = 812.0 acre-feet
3.75 acre-feet per water-right acre = 870.0 acre-feet
4.00 acre-feet per water-right acre = 928.0 acre-feet

In table 11 the whole farm budget for the typical crop year is compared with the results of model A. The linear programming solutions presented in table 11 indicate the optimal net farm returns and the combinations of the nine crops that would be produced if there were no assumed crop rotation program on Case Farm A.

In table 11 the net farm return obtained from the linear programming solutions is also contrasted with $26,896.89, which was obtained from the typical crop year with 671.56 acre-feet of irrigation water (2.89 acre-feet per water-right acre). The net farm return for the typical crop year would have been increased about 10 percent with the combination of crop enterprises that is indicated in model A with 2.50 acre-feet of irrigation water; about 12 percent with 2.75 acre-feet; about 14 percent with 3.00 acre-feet; and about 15 percent with 3.25 acre-feet.

This farm would not use more than 3.18 acre-feet of water per water-right acre under conditions of this study. The maximum cropping program of 133 acres of planted cotton, and 66.60 acres of alfalfa D is reached with this amount of irrigation water. The net farm return is $30,909.61 which is 14.9 percent above the typical whole farm budget.

Table 11. Case Farm A: Whole farm budget and linear programming solutions, models A, B, and C, Roswell Artesian Basin, New Mexico.

		Whole Farm Budget			Linear Programming Solutions																				
					2.50 acre feet per acre			2.75 acre feet per acre			3.00 acre feet per acre			3.25 acre feet per acre			3.50 acre feet per acre			3.75 acre feet per acre			4.00 acre feet per acre		
Vari-able	Crop	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars
	MODEL A																								
X_1	Cotton (65)																								
X_2	Cotton (80)	140.00[1]	261.65	22,355.26																					
X_3	Cotton (95)				140.00	338.80	25,858.00	140.00	338.80	25,858.00	140.00	338.80	25,858.00	140.00	338.80	25,858.00	140.00	338.80	25,858.00	140.00	338.80	25,858.00	140.00	338.80	25,858.00
X_4	Alfalfa (A)																								
X_5	Alfalfa (B)	79.10[2]	378.98	4,525.31																					
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)				20.55	123.30	1,558.72	37.41	224.46	2,837.55	54.27	325.63	4,116.38	66.60	399.60	5,051.61	66.60	399.60	5,051.61	66.60	399.60	5,051.61	66.60	399.60	5,051.61
X_8	Grain Sorghum				46.05	117.90	2,215.47	29.19	74.74	1,404.33	12.33	31.57	593.20												
X_9	Barley	24.00[3]	30.93	16.32																					
	Fallow	25.40[4]			25.40			25.40			25.40			25.40			25.40			25.40			25.40		
	Total	232.00	671.56	26,896.89	232.00	580.00	29,632.19	232.00	638.00	30,099.88	232.00	696.00	30,567.58	232.00	738.40	30,909.61	232.00	738.40	30,909.61	232.00	738.40	30,909.61	232.00	738.40	30,909.61
	MODEL B																								
X_1	Cotton (65)																								
X_2	Cotton (80)	140.00[1]	261.65	22,355.26																					
X_3	Cotton (95)				140.00	322.00	25,858.00	140.00	322.00	25,858.00	140.00	322.00	25,858.00	140.00	322.00	25,858.00	140.00	322.00	25,858.00	140.00	322.00	25,858.00	140.00	322.00	25,858.00
X_4	Alfalfa (A)																								
X_5	Alfalfa (B)	79.10[2]	378.98	4,525.31																					
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)				29.41	167.64	2,230.75	47.14	268.70	3,575.57	64.88	369.82	4,921.15	66.60	379.62	5,051.61	66.60	379.62	5,051.61	66.60	379.62	5,051.61	66.60	379.62	5,051.61
X_8	Grain Sorghum				37.19	90.36	1,789.21	19.46	47.30	936.22	1.72	4.18	82.75												
X_9	Barley	24.00[3]	30.93	16.32																					
	Fallow	25.40[4]			25.40			25.40			25.40			25.40			25.40			25.40			25.40		
	Total	232.00	671.56	26,896.89	232.00	580.00	29,877.96	232.00	638.00	30,369.79	232.00	696.00	30,861.90	232.00	701.62	30,909.61	232.00	701.62	30,909.61	232.00	701.62	30,909.61	232.00	701.62	30,909.61
	MODEL C																								
X_1	Cotton (65)				140.00	232.40	21,539.00																		
X_2	Cotton (80)	140.00[1]	261.65	22,355.26				140.00	285.60	23,769.20															
X_3	Cotton (95)										140.00	338.80	25,858.00	140.00	338.80	25,858.00	140.00	338.80	25,858.00	140.00	338.80	25,858.00	140.00	338.80	25,858.00
X_4	Alfalfa (A)				2.61	12.29	99.31																		
X_5	Alfalfa (B)	79.10[2]	378.98	4,525.31	63.99	335.31	3,660.87	62.11	325.46	3,553.31	55.79	292.34	3,191.75												
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)							4.49	26.94	340.57	10.81	64.86	819.94	66.60	399.60	5,051.61	66.60	399.60	5,051.61	66.60	399.60	5,051.61	66.60	399.60	5,051.61
X_8	Grain Sorghum																								
X_9	Barley	24.00[3]	30.93	16.32																					
	Fallow	25.40[4]			25.40			25.40			25.40			25.40			25.40			25.40			25.40		
	Total	232.00	671.56	26,896.89	232.00	580.00	25,299.18	232.00	638.00	27,663.08	232.00	696.00	29,869.69	232.00	738.40	30,909.61	232.00	738.40	30,909.61	232.00	738.40	30,909.61	232.00	738.40	30,909.61

1 Not included in total, 4.9 acres

2 Not included in total, 7.6 acres

3 Not included in total, was diverted

4 Was out of production (not cropped)

The lower net farm return for the typical crop year can be attributed primarily to the production of cotton at the 73.3 percent level of the allotment, and to the pasturing of alfalfa. Even at low levels (2.50 acre-feet of water per water-right acre) of irrigation water diversions, cotton would be produced on the maximum number of acres allowed under the cotton program, or about 57 percent of the water-right acres. About 10 percent of the water-right acres would be devoted to the production of alfalfa at the "D" level and the remaining tillable acres (20 percent of the water-right acres) would be devoted to grain sorghum. The above combination of enterprises would result in a net farm return of approximately $29,632.

As more irrigation water becomes available, alfalfa D substitutes for grain sorghum at a rate of 16.86 acres per one-fourth acre-foot of irrigation water per water-right acre until 3.18 acre-feet of irrigation water are pumped per water-right acre, where only cotton and alfalfa are produced on the cropable acres. If more than 3.18 acre-feet were available, net farm return would be increased by bringing the 25.4 acres presently out of production into alfalfa D, and maximum net farm return would occur at 3.84 acre-feet per water-right acre with a return of $32,826 to land and management.

Although the above combinations of crop enterprises result in the maximum returns for each quantity of irrigation water, they do not specifically allow for a crop rotation program. Crop yields, and therefore returns, would be reduced if these combinations of crop enterprises were produced for extended time periods at the lower levels of irrigation water pumpage.

Linear Programming Solutions--Model B

The coefficients and constraints for model B are the same as for model A except that irrigation water coefficients have been reduced by 5 percent. The irrigation water coefficients and the first irrigation water constraint for model B are listed below:

$$1.58X_1 + 1.94X_2 + 2.30X_3 + 4.47X_4 + 4.98X_5 + 5.06X_6 + 5.70X_7 + 2.43X_8$$

$$+ 0.99X_9 \leq 580 \text{ acre-feet of irrigation water}$$

The X variables are identified in table 11.

In table 11 the whole farm budget for the typical crop year is compared with the results of model B. These solutions presented in table 11 indicate the optimal net farm returns and the combinations of crops that would be produced if there were no assumed crop rotation program on Case Farm A.

In table 11 the net farm return obtained from the linear programming solutions is also contrasted with $26,896.89, which was obtained from the typical crop year with 2.89 acre-feet of irrigation water per water-right acre. The net farm return for the typical crop year would have been increased about 11 percent with the combination of crop enterprises that is indicated in model B with 2.50 acre-feet of irrigation water; about 13 percent with 2.75 acre-feet; about 15 percent with 3.02 acre-feet

Case Farm A would not use more than 3.02 acre-feet of irrigation water per acre under conditions of this study. The maximum cropping program of 133 acres of planted cotton, and 66.60 acres of alfalfa D is reached with this amount of irrigation water. The net farm return is $30,909.61 which is 14.9 percent above the typical whole farm budget.

The solutions for model B reflect a 5 percent increase in irrigation water efficiency on each crop. If 2.50 acre-feet of irrigation water per water-right acre are available, cotton would comprise about 57 percent of the water-right acres, grain sorghum about 16 percent, alfalfa about 13 percent, and the remaining 14 percent would be diverted or out of production. As more irrigation water becomes available, alfalfa D (5.70 acre-feet) substitutes for grain sorghum at a rate of 17.73 acres per one-fourth acre-foot per water-right acre until 3.02 acre-feet per acre are pumped. If more than 3.02 acre-feet were available, net farm return would be increased by bringing the 25.4 acres presently out of production into alfalfa C, which would maximize net farm return at 3.68 acre-feet of irrigation water diverted per water-right acre. The net returns figure would be $32,836.20 or about 22 percent above the typical whole farm budget. A 5 percent increase in irrigation efficiency increased the optimal net farm return by an average of 1 percent.

Linear Programming Solutions--Model C

The coefficients and constraints for model C are the same as for model A except that an additional constraint was placed on a minimum amount of alfalfa being produced. The coefficients and the added constraint are listed below:

$0X_1 + 0X_2 + 0X_3 + 1X_4 + 1X_5 + 1X_6 + 1X_7 + 0X_8 + 0X_9 \geq$ 66.6 acres of alfalfa

The X variables are identified in table 11.

In table 11 the whole farm budget for the typical crop year is compared with the results of model C. These solutions, presented in table 11, indicate the optimal net farm returns and the combinations of crops that would be produced if a minimum of one-third of the water-right acres were devoted to alfalfa production, which is the assumed crop rotation program.

In table 11 the net farm return obtained from the linear programming solutions is also contrasted with $26,896.89, which was obtained from the typical crop year with 2.89 acre-feet of irrigation water per water-right acre. The net farm return for the typical crop year would have been decreased about 6 percent with the combination of crop enterprises that is indicated in model C with 2.50 acre-feet of irrigation water; increased about 3 percent with 2.75 acre-feet; increased about 11 percent with 3.00 acre-feet; and increased about 15 percent with 3.25 acre-feet.

Case Farm A would not require more than 3.18 acre-feet of irrigation water per water-right acre under conditions of this study, as the maximum optimal cropping program is reached with this amount of irrigation water.

The primary reason for the lower net return figure at 2.50 acre-feet of irrigation water per water-right acre is the level of cotton production. In order to have enough water for alfalfa, even at a low level, cotton would be planted on 65 percent or 91 acres of the cotton allotment of 140 acres. Also, alfalfa A and B would be produced, which require 4.71 and 5.24 acre-feet of irrigation water per acre, respectively.

As more irrigation water becomes available more acres would be devoted to cotton, and alfalfa would be produced on a more intensive basis. At the 2.75 level of irrigation water diversion, planted cotton shifts from 91 acres to 112 acres and alfalfa B acreage remains fairly stable, and alfalfa A shifts to alfalfa D. At the 3.00 acre-feet irrigation water diversion level, planted cotton acreage shifts to 133 acres and alfalfa shifts slightly, to 55.79 acres of alfalfa pasture and 10.81 acres of intensive alfalfa D. With 3.18 acre-feet of irrigation water available per water-right acre the maximum net farm return is obtained with 133 acres of planted cotton and 66.6 acres of alfalfa D.

The immediate economic effect of forcing a crop rotation of about one-third of the farm into alfalfa is a reduction in net farm return, at irrigation water diversion less than 3.18 acre-feet per water-right acre. This effect can be estimated by comparing solutions from model A with solutions from model C. Net farm return would be reduced by $4,334.01 (18 percent) at the 2.50 acre-feet diversion level, by $3,436.80 (9 percent) at the 2.75 acre-feet level, and by $678.89 (2 percent) at the 3.25 acre-feet level.

The results obtained from the three linear programming models are graphically summarized in figure 7. This graph indicates the effects of the seven quantities of irrigation water on the net farm

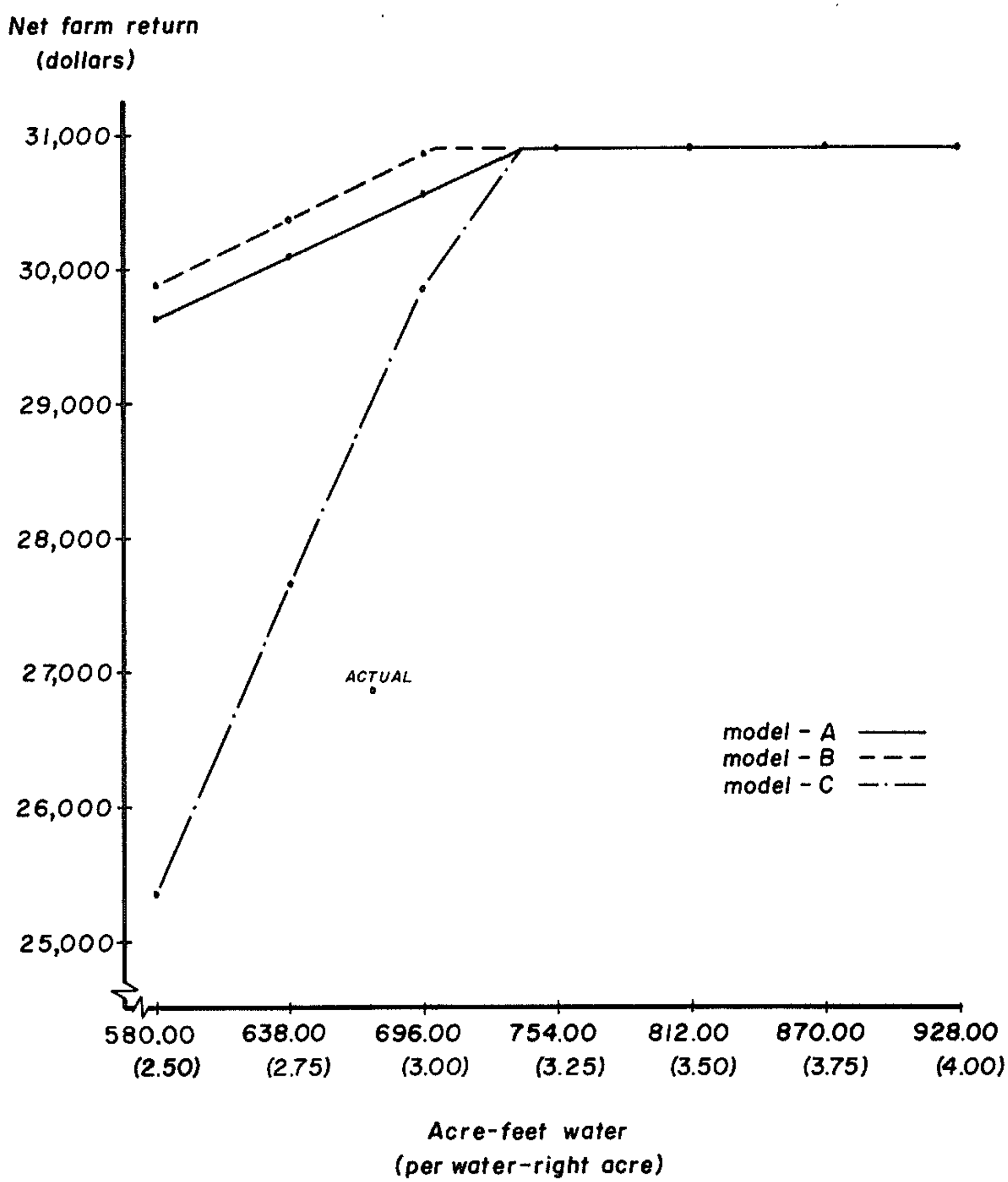


Figure 7. Case Farm A: Net farm return for seven quantities of irrigation water, Roswell Artesian Basin, New Mexico.

return. In models A and B, as irrigation water is increased from 580 acre-feet to 737.76 acre-feet (2.50 to 3.18 acre-feet per water-right acre), and 580 to 700.64 acre-feet (2.50 to 3.00 acre-feet per water-right acre) the net farm return increases at a constant rate. Beyond 3.18 and 3.02 acre-feet for models A and B respectively, the size of farm (cultivated acres) and cropping enterprises considered in this study become the factors that restrict net farm returns.

In model C, as irrigation water is increased from 580 acre-feet to 696 acre-feet (2.50 to 3.00 acre-feet per water-right acre), the net return per water-right acre increases at almost a constant rate. From 696 to 737.76 acre-feet (3.00 to 3.18 acre-feet) the rate of increase is at a decreasing rate, and beyond 737.76 acre-feet (3.18 acre-feet per water-right acre) the size of the farm (cultivated acres) and cropping enterprises considered become the limiting factors.

Optimal Quantity of Irrigation Water

The shadow prices (marginal value products) for an additional acre-foot of irrigation water are presented in table 12. The optimal level of irrigation water diversion for each model can be determined by equating the shadow price with the cost of pumping an acre-foot of irrigation water which was $7.68. For model A the optimal quantity of water was 737.76 acre-feet (3.18 acre-feet per water-right acre); for model B, 700.64 acre-feet (3.02 acre-feet); and for model C, 737.76 acre-feet (3.18 acre-feet).

If irrigation water diversion were limited to 696 acre-feet (3.00 acre-feet per water-right acre) instead of the optimal quantities in each model, net farm return would be decreased by $342.02 (1.1 percent), $47.71 (0.2 percent), and $1,039.92 (3.4 percent) for models A, B, and C, respectively. It would appear that Case Farm A was being operated at near the optimal cropping program for maximum return.

Table 12. Case Farm A: Shadow prices for seven quantities of irrigation water diversion, Roswell Artesian Basin, New Mexico.

Quantity of Irrigation Water Diverted (acre-feet)	Shadow Price Model A (dollars)	Shadow Price Model B (dollars)	Shadow Price Model C (dollars)
580	8.06	8.48	41.92
638	8.06	8.48	39.26
696	8.06	8.48	24.53
754	0.00	0.00	0.00
812	0.00	0.00	0.00
870	0.00	0.00	0.00
928	0.00	0.00	0.00

CASE FARM B

GENERAL DESCRIPTION

Case Farm B was a rented farm with 278.9 acres of artesian water rights. This farm was part of a large commercial farming operation. Case Farm B was located in the Roswell-East Grand Plains Area (figure 2). This farm was in the study for only two years, 1966 and 1967.

Soils

The soils included on Case Farm B were Reagan Loam, comprising about 46 percent of the irrigated cropland; Balmorrhea Silty Clay, comprising about 7.2 percent; Reeves Loam, comprising about 37 percent; and Reeves Loam, Shallow, comprising about 9.8 percent (figure 8). The Reagan Loam was SCS Capability Class I, Balmorrhea Silty Clay Loam and Reeves Loam were Capability Class II, and the Reeves Loam, Shallow was Capability Class IV. These soils are described further in appendix A.

Irrigation Water

Case Farm B had three artesian wells, which produced an average of 900 gallons per minute. These wells had a pumping lift of about 200 feet. The water from these wells had an average total soluble salt content of 4,208 millihmos, and the average sodium adsorption ratio was about 6.06 for the two-year period (2). The quality classification of this water was Class 3.

Irrigation System

Two of the three artesian wells were pumped into the two reservoirs on Farm B (figure 8). These reservoirs drained principally into an underground pipeline system of approximately 5,940 feet. The third artesian well was pumped directly into the underground pipeline and/or a concrete ditch. In addition to the underground pipeline, approximately 9,850 feet of concrete-lined ditch and 19,400 feet of earthen primary and secondary ditches were contained in the irrigation system.

The cropland on Farm B had been leveled with an irrigation slope primarily to the east (figure 8). Borders were not employed in the irrigation of the alfalfa fields as the irrigation water runs were relatively short (table 13).

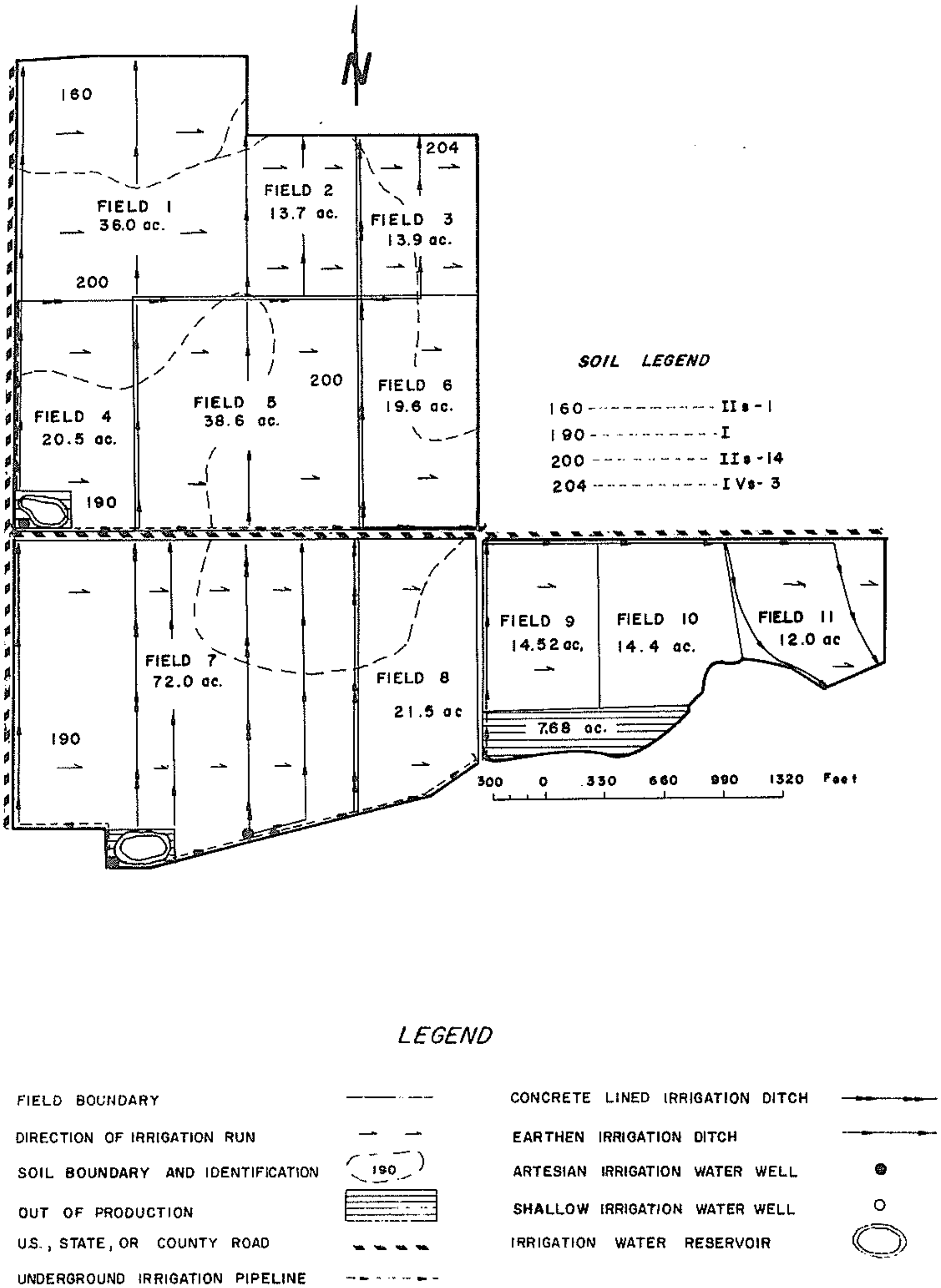


Figure 8. Map of Case Farm B.

Table 13. Case Farm B: Crops planted and approximate lengths of irrigation water runs by field, Roswell Artesian Basin, New Mexico.

Field Number	Crop Planted 1966	Crop Planted 1967	Length of Run (feet)
1	Alfalfa	Alfalfa	580-660
2	Alfalfa	Alfalfa	320-360
3	Alfalfa	Alfalfa	320-360
4	Alfalfa	Alfalfa	350-400
5	Cotton	Cotton	600-630
6	Diverted Barley	Barley	630-660
7	Alfalfa	Alfalfa	210-690
8	Cotton	Cotton	600-690
9	Cotton	Cotton Alfalfa	600-690
10	Forage sorghum	Diverted	530-800
11	Barley pasture	Barley pasture	210-600

Crops Produced

The principal crops grown on Case Farm B were cotton and alfalfa, with small acreages of barley and forage sorghum. The cotton allotment on Case Farm B was combined with those of two other farms. The total allotment was 163.6 acres. Planted acreage for the three farms, in 1966 and 1967, totaled 106.3 acres. Approximately 70 percent of the total cotton allotment was used on Case Farm B (table 14). Diverted acreage was 19.6 acres in 1966 and 14.4 acres in 1967. The diversion rates were 34 percent of the total allotment for all three farms. The same fields were involved in cotton production for both years, fields 5, 8, and 9 (table 13). The projected per-acre cotton yields by ASC for the complete farming operation were 830 pounds for 1966, and 860 pounds for 1967. The actual cotton yields were 1,125 pounds for 1966, and 898 pounds for 1967 (table 15).

Table 14. Case Farm B: Crop acreages and irrigation water pumpage, Roswell Artesian Basin, New Mexico

	Acres			Irrigation Water Pumped					
				Per Crop			Per Acre		
Crop	1966	1967	Average	1966	1967	Average	1966	1967	Average
				(acre-feet)			(acre-feet)		
Cotton	74.62	74.62	74.62	169.39	205.49	187.44	2.27	2.75	2.51
Diverted	19.60	14.40	17.00	0.00	0.00	0.00	0.00	0.00	0.00
Alfalfa	156.10	156.10	156.10	819.53	568.20	693.86	5.25	3.64	4.44
Barley	19.60[1]	19.60	19.60[2]	36.85	47.06	41.96	1.88	2.40	2.14
Barley pasture	12.00	12.00	12.00	16.92	15.00	15.96	1.41	1.25	1.33
Forage sorghum	14.40	0.00	7.20	31.54	0.00	15.77	2.19	0.00	1.10
Fallow	2.18	2.18	2.18	0.00	0.00	0.00	0.00	0.00	0.00
Total	278.90	278.90	278.90	1,074.23	835.75	954.99	3.85	3.00	3.42

1. Not included in total, was diverted acreage.
2. Not included in total, 9.8 acres.

Alfalfa was produced on 156.1 acres in both 1966 and 1967, on fields 1, 2, 3, 4, and 7 (figure 8; table 13). The yields were adjusted to allow for the lower yields that are obtained in the first year of the production period (table 15).

Barley was produced primarily as a pasture in 1966, but was also harvested for grain in both years (table 15). Forage sorghum was produced in 1966 on 14.4 acres. The yield was 15.0 tons of silage per acre (table 15).

Table 15. Case Farm B: Crops and yields per acre, Roswell Artesian Basin, New Mexico.

Crop	Unit	Yield per Acre 1966	1967	1968[1]	Average
Cotton planted					
Lint	lb.	1,125.2	898.0	540.0[2]	854.4
Seed	ton	0.96	0.58	0.41	0.65
Alfalfa	ton	6.2	6.3	5.5	6.0
Barley	bu.	73.0	42.0	----	57.50
Barley pasture	a.u.m.	9.6	9.6	----	9.6
Forage sorghum	ton	15.0	----	----	15.0

1. Yield data for 1968 were obtained in order that this farm's yields would be comparable to those of other case farms in the study.
2. Hail damage was 86 percent.

Irrigation Water Pumped

Total pumpage for the two years, 1966 and 1967, was 1,074.23 and 835.75, with an average diversion of 3.85 and 3.00 acre-feet per water-right acre, respectively (table 14). The average per-acre diversion for cotton for the two-year period was 2.51 acre-feet per acre. Alfalfa received an average of 4.44 acre-feet per acre. The barley received an average of 2.14 acre-feet per acre. The barley pasture received an average of 1.33 acre-feet per acre, and the forage sorghum received 1.10 acre-feet per acre.

The average quantity of irrigation water diverted on Case Farm B, in 1967 was slightly higher than the average quantity of irrigation water diverted on farms in the Roswell-East Grand Plains Area of the Roswell Artesian Basin. The average irrigation water diversion on Farm B was 3.00 acre-feet per water-right acre, 3.02 acre-feet per cultivated acre, and 3.19 acre-feet per cropped acre, compared with averages of 2.66 acre-feet per water-right acre, 2.94 acre-feet per cultivated acre, and 3.39 acre-feet per cropped acre for the area as a whole (10, p. 130).

Irrigation Efficiency

The typical irrigation efficiency by crops is reported in table 16, and yearly estimates in table C2. Irrigation efficiency on cotton ranged from 58.64 to 68.72 with an average of 63.21 percent; on alfalfa from 47.95 to 70.97 percent with an average of 57.39 percent; on barley from 45.42 to 61.57 percent with an average of 52.53 percent; on forage sorghum, 53.39 percent; and on barley pasture from 87.20 to 82.09 percent with an average of 84.52 percent (table C2).

Table 16. Case Farm B: Typical consumptive irrigation requirement, irrigation water applied, and farm irrigation efficiency.

Crop	Consumptive Irrigation Requirement (acre-inches)	Irrigation Water Applied (acre-inches)	Farm Irrigation Efficiency (percent)
Cotton	19.04	30.12	63.21
Alfalfa	30.61	53.34	57.39
Barley	13.49	25.68	52.53
Barley pasture	13.49	15.94	84.52
Forage sorghum	14.03	26.28	53.39

ECONOMIC ANALYSIS

Financial Summary

The typical per-acre net returns by crops are reported in table 17 and yearly return figures are reported in table D2. The net farm return was $31,749.19 for 1966, and $29,653.39 for 1967.

Table 17. Case Farm B: Typical per-acre returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns per Acre	Gross Expenses per Acre	Net Returns to Land and Management per Acre
	(dollars)	(dollars)	(dollars)
Cotton planted	391.31	148.70	242.61
Cotton diverted	88.29	6.57	81.72
Alfalfa	143.75	106.77	36.98
Forage sorghum	67.50	32.43	35.07
Barley	33.38	33.47	9.76
Weighted average	191.93	101.79	90.14

Because of these wide variations in yields, prices, acreage, and net farm returns, a typical whole farm budget was computed using typical yields, prices, acreage, and costs (table 18). This typical whole farm budget will be used to compare with the linear programming solutions to determine the effect of different levels of irrigation water diversions upon net farm returns. The annual whole farm budgets are presented in appendix E (table E2).

Table 18. Case Farm B: Typical whole farm returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns	Gross Expenses	Net Returns to Land and Management
		(dollars)	(dollars)	(dollars)
Cotton planted	74.62	29,199.55	11,095.99	18,103.56
Cotton diverted	17.00	1,500.93	111.69	1,389.24
Alfalfa	156.10	22,439.38	16,666.80	5,772.58
Forage sorghum	7.20	486.00	233.50	252.50
Barley	31.60	1,365.91	1,057.61	308.30
Total	286.52	54,991.77	29,165.59	25,826.18

Linear Programming Solutions--Model A

The coefficients and constraints for model A are presented below:

$1X_1 + 1X_2 + 1X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 1X_8 + 1X_9 + 1X_{10} \leq 278.9$

acres

$$1X_1 + 1X_2 + 1X_3 + 0X_4 + 0X_5 + 0X_6 + 0X_7 + 0X_8 + 0X_9 + 0X_{10} \leq 91.62$$

acres of cotton

$$1.63X_1 + 2.01X_2 + 2.38X_3 + 4.44X_4 + 0X_5 + 5.33X_6 + 6.00X_7 + 2.25X_8$$

$$+ 1.10X_9 + 2.14X_{10} \leq 697.25$$ acre-feet of irrigation water

The X variables are identified in table 19.

The parameter changes in irrigation water diversion (Qt), where Q = 687.25 acre-feet of irrigation water and t = 69.725 acre-feet, result in the following irrigation water constraints:

2.75 acre-feet of irrigation water = 766.98 acre-feet
3.00 acre-feet of irrigation water = 836.70 acre-feet
3.25 acre-feet of irrigation water = 906.43 acre-feet
3.50 acre-feet of irrigation water = 976.15 acre-feet
3.75 acre-feet of irrigation water = 1,045.88 acre-feet
4.00 acre-feet of irrigation water = 1,115.65 acre-feet

In table 19 the whole farm budget for the typical crop year is compared with the results of model A. The linear programming solutions presented in table 19 indicate the optimal net farm returns and the combinations of the nine crops that would be produced if there were no assumed crop rotation program on Case Farm B.

In table 19 the net farm return obtained from the linear programming solutions is also contrasted with $25,826.18, which was obtained from the typical crop year with 954.99 acre-feet of irrigation water (3.42 acre-feet per water-right acre). The net farm return for the typical crop year would have been increased about 24 percent with the combination of crop enterprises that is indicated in model A with 2.50 acre-feet of irrigation water; increased about 27 percent with 2.75 acre-feet; increased about 29 percent with 3.00 acre-feet; increased about 32 percent with 3.25 acre-feet; increased about 34 percent with 3.50 acre-feet; increased about 36 percent with 3.75 acre-feet; increased about 39 percent with 4.00 acre-feet.

The lower net farm return for the typical crop year can be attributed primarily to the production of cotton at the 81.4 percent level of the allotment and to the production of barley. Even at low levels (2.50 acre-feet of water per water-right acre) of irrigation water diversions, cotton would be produced on the maximum number of acres allowed under the cotton program, or about 31 percent of the water-right acres. About 5.5 percent of the water-right acres would be devoted to the production of alfalfa at the "D" level and the remaining tillable acres (62 percent of the water-right acres) would be devoted to grain sorghum. The above combination of enterprises

Table 19. Case Farm B: Whole farm budget and linear programming solutions, models A, B, and C, Roswell Artesian Basin, New Mexico.

		Whole Farm Budget			Linear Programming Solutions: 2.50 acre feet per acre			2.75 acre feet per acre			3.00 acre feet per acre			3.25 acre feet per acre			3.50 acre feet per acre			3.75 acre feet per acre			4.00 acre feet per acre		
Variable	Crop	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars
	MODEL A																								
X_1	Cotton (65)																								
X_2	Cotton (80)	91.62	187.44	19,492.80																					
X_3	Cotton (95)				91.62	218.06	21,491.30	91.62	218.06	21,491.30	91.62	218.06	21,491.30	91.62	218.06	21,491.30	91.62	218.06	21,491.30	91.62	218.06	21,491.30	91.62	218.06	21,491.30
X_4	Alfalfa (A)	156.10	693.86	5,772.58																					
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)				15.42	92.51	1,345.55	34.01	204.06	2,967.71	52.61	315.64	4,590.75	71.20	427.20	6,212.91	89.80	538.78	7,835.95	108.39	650.33	9,458.11	126.99	761.94	11,081.15
X_8	Grain Sorghum				171.86	386.68	9,299.34	153.27	344.86	8,293.44	134.67	303.00	7,286.99	116.08	261.17	6,281.09	97.48	219.31	5,274.64	78.89	177.49	4,268.74	60.29	135.65	3,262.29
X_9	Forage Sorghum	7.20	15.77	252.50																					
X_{10}	Barley	31.60[1]	57.92	308.30																					
	Fallow	2.18	0.00	0.00																					
	Total	278.90	954.99	25,826.18	278.90	697.25	32,136.19	278.90	766.98	32,752.45	278.90	836.70	33,369.04	278.90	906.43	33,985.30	278.90	976.15	34,601.89	278.90	1,045.88	35,218.15	278.90	1,115.65	35,834.74
	MODEL B																								
X_1	Cotton (65)																								
X_2	Cotton (80)	91.62	187.44	19,492.80																					
X_3	Cotton (95)				91.62	207.06	21,491.30	91.62	207.06	21,491.30	91.62	207.06	21,491.30	91.62	207.06	21,491.30	91.62	207.06	21,491.30	91.62	207.06	21,491.30	91.62	207.06	21,491.30
X_4	Alfalfa (A)	156.10	693.86	5,772.58																					
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)				25.12	143.18	2,191.97	44.70	254.79	3,900.52	64.29	366.45	5,609.95	83.87	478.06	7,318.50	103.46	589.72	9,027.92	123.04	701.34	10,736.47	142.63	812.99	12,445.89
X_8	Grain Sorghum				162.16	347.01	8,774.48	142.58	305.13	7,715.00	122.99	263.19	6,654.99	103.41	221.31	5,595.52	83.82	179.37	4,535.50	64.24	137.48	3,476.03	44.65	95.55	2,416.01
X_9	Forage Sorghum	7.20	15.77	252.50																					
X_{10}	Barley	31.60[1]	57.92	308.30																					
	Fallow	2.18	0.00	0.00																					
	Total	278.90	954.99	25,826.18	278.90	697.25	32,457.75	278.90	766.98	33,106.82	278.90	836.70	33,756.24	278.90	906.43	34,405.32	278.90	976.15	35,054.72	278.90	1,045.88	35,703.80	278.90	1,115.60	36,353.20
	MODEL C																								
X_1	Cotton (65)																								
X_2	Cotton (80)	91.62	187.44	19,492.80																					
X_3	Cotton (95)				91.62	218.06	21,491.30	91.62	218.06	21,491.30	91.62	218.06	21,491.30	91.62	218.06	21,491.30	91.62	218.06	21,491.30	91.62	218.06	21,491.30	91.62	218.06	21,491.30
X_4	Alfalfa (A)	156.10	693.86	5,772.58	12.55	55.72	464.10																		
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)				79.45	423.47	5,474.11	92.00	490.36	6,338.80	56.96	303.60	3,924.54												
X_7	Alfalfa (D)										35.04	210.24	3,057.59	92.00	552.00	8,027.92	92.00	552.00	8,027.92	108.38	650.28	9,457.24	126.99	761.94	11,081.15
X_8	Grain Sorghum													27.44	61.74	1,484.78	88.08	198.18	4,766.01	78.90	177.54	4,269.28	60.29	135.65	3,262.29
X_9	Forage Sorghum	7.20	15.77	252.50				53.24	58.56	1,867.13	95.28	104.80	3,341.47	67.84	74.63	2,379.15	7.20	7.91	252.50						
X_{10}	Barley	31.60[1]	57.92	308.30																					
	Fallow	2.18	0.00	0.00	95.28	0.00	0.00	42.04	0.00	0.00															
	Total	278.90	954.99	25,826.18	278.90	697.25	27,429.51	278.90	766.98	29,697.23	278.90	836.70	31,814.90	278.90	906.43	33,383.15	278.90	976.15	34,537.73	278.90	1,045.88	35,217.82	278.90	1,115.65	35,834.74

1 Not included in total, 9.8 acres

would result in a net farm income of approximately $32,126.

As more irrigation water becomes available, alfalfa D substitutes for grain sorghum at a rate of 18.59 acre per one-fourth acre-foot of irrigation water per water-right acre until 4.81 acre-feet of irrigation water is pumped per water-right acre, where only cotton 95 and alfalfa D are produced on the cropable acres. If more than 4.81 acre-feet were available net farm returns to land and management would not increase, but would remain at $37,833.35 which is 46.5 percent above the typical whole farm budget.

Although the above combinations of crop enterprises result in the maximum returns for each quantity of irrigation water, they do not specifically allow for a crop rotation program. Crop yields, and therefore returns, would be reduced if these combinations of crop enterprises were produced for extended time periods at the lower levels of irrigation water pumpage.

Linear Programming Solutions--Model B

The coefficients and constraints for model B are the same as for model A except that irrigation water coefficients have been reduced 5 percent. The irrigation water coefficients and the first irrigation water constraint for model B are listed below:

$$1.55X_1 + 1.91X_2 + 2.26X_3 + 4.22X_4 + 0X_5 + 5.06X_6 + 5.70X_7 + 2.14X_8$$

$$+ 1.05X_9 + 2.03X_{10} \leq 697.25 \text{ acre-feet of irrigation water}$$

The X variables are identified in table 19.

In table 19 the whole farm budget for the typical crop year is compared with the results of model B. These solutions, presented in table 19, indicate the optimal net farm returns and the combinations of crops that would be produced if the irrigation efficiency were increased 5 percent on each crop alternative and if there were no assumed crop rotation programs on Case Farm B.

In table 19 the net farm return obtained from the linear programming solutions is also contrasted with $25,826.18, which was obtained from the typical crop year with 954.99 acre-feet of irrigation water (3.42 acre-feet per water-right acre). The net farm return for the typical crop year would have been increased about 25 percent with the combination of crop enterprises that is indicated in model B with 2.50 acre-feet of irrigation water; about 28 percent with 2.75 acre-feet; about 30 percent with 3.00 acre-feet; about 33 percent with 3.25 acre-feet; about 36 percent with 3.50 acre-feet; about 38 percent with 3.75 acre-feet; and about 41 percent with 4.00 acre-feet.

The solutions for model B reflect a 5 percent increase in irrigation water efficiency on each crop. If 2.50 acre-feet of irrigation water per water-right acre were available, cotton would comprise about 31 percent of the water-right acres, grain sorghum about 59 percent, alfalfa about 8 percent, and the remaining 2 percent would be diverted. As more irrigation water becomes available, alfalfa at the high irrigation level (5.70 acre-feet) substitutes for grain sorghum at a rate of 19.59 acres per one-fourth acre-foot of irrigation water per water-right acre until 4.57 acre-feet per acre are pumped. If more than 4.57 acre-feet were available net farm returns would not be increased, but would remain at $37,833.35. This is about 46.5 percent above the typical whole farm budget. A 5 percent increase in irrigation efficiency increased the optimal net farm returns to land and management by an average of 1 percent.

Linear Programming Solutions--Model C

The coefficients and constraints for model C are the same as for model A except that an additional constraint was placed on a minimum amount of alfalfa being produced. The coefficients and constraints are listed below:

$0X_1 + 0X_2 + 0X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 0X_8 + 0X_9 + 0X_{10} \geq 92.0$ acres of alfalfa

The X variables are identified in table 19.

In table 19 the whole farm budget for the typical crop year is compared with the results of model C. These solutions, presented in table 19, indicate the optimal net farm returns and the combinations of crops that would be produced if a minimum of one-third of the water-right acres were devoted to alfalfa production, which is the assumed crop rotation program.

In table 19 the net farm return obtained from the linear programming solutions is also contrasted with $25,826.18, which was obtained from the typical crop year with 954.99 acre-feet of irrigation water (3.42 acre-feet per water-right acre). The net farm return for the typical crop year would have been increased about 6 percent with the combination of crop enterprises that is indicated in model C with 2.50 acre-feet of irrigation water; increased about 15 percent with 2.75 acre-feet; increased about 23 percent with 3.00 acre-feet; increased about 29 percent with 3.25 acre-feet; increased about 34 percent with 3.50 acre-feet; increased about 36 percent with 3.75 acre-feet; and increased about 39 percent with 4.00 acre-feet.

The primary reason for the lower return figure at 2.50 acre-feet of irrigation water per water-right acre is the requirement that about one-third of the farm be planted in alfalfa. In order to have enough water for alfalfa, approximately one-third of the farm must be left fallow. Also, alfalfa A and C would be produced which require 4.44 and 5.33 acre-feet of irrigation per acre.

As more irrigation water becomes available more acres would be devoted to alfalfa C and forage sorghum. At the 2.75 level of irrigation water diversion, alfalfa A shifts to forage sorghum and alfalfa B acreage would increase from 79.45 to 92.0 acres. At the 3.00 acre-feet irrigation water diversion level, alfalfa C acreage would decrease to 56.96 acres and alfalfa D would be produced on 35.04 acres. Forage sorghum would be increased to 95.28 acres. With 3.25 acre-feet of irrigation water available per water-right acre, the maximum net farm return is obtained with 87.04 acres of planted cotton, 92.0 acres of alfalfa D, 27.44 acres of grain sorghum, and 67.84 acres of forage sorghum. The optimal solutions and cropping patterns for 3.50, 3.75, and 4.00 acre-feet per water-right acre are reported in table 19.

The immediate economic effect of forcing a crop rotation of about one-third of the farm into alfalfa is a reduction in net farm returns at irrigation water diversion less than 3.75 acre-feet per water-right acre. This effect can be estimated by comparing solutions from model A with solutions from model C. Net farm return would be reduced by $4,706.47 (17.2 percent) at 2.50 acre-feet per water-right acre, by $3,055.22 (10.3 percent) at 2.75 acre-feet per water-right acre, by $1,554.14 (4.9 percent) at 3.00 acre-feet per water-right acre, by $602.15 (1.8 percent) at 3.25 acre-feet per water-right acre, by $64.16 (0.2 percent) at 3.50 acre-feet per water-right acre, and by $0.33 at 3.75 acre-feet per water-right acre.

The results obtained from the three linear programming models are graphically summarized in figure 9. This graph indicates the effects of the seven quantities of irrigation water on the net farm return. In models A and B, as irrigation water is increased from 697.25 acre-feet to 1,341.75 acre-feet (2.50 to 4.81 acre-feet per water-right acre), and from 697.25 to 1,274.56 acre-feet (2.50 to 4.57 acre-feet per water-right acre) the net farm return increases at a constant rate. Beyond 4.81 and 4.57 acre-feet for models A and B respectively, the size of farm and cropping enterprises considered in this study become the factors that restrict net farm returns.

In model C, as irrigation water is increased from 697.25 acre-feet to 836.70 acre-feet (2.50 to 3.00 acre-feet per water-right acre), the net return per water-right acre increases at almost a constant rate. From 836.70 to 1,045.88 acre-feet (3.00 to 3.75 acre-feet) the rate of increase is at a decreasing rate, and beyond 1,045.88 acre-feet (3.75 acre-feet per water-right acre) the size of the farm (water-right acres) and cropping enterprises considered become the limiting factors.

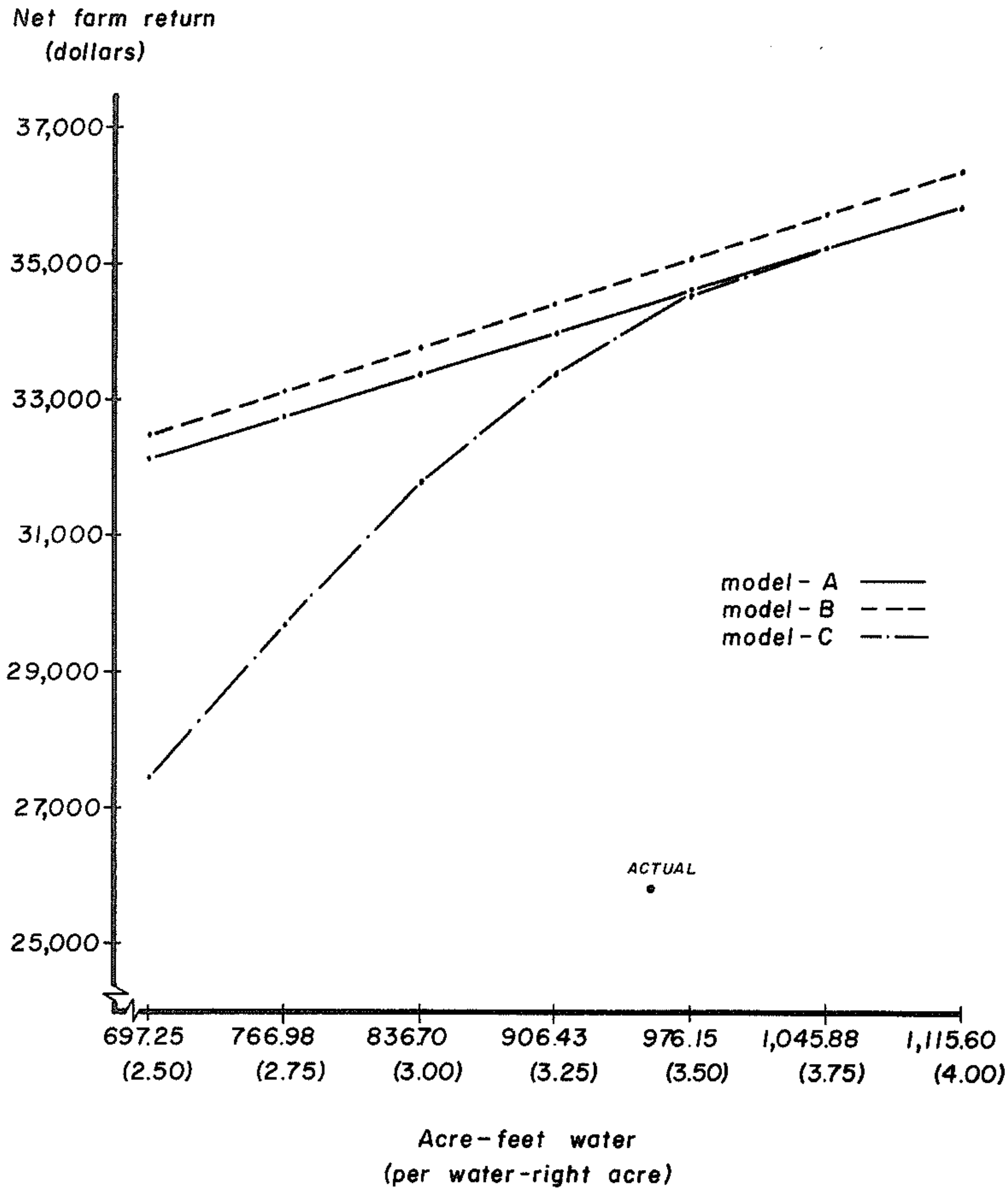


Figure 9. Case Farm B: Net farm return for seven quantities of irrigation water, Roswell Artesian Basin, New Mexico.

Optimal Quantity of Irrigation Water

The shadow prices (marginal value products) for an additional acre-foot of irrigation water are presented in table 20. The optimal level of irrigation water diversion for each model can be determined by equating the shadow price with the cost of pumping an acre-foot of irrigation water, which was estimated at $7.68. For model A the optimal quantity of water was 1,341.77 acre-feet (4.81 acre-feet per water-right acre); for model B, 1,274.56 acre-feet (4.57 acre-feet per water-right acre); and for model C, 1,341.74 acre-feet (4.81 acre-feet per water-right acre).

If irrigation water diversion were limited to 836.70 acre-feet (3.00 acre-feet per water-right acre) instead of the optimal quantities in each model, net farm return would be reduced by $4,464.31 (13.4 percent), $4,077.11 (12.1 percent) and $6,018.45 (18.9 percent) for models A, B, and C respectively. It would appear that Case Farm B was being operated at less than the optimal cropping program for maximum return.

Table 20. Case Farm B: Shadow prices for seven quantities of irrigation water diversion, Roswell Artesian Basin, New Mexico.

Quantity of Irrigation Water Diverted	Shadow Price Model A (dollars)	Shadow Price Model B (dollars)	Shadow Price Model C (dollars)
697.25	8.84	8.59	35.87
766.98	8.84	8.59	31.88
836.70	8.84	8.59	27.40
906.43	8.84	8.59	16.56
976.15	8.84	8.59	16.56
1,045.88	8.84	8.59	8.84
1,115.65	8.84	8.59	8.84

CASE FARM C

GENERAL DESCRIPTION

Case Farm C was a rented farm with 158.5 acres of artesian water rights. The farm was located in the Roswell-East Grand Plains Area of the basin (figure 2).

Soils

The major soils on Case Farm C were Reagan Loam, comprising about 93.7 percent of the irrigated cropland; Harkey Loam, about 5 percent; Atoka Loam, about 0.7 percent; and Cave Gravelly Loam, about 0.6 percent (figure 10). The Reagan Loam and Harkey Loam were SCS Capability Class I soils, the Atoka Loam was Class II, and the Cave Gravelly Loam was Class VII (appendix A).

Irrigation Water

Case Farm C had two artesian wells, 2,200 and 2,500 feet deep, producing 1,200 and 2,000 gallons per minute respectively. The water from these wells had an average total soluble salt content of about 7,172 millimhos and the average sodium adsorption ratio was 10.05 for the three-year period (2). The quality classification of this water was Class 3.

Irrigation System

The two artesian wells on Case Farm C were pumped into 750 feet of underground pipeline which drained into a reservoir, which in turn drained into an underground pipeline approximately 4,540 feet long (figure 10). The underground pipeline, in turn, drained into approximately 5,690 feet of concrete-lined ditch and about 2,590 feet of earthen ditch.

All of the irrigated cropland on Farm C, except 81.6 acres, had been either grade or bench leveled. The unleveled cropland included all of fields 5 and 6 (figure 10). Borders were employed in the irrigation of all alfalfa fields. Approximate lengths of irrigation water runs for the different fields are reported in table 21.

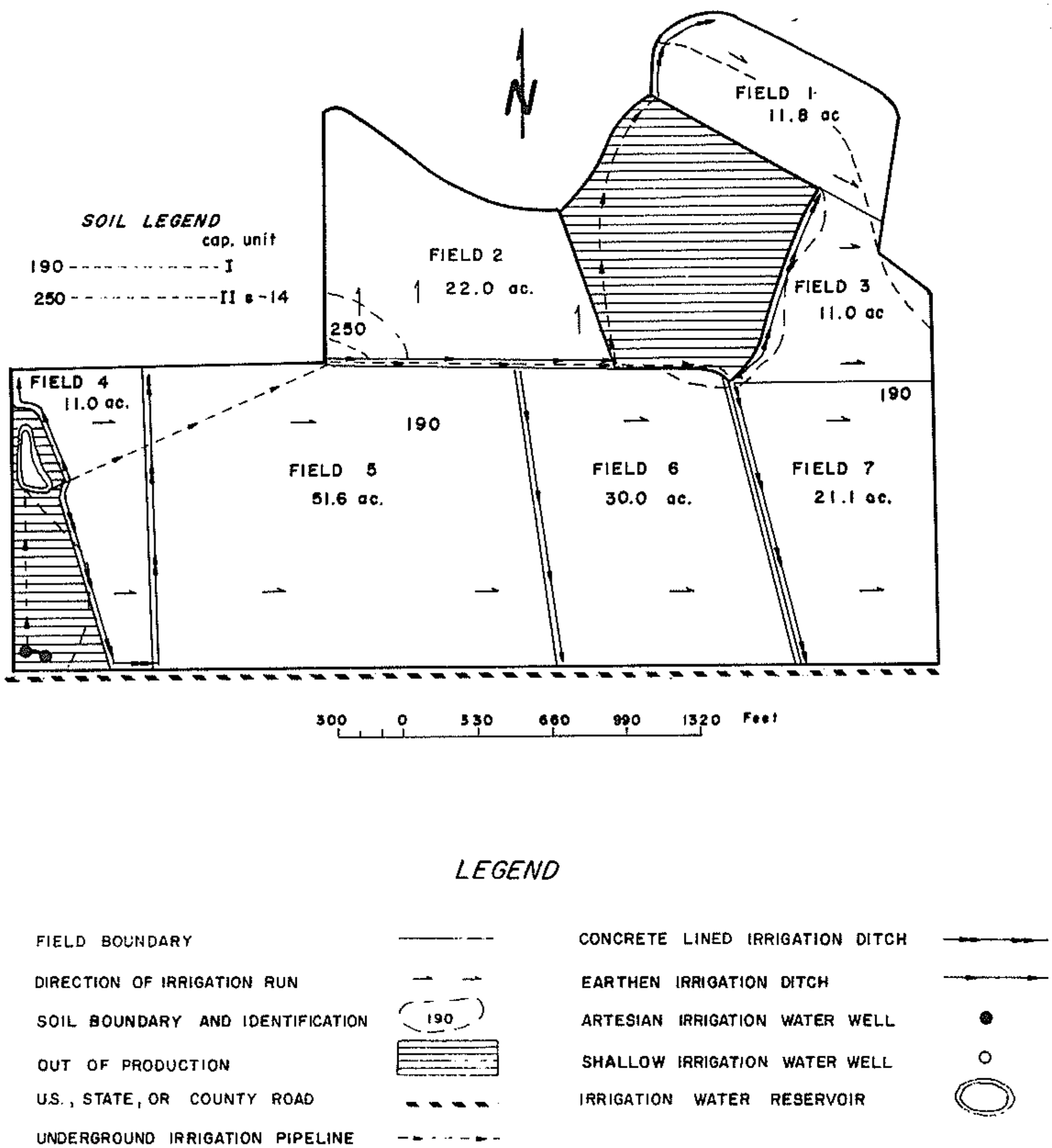


Figure 10. Map of Case Farm C.

Table 21. Case Farm C: Crops planted and approximate lengths of irrigation water runs by field, Roswell Artesian Basin, New Mexico.

Field Number	Crop Planted 1966	1967	1968	Length of Run (feet)
1	Cotton	Cotton	Cotton	920-1,130
2	Diverted Barley	Diverted Grain sorghum Barley	Barley Alfalfa	320-1,100
3	Alfalfa	Alfalfa	Cotton Forage sorghum	320- 680
4	Alfalfa	Alfalfa	Alfalfa	180- 550
5	Alfalfa	Cotton	Cotton	1,640-1,770
6	Cotton	Barley Grain sorghum	Barley Forage sorghum	900-1,030
7	Fallow Alfalfa	Alfalfa	Alfalfa	580- 840

Crops Produced

The principal crops produced on Case Farm C were cotton and alfalfa. Case Farm C had a cotton allotment of 63.0 acres in 1966, 81.3 acres in 1967, and 69.2 acres in 1968. In 1966 there were 41.8 acres planted to cotton and 22.0 acres were diverted, under provisions of the 1966 Upland Cotton Program. In 1967 there were 71.1 acres planted in cotton. However, 7.7 acres were plowed under following hail damage, leaving 63.4 acres in cotton and 14.26 acres diverted (table 22). In 1968, cotton was planted in fields 1, 3, and 5 for a total of 65.7 acres. The diversion rates were 35 percent for 1966, 22 percent for 1967, and 9.5 percent for 1968. Projected yields by ASC were 705 pounds for 1966, 725 pounds for 1967, and 705 pounds for 1968. The actual yields in pounds were 359, 365, and 789 for the same years (table 23).

Alfalfa was produced on 94.7 acres in 1966, 43.1 acres in 1967, and 54.1 acres in 1968 (table 22). The alfalfa yields were adjusted, to allow for the lower yields obtained the first year, to 5.0 tons in 1966, 5.2 tons in 1967, and 4.5 tons in 1968 (table 23).

Table 22. Case Farm C: Crop acreages and irrigation water pumpage, Roswell Artesian Basin, New Mexico

	Acres				Irrigation Water Pumped							
					Per Crop				Per Acre			
Crop	1966	1967	1968	Average	1966	1967	1968	Average	1966	1967	1968	Average
						(acre-feet)				(acre-feet)		
Cotton	41.80	63.40	65.70	57.00	117.04	173.08	188.10	159.41	2.80	2.73	2.86	2.80
Diverted	22.00	14.26	3.50	13.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alfalfa	73.60	43.10	32.10	49.60	396.70	163.35	118.77	226.27	5.39	3.79	3.70	4.56
Seedling alfalfa	21.10[1]	0.00	22.00[2]	14.40[1,2]	51.68	0.00	38.50	30.06	2.45	0.00	1.75	2.09
Barley	22.00[3]	52.00[4]	52.00	42.00[5]	22.00	55.20	99.04	58.75	1.00	1.06	1.90	1.40
Grain sorghum	0.00	52.00[6]	0.00	17.30[7]	0.00	68.64	0.00	22.88	0.00	1.32	0.00	1.32
Forage sorghum	0.00	0.00	35.20[8]	11.70[9]	0.00	0.00	72.00	24.00	0.00	0.00	2.05	2.05
Fallow	21.10	0.00	0.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	158.50	158.50	158.50	158.50	587.42	459.57	516.41	521.37	3.71	2.90	3.26	3.29

1. Fall planted, not included in total, was fallow.
2. Fall planted, not included in total, was barley acreage.
3. Not included in total, was diverted acreage.
4. Not included in total, was grain sorghum acreage.
5. Not included in total, 24.7 acres.
6. Not included in total, 14.26 acres.
7. Not included in total, 4.7 acres.
8. Not included in total, 30 acres.
9. Not included in total, 10.0 acres.

Barley was used primarily as pasture in 1966 and 1967, and as grain in 1968. The yields are presented in table 23. Other crops included grain sorghum and forage sorghum averaging 17.3 and 11.7 acres respectively.

Table 23. Case Farm C: Crops and yield per acre for Roswell Artesian Basin, New Mexico.

Crop	Unit	Yield per Acre			
		1966	1967	1968	Average
Cotton planted					
Lint	lb.	358.9	365.0	788.6	504.2
Seed	ton	0.27	0.27	0.59	0.38
Alfalfa	ton	5.0	5.2	4.5	4.9
Barley					
Seed	bu.	----	----	40.6	40.6
Pasture	a.u.m.	5.0	----	----	5.0
Sorghum					
Grain	cwt	----	0.34	----	0.34
Silage	ton	----	----	0.71	0.71
Pasture	a.u.m.	----	----	4.44	4.44

Irrigation Water Pumped

In 1966 a total of 587.42 acre-feet of irrigation water were pumped on Case Farm C, and in 1967 the total was 459.57 acre-feet, or 127.85 acre-feet less than the previous year. The total for 1968 was 516.41 acre-feet, which was 56.84 acre-feet more than in 1967, but 71.01 acre-feet less than in 1966 (table 22).

Diversions per acre were higher in 1966 than in the following two years. This might be partly attributed to the operators, since the farm changed operators after the 1966 crop year. The average per=acre diversion for cotton for the three year period was 2.80 acre-feet per acre. Alfalfa received an average of 4.56 acre-feet per acre on the established stand. The seedling alfalfa which was planted in the fall received an average of 2.09 acre-feet per acre. The barley received an average of 1.40 acre-feet per acre, the grain sorghum received 1.32 acre-feet, and forage sorghum received 2.05 acre-feet per acre.

The average quantity of irrigation water diverted per acre on Case Farm C in 1967 was slightly higher than the average for all farms in the Roswell-East Grand Plains Area of the Roswell Artesian Basin. The average irrigation water diversion of Case Farm C was 2.90 acre-feet per cropped acre. The average diversion per acre for the Roswell-East Grand Plains Area in 1967 was 2.66 acre-feet per water-right acre, 2.94 acre-feet per cultivated acre, and 3.39 acre-feet per cropped acre (9, p. 130).

In 1968 the average quantity of irrigation water diverted on Farm C was 3.26 acre-feet per water-right acre, 0.39 acre-feet per acre more than the average of 2.87 acre-feet per water-right acre for the Roswell-East Grand Plains Area (12).

Irrigation Efficiency

The typical irrigation efficiency by crops is reported in table 24 and yearly estimates in table C3. Irrigation efficiency on cotton ranged from 53.38 to 59.07 with an average of 56.02 percent; on alfalfa, from 46.71 to 68.16 with an average of 56.89 percent; on barley from 116.42 to 76.40 with an average of 91.22 percent. Grain sorghum had 112.94 percent and forage sorghum had 48.74 percent (table 24).

Table 24. Case Farm C: Typical consumptive irrigation requirement, irrigation water applied, and farm irrigation efficiency.

Crop	Consumptive Irrigation Requirement	Irrigation Water Applied	Farm Irrigation Efficiency
	(acre-inches)	(acre-inches)	(percent)
Cotton	18.80	33.56	56.02
Alfalfa	29.31	51.52	56.89
Barley	14.45	15.84	91.22
Grain sorghum	17.89	15.84	112.94
Forage sorghum	11.99	24.60	48.74

ECONOMIC ANALYSIS

Financial Summary

The typical per-acre net returns by crops are reported in table 25 and yearly figures are reported in table D3. The net farm returns for the three years were $5,529.24, $8,905.50, and $10,977.61 for 1966, 1967, and 1968 respectively (table E3). The primary reasons for the variations in net farm returns were favorable prices for cotton and alfalfa in 1967, and favorable yield for cotton in 1968.

Table 25. Case Farm C: Typical per-acre returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns per Acre	Gross Expenses per Acre	Net Returns to Land and Management per Acre
	(dollars)	(dollars)	(dollars)
Cotton planted	253.85	142.53	111.32
Cotton diverted	76.02	14.58	61.44
Alfalfa	127.70	102.24	25.46
Barley	21.19	34.02	- 12.83
Grain sorghum	60.35	44.82	15.53
Forage sorghum	15.19	38.29	- 23.10
Weighted average	125.50	85.31	40.19

Because of these variations a typical whole farm budget was computed using typical yields, prices, and costs (table 26). This typical whole farm budget will be used to compare with the linear programming solutions to determine the effect of different levels of irrigation water diversions on net farm returns. The annual whole farm budgets are presented in appendix E (table E3).

Table 26. Case Farm C: Typical whole farm returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns	Gross Expenses	Net Returns to Land and Management
		(dollars)	(dollars)	(dollars)
Cotton planted	57.0	14,469.45	8,124.21	6,345.24
Cotton diverted	13.3	1,011.07	193.91	817.16
Alfalfa	64.0	8,172.80	6,543.36	1,629.44
Barley	42.0	889.98	1,428.84	- 538.86
Grain sorghum	17.3	1,044.06	755.39	268.67
Forage sorghum	11.7	177.72	447.99	- 270.27
Total	205.3	25,765.08	17,513.70	8,251.38

Linear Programming Solutions-Model A

The coefficients and constraints for model A are presented below:

$$1X_1 + 1X_2 + 1X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 1X_8 + 1X_9 + 1X_{10} \leq 158.5$$

acres

$$1X_1 + 1X_2 + 1X_3 + 0X_4 + 0X_5 + 0X_6 + 0X_7 + 0X_8 + 0X_9 + 0X_{10} \leq 70.3$$

acres of cotton

$$1.82X_1 + 2.24X_2 + 2.66X_3 + 4.29X_4 + 0X_5 + 5.33X_6 + 6.00X_7 + 1.32X_8$$

$+ 2.05X_9 + 1.40X_{10} \leq$ 396.25 acre-feet of irrigation water.

The X variables are identified in table 27.

The parameter changes in irrigation water diversion (Qt), where q = 396.25 acre-feet of irrigation water and t = 39.625 acre-feet result in the following irrigation water constraints:

2.75 acre-feet per water-right acre = 435.88 acre-feet
3.00 acre-feet per water-right acre = 475.50 acre-feet
3.25 acre-feet per water-right acre = 515.12 acre-feet
3.50 acre-feet per water-right acre = 554.75 acre-feet
3.75 acre-feet per water-right acre = 594.38 acre-feet
4.00 acre-feet per water-right acre = 634.00 acre-feet

In table 27 the whole farm budget for the typical crop year is compared with the results of model A. The linear programming solutions presented in table 27 indicate the optimal net farm returns and the combinations of the nine crops that would be produced if there were no assumed crop rotation program on Case Farm C.

In table 27 the net farm return obtained from the linear programming solutions is also contrasted with $8,251.38, which was obtained from the typical crop year with 521.37 acre-feet of irrigation water (3.29 acre-feet per water-right acre). The net farm return for the typical crop year would have been increased about 21 percent with the combination of crop enterprises that is indicated in model A with 2.50 acre-feet of irrigation water; about 26 percent with 2.75 acre-feet; about 31 percent with 3.00 acre-feet; about 36 percent with 3.25 acre-feet; about 41 percent with 3.50 acre-feet; about 46 percent with 3.75 acre-feet; and about 52 percent with 4.00 acre-feet.

The lower net farm return for the typical crop year can be attributed primarily to the production of cotton at the 81 percent level of the allotment, and to the production of barley and grain sorghums. Even at low levels (2.50 acre-feet of water per water-right

Table 27. Case Farm C: Whole farm budget and linear programming solutions, models A, B, and C, Roswell Artesian Basin, New Mexico.

		Whole Farm Budget			Linear Programming Solutions																				
					2.50 acre feet per acre			2.75 acre feet per acre			3.00 acre feet per acre			3.25 acre feet per acre			3.50 acre feet per acre			3.75 acre feet per acre			4.00 acre feet per acre		
Variable	Crop	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars
											MODEL A														
X_1	Cotton (65)																								
X_2	Cotton (80)	70.30	159.41	7,162.40																					
X_3	Cotton (95)				70.30	187.00	7,650.75	70.30	187.00	7,650.75	70.30	187.00	7,650.75	70.30	187.00	7,650.75	70.30	187.00	7,650.75	70.30	187.00	7,650.75	70.30	187.00	7,650.75
X_4	Alfalfa (A)	64.00[1]	256.33	1,629.44																					
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)				19.84	119.03	1,287.42	28.30	169.80	1,836.39	36.77	220.62	2,386.01	45.24	271.43	2,935.62	53.71	322.24	3,485.24	62.17	373.02	4,034.21	70.64	423.83	4,583.83
X_8	Grain Sorghum	17.30[2]	22.88	268.67	68.36	90.22	1,061.63	59.90	79.08	930.25	51.43	67.88	798.71	42.96	56.70	667.17	34.49	45.51	535.63	26.03	34.36	404.25	17.56	23.17	272.71
X_9	Forage Sorghum	11.70[3]	24.00	-270.27																					
X_{10}	Barley	42.00[4]	58.75	-538.86																					
	Fallow																								
	Total	158.50	521.37	8,251.38	158.50	396.25	9,999.80	158.50	435.88	10,417.39	158.50	475.50	10,835.47	158.50	515.13	11,253.54	158.50	554.75	11,671.62	158.50	594.38	12,089.21	158.50	634.00	12,507.29
											MODEL B														
X_1	Cotton (65)																								
X_2	Cotton (80)	70.30	159.41	7,162.40																					
X_3	Cotton (95)				70.30	177.86	7,650.75	70.30	177.86	7,650.75	70.30	177.86	7,650.75	70.30	177.86	7,650.75	70.30	177.86	7,650.75	70.30	177.86	7,650.75	70.30	177.86	7,650.75
X_4	Alfalfa (A)	64.00[1]	256.33	1,629.44																					
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)				24.30	138.51	1,576.83	33.21	189.30	2,155.00	42.11	240.03	2,732.52	51.02	290.80	3,310.69	59.92	341.54	3,888.21	68.83	392.32	4,466.38	77.74	443.09	5,044.55
X_8	Grain Sorghum	17.30[2]	22.88	268.67	63.90	79.88	992.37	54.99	68.72	853.99	46.09	57.61	715.78	37.18	46.47	577.41	28.28	35.35	439.19	19.37	24.20	300.82	10.46	13.05	162.44
X_9	Forage Sorghum	11.70[3]	24.00	-270.27																					
X_{10}	Barley	42.00[4]	58.75	-538.86																					
	Fallow																								
	Total	158.50	521.37	8,251.38	158.50	396.25	10,219.95	158.50	435.88	10,659.74	158.50	475.50	11,099.05	158.50	515.13	11,538.85	158.50	554.75	11,978.15	158.50	594.38	12,417.95	158.50	634.00	12,857.74
											MODEL C														
X_1	Cotton (65)				70.30	127.95	6,598.35	70.30	127.95	6,598.35															
X_2	Cotton (80)	70.30	159.41	7,162.40																					
X_3	Cotton (95)										70.30	187.00	7,650.75	70.30	187.00	7,650.75	70.30	187.00	7,650.75	70.30	187.00	7,650.75	70.30	187.00	7,650.75
X_4	Alfalfa (A)	64.00[1]	256.33	1,629.44	25.55	109.60	650.00	2.38	10.21	60.59	13.74	58.94	349.82												
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)				26.45	158.70	1,716.34	49.62	297.72	3,219.84	38.26	229.56	2,482.69	52.00	312.00	3,374.28	53.70	322.20	3,484.59	62.17	373.02	4,034.21	70.64	423.83	4,583.83
X_8	Grain Sorghum	17.30[2]	22.88	268.67										12.22	16.13	189.78	34.50	45.55	535.79	26.03	34.36	404.25	17.56	23.17	272.71
X_9	Forage Sorghum	11.70[3]	24.00	-270.27																					
X_{10}	Barley	42.00[4]	58.75	-538.86																					
	Fallow				36.20	0.00	0.00	36.20	0.00	0.00	36.20	0.00	0.00	23.98	0.00	0.00									
	Total	158.50	521.37	8,251.38	158.50	396.25	8,965.19	158.50	435.88	9,878.78	158.50	475.50	10,483.26	158.50	515.13	11,214.81	158.50	554.75	11,671.13	158.50	594.38	12,089.21	158.50	634.00	12,507.29

1 Not included in total, 7.4 acres

2 Not included in total, 4.7 acres

3 Not included in total, 10.0 acres

4 Not included in total, 24.7 acres

acre) of irrigation water diversions, cotton would be produced on the maximum number of acres allowed under the cotton program, or about 44 percent of water-right acres. About 13 percent of the water-right acres would be devoted to the production of alfalfa at the "D" level and the remaining acres (43 percent of water-right acres) would be devoted to grain sorghum. The above combinations of enterprises would result in a net farm return of approximately $9,999.80.

As more irrigation becomes available, alfalfa D substitutes for grain sorghum at a rate of 8.40 acres per one-fourth acre-foot of irrigation water per water-right acre until 4.52 acre-feet of irrigation water is pumped per water-right acre, where only cotton (95) and alfalfa (D) are produced on the water-right acres. If more than 4.52 acre-feet were available net farm returns to land and management would not increase, but would remain at $13,374.05, which is about 62 percent above the typical whole farm budget.

Although the above combinations of crop enterprises result in the maximum returns for each quantity of irrigation water, they do not specifically allow for a crop rotation program. Crop yields, and therefore returns, would be reduced if these combinations of crop enterprises were produced for extended time periods at the lower levels of irrigation water pumpage.

Linear Programming Solutions--Model B

The coefficients and constraints for model B are the same as for model A except that irrigation water coefficients have been reduced by 5 percent. The irrigation water coefficients and constraints for model B are listed below:

$$1.73X_1 + 2.13X_2 + 2.53X_3 + 4.08X_4 + 0X_5 + 5.06X_6 + 5.70X_7 + 1.25X_8$$

$$+ 1.95X_9 + 1.33X_{10} \leq 396.25 \text{ acre-feet of irrigation water}$$

The X variables are identified in table 27.

In table 27 the whole farm budget for the typical crop year is compared with the results of model B. These solutions, presented in table 27, indicate the optimal net farm returns and the combinations of crops that would be produced if there were no assumed crop rotation program on Case Farm C.

In table 27 the net farm return obtained from the linear programming solutions is also contrasted with $8,251.38, which was obtained from the typical crop year with 521.37 acre-feet of irrigation water (3.29 acre-feet per water-right acre). The net farm return for the typical crop year would have been increased about 24 percent with the combination of crop enterprises that is indicated in model B with 2.50 acre-feet of irrigation water; about 29 percent with 2.75 acre-feet;

about 35 percent with 3.00 acre-feet; about 40 percent with 3.25 acre-feet; about 45 percent with 3.50 acre-feet; about 50 percent with 3.75 acre-feet; and about 56 percent with 4.00 acre-feet.

The solutions for model B reflect a 5 percent increase in irrigation water efficiency on each crop. If 2.50 acre-feet of irrigation water per water-right acre were available, cotton would comprise about 44 percent of the water-right acres, grain sorghum about 41 percent, and alfalfa D about 15 percent. As more irrigation water becomes available, alfalfa D substitutes for grain sorghum at a rate of 8.91 acres per one-fourth acre-foot per water-right acre until 4.29 acre-feet per acre are pumped. If more than 4.29 acre-feet were available, net farm returns would not be increased, but would remain at $13,374.05. This is about 62 percent of the whole farm budget. A 5 percent increase in irrigation efficiency increased the optimal net farm return by an average of about 2.5 percent.

Linear Programming Solutions--Model C

The coefficients and constraints for model C are the same as for model A except that an additional constraint was placed on a minimum amount of alfalfa being produced. The coefficients and the added constraint are listed below:

$$0X_1 + 0X_2 + 0X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 0X_8 + 0X_9 + 0X_{10} \geq 52.00$$

acres of alfalfa

The X variables are identified in table 27.

In table 27 the whole farm budget for the typical crop year is compared with the results of model C. These solutions, presented in table 27, indicate the optimal net farm returns and the combinations of crops that would be produced if a minimum of about one-third of the water-right acres were devoted to alfalfa production, which is the assumed crop rotation program.

In table 27 the net farm return obtained from the linear programming solutions is also contrasted with $8,251.38, which was obtained from the typical crop year with 521.37 acre-feet of irrigation water (3.29 acre-feet per water-right acre). The net farm return for the typical crop year would have been increased about 9 percent with the combination of crop enterprises that is indicated in model C with 2.50 acre-feet of irrigation water; increased about 20 percent with 2.75 acre-feet; increased about 27 percent with 3.00 acre-feet; increased about 40 percent with 3.25 acre-feet; increased about 41 percent with 3.50 acre-feet; increased about 47 percent with 3.75 acre-feet; and increased about 52 percent with 4.00 acre-feet.

The primary reason for the lower net return figure at 2.50 acre-feet of irrigation water per water-right acre is the requirement that about one-third of the farm be planted in alfalfa. In order to have enough water for alfalfa, cotton must be planted at the 35 percent diversion level and approximately one-fourth of the farm must be left fallow. Also, alfalfa A and D would be produced which require 4.29 and 6.00 acre-feet of irrigation per acre respectively.

As more irrigation water becomes available more acres would be devoted to alfalfa D. At the 2.75 level of irrigation water diversion alfalfa A shifts to alfalfa D acreage. At the 3.00 acre-feet irrigation water diversion level, alfalfa D acreage would decrease to 38.26 acres as the cotton acreage shifts from 65 percent to 95 percent planted. With 3.25 acre-feet of irrigation water available per water-right acre, the maximum net farm return is obtained with 66.79 acres of planted cotton, 52.0 acres of alfalfa D, 12.22 acres of grain sorghum, and 23.98 acres of fallow.

The optimal solutions and cropping patterns for 3.50, 3.75, and 4.00 acre-feet per water-right acre are reported in table 27.

The immediate economic effect of forcing a crop rotation of about one-third of the farm into alfalfa is a reduction in net farm returns at irrigation water diversion less tha 554.75 acre-feet (3.50 acre-feet per water-right acre). This effect can be estimated by comparing those linear programming solutions from model A with solutions from model C. Net farm return would be reduced by $1,034.61 (11.5 percent) at the 2.50 acre-feet per water-right acre, $538.61 (5.5 percent) at 2.75 acre-feet, $352.21 (3.4 percent) at 3.00 acre-feet, $38.73 (0.3 percent) at 3.25 acre-feet, $0.49 at 3.50 acre-feet, and $0.00 at 3.75 acre-feet per water-right acre.

The results obtained from the three linear programming models are graphically summarized in figure 11. This graph indicates the effects of the seven quantities of irrigation water on the net farm return. In models A and B, as irrigation water is increased from 396.25 acre-feet to 716.20 acre-feet (2.50 to 4.52 acre-feet per water-right acre), and 396.25 to 680.60 acre-feet (2.50 to 4.29 acre-feet per water-right acre) the net farm return increases at a constant rate. Beyond 716.20 and 680.60 acre-feet for models A and B respectively, the size of farm (cultivated acres) and cropping enterprises considered in this study become the factors that restrict net farm returns.

In model C, as irrigation water is increased from 396.25 acre-feet to 435.88 acre-feet (2.50 to 2.75 acre-feet per water-right acre), the net return per water-right acre increases at almost a constant rate. From 435.88 to 554.75 acre-feet (2.75 to 3.50 acre-feet) the rate of increase is at a decreasing rate, and beyond 554.75 acre-feet (3.50 acre-feet per water-right acre) the cropping programs and net farm returns are identical to model A.

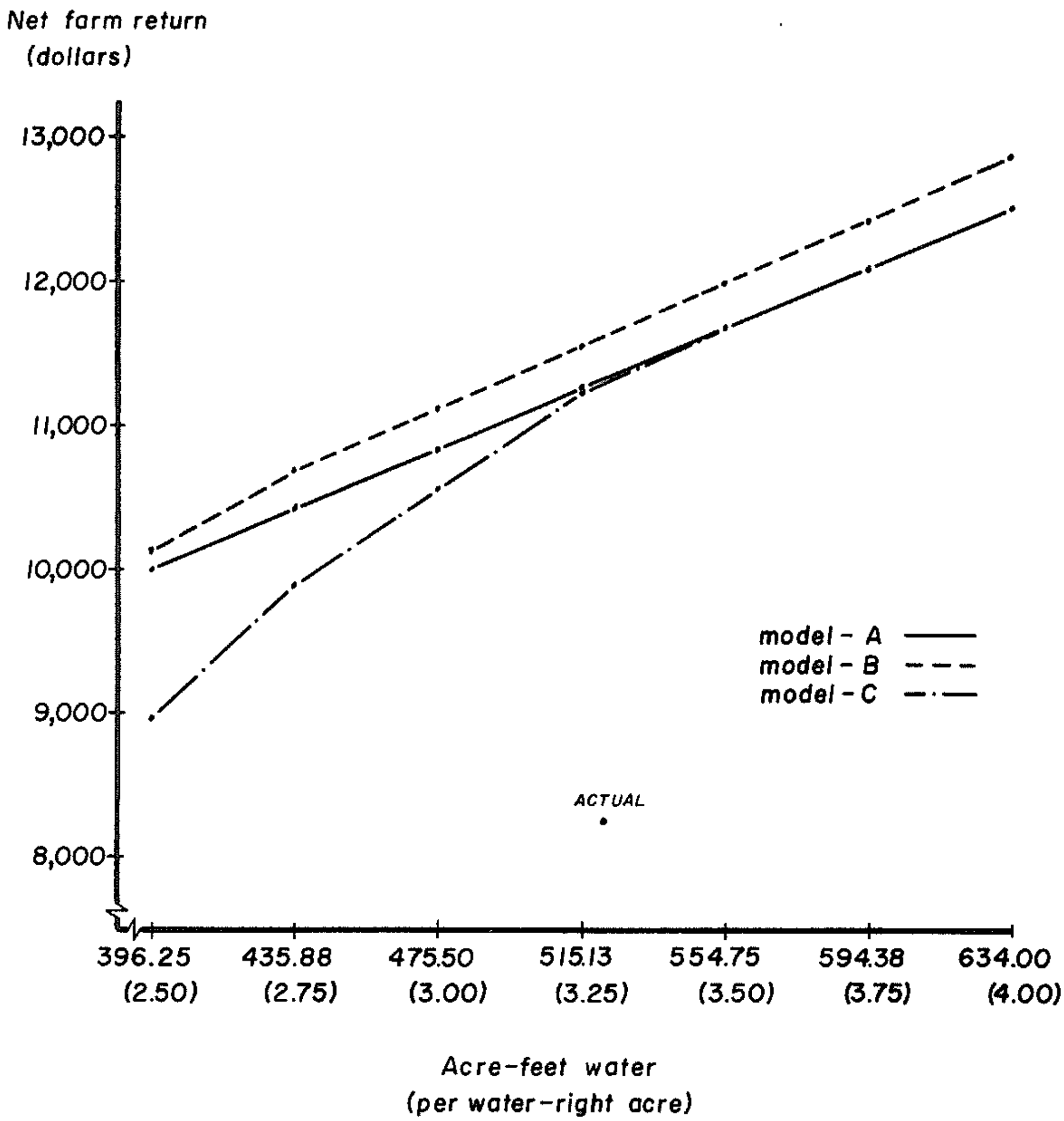


Figure 11. Case Farm C: Net farm return for seven quantities of irrigation water, Roswell Artesian Basin, New Mexico.

Optimal Quantity of Irrigation Water

The optimal prices (marginal value products) for an additional acre-foot of irrigation water are presented in table 28. The optimal level of irrigation water diversion for each model can be determined by equating the shadow price with the cost of pumping an acre-foot of irrigation water, which was $7.68. For model A the optimal quantity of water was 716.20 acre-feet (4.52 acre-feet per water-right acre); for model B, 680.60 acre-feet (4.29 acre-feet per water-right acre); and for model C, 716.20 acre-feet (4.52 acre-feet per water-right acre).

If irrigation water diversion were limited to 475.50 acre-feet (3.00 acre-feet per water-right acre) instead of the optimal quantities in each model, net farm return would be reduced by $2,538.58 (23.4 percent), $2,275.00 (20.5 percent), and $2,890.79 (27.6 percent) for models A, B, and C respectively. It would appear that Case Farm C was being operated below the optimal cropping program for maximum return.

Table 28. Case Farm C: Shadow prices for seven quantities of irrigation water diversion, Roswell Artesian Basin, New Mexico.

Quantity of Irrigation Water Diverted	Shadow Price Model A	Shadow Price Model B	Shadow Price Model C
(acre-feet)	(dollars)	(dollars)	(dollars)
396.25	10.55	11.09	23.06
435.88	10.55	11.09	23.06
475.50	10.55	11.09	17.82
515.13	10.55	11.09	11.77
554.75	10.55	11.09	10.55
594.38	10.55	11.09	10.55
634.00	10.55	11.09	10.55

CASE FARM D

GENERAL DESCRIPTION

Case Farm D was an owner-operator farm with 313.0 acres of artesian water rights. The actual irrigated acreage was 303.7 acres in 1966 and 1967, and 299.7 acres in 1968. A feedlot occupied 9.3 acres in 1966 and 1967, and 13.3 acres in 1968. The feedlot was not included in the analysis of Farm D because sufficient economic data could not be obtained from the operator. This farm changed operators in 1968. Case Farm D was located in the Roswell-East Grand Plains Area (figure 2). For purposes of this study water-right acres were assumed to be 303.7 acres.

Soils

Soils included on Farm D were Reagan Loam and Atoka Loam. The Reagan Loam comprised about 98.4 percent of the irrigated cropland and the Atoka Loam about 1.6 percent. The location of these soils is shown in figure 12. The Reagan Loam was SCS Capability Class I and the Atoka Loam was SCS Capability Class II. A further soils description appears in appendix A.

Irrigation Water

Case Farm D had four artesian wells producing from 500 to 1,000 gallons per minute. The water from these wells had an average total soluble salt content of about 914 millimhos and the average sodium adsorption ratio was about 0.7 for the three-year period (2). The quality classification of this water was Class 3.

Irrigation System

Two reservoirs were used on Farm D in 1966 and 1967. The larger reservoir was supplied with water from three artesian wells (figure 12) and one artesian well supplied irrigation water for the small reservoir, located in the southwest corner of the farm. These reservoirs drained into both underground pipeline and concrete ditch. The large reservoir was taken out following the 1967 crop year. Approximately 250 feet of underground pipeline, 13,860 feet of concrete ditch, and 19,470 feet of earthen primary and secondary ditches were included in the irrigation system.

Except for 155.2 acres in fields 1, 2, 3, 9, and 11, all of the cropland on Farm D was leveled in 1966 and 1967. During 1968 field 9 was leveled. Borders were not employed in the irrigation of the alfalfa fields.

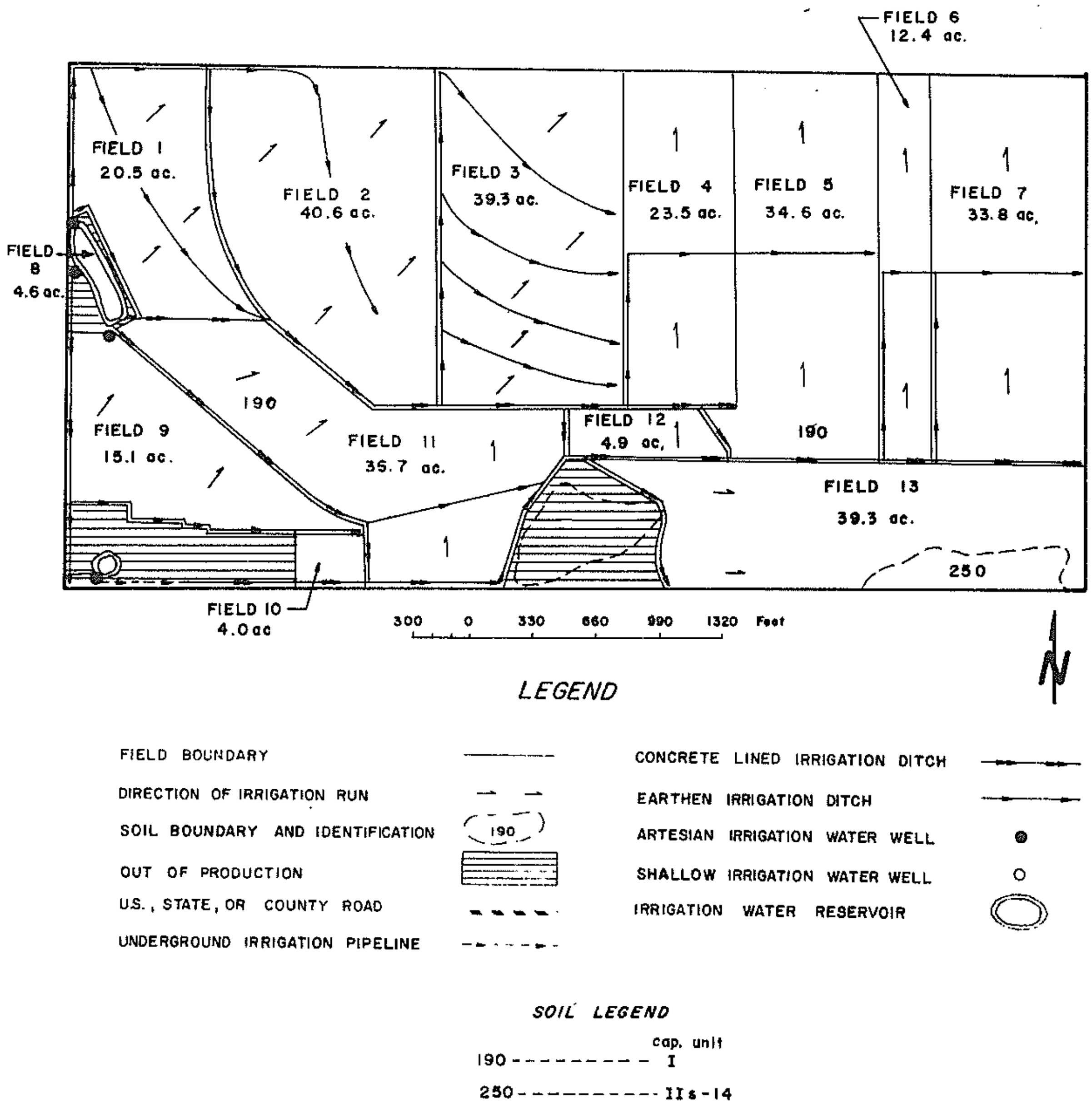


Figure 12. Map of Case Farm D.

The approximate lengths of irrigation water runs for the different fields on Case Farm D are reported in table 29.

Table 29. Case Farm D: Crops planted and approximate lengths of irrigation water runs by field, Roswell Artesian Basin, New Mexico.

Field Number	Crops Planted 1966	1967	1968	Length of Run (feet)
1	Alfalfa	Alfalfa	Alfalfa	210- 580
2	Cotton	Sudex	Sudex	400- 580
3	Alfalfa	Alfalfa	Alfalfa	240- 660
4	Corn silage	Barley Corn	Cotton Diverted Corn Alfalfa	790- 920
5	Alfalfa	Cotton	Cotton Barley Hegari	920-1060
6	Hegari	Corn	Cotton	980-1,030
7	Diverted Barley	Barley Corn	Cotton	980-1,030
8	Reservoir	Reservoir	Diverted	----
9	Cotton	Cotton	Barley Alfalfa	320- 660
10	Sudex	Out	Out	300- 330
11	Corn Alfalfa	Alfalfa	Alfalfa	580- 790
12	Alfalfa	Alfalfa	Alfalfa	210- 260
13	Alfalfa	Cotton Diverted	Cotton	660- 700

Crops Produced

Cotton, alfalfa, barley, sudex, and corn silage were the principal crops produced on Case Farm D. The farm had a cotton allotment of 93.0 acres in 1966 and 1967, and 89.0 acres in 1968. In 1966 there were 60.6 acres planted in cotton and 32.5 acres were diverted. Planted acres were 81.0 in 1968 with 8.0 diverted (table 30). The diversion rates were 35 percent in 1966 and 1967, and 9 percent in 1968. Projected per-acre yields in pounds by ASC were 880 in 1966, 915 in 1967, and 885 in 1968. The actual per-acre yields in pounds were 704 in 1966, 612 in 1967, and 581 in 1968 (table 31).

Alfalfa was produced on 133.7 acres in 1966, 100.4 acres in 1967, and 131.1 acres in 1968 (table 30). The alfalfa hay yields were adjusted to 8.0 tons in 1966, 5.7 tons in 1967, and 6.7 tons in 1968, to allow for the lower yield obtained in the first year of the assumed five-year production period (table 31). Barley was produced on 33.8 acres in 1966, 57.3 acres in 1967, and 49.6 acres in 1968. The yields are reported in table 31. Corn silage was produced on 59.2 acres in 1966, 69.7 acres in 1967, and 11.0 acres in 1968. Sudex was produced on 4.0 acres in 1966 and 40.6 acres in 1967 and 1968. Hegari was produced in 1966 and 1968 on 12.4 and 34.5 acres respectively. The acreage and per-acre yields are presented in tables 30 and 31 for all crops.

Irrigation Water Pumped

In 1966 a total of 1,035 acre-feet of irrigation water were pumped on Farm D (table 30). In 1967, 1,036 acre-feet were diverted with an average of 3.41 acre-feet per water-right acre, 3.41 acre-feet per cultivated acre, and 3.82 acre-feet per cropped acre. The average quantity of irrigation water diverted for all farms in the Roswell-East Grand Plains Area was 2.66 acre-feet per water-right acre, 2.94 acre-feet per cultivated acre, and 3.39 acre-feet per cropped acre (9, p. 130).

In 1968 the quantity of irrigation water diverted on Farm D was 832 acre-feet, 203 acre-feet less than in 1966 and 204.30 acre-feet less than in 1967. The per-acre diversion was 2.74 acre-feet, which is slightly below the average of the Roswell-East Grand Plains Area (12). This reduction in irrigation water pumpage can be partially attributed to the change in operators for the 1968 crop year and climate conditions. The average per-acre diversion for cotton for the three-year period was 2.38 acre-feet per acre. Alfalfa received an average of 4.97 acre-feet per acre on the established stand. The seedling alfalfa received an average of 2.80 acre-feet per acre. The corn silage received an average of 1.97 acre-feet per

Table 30. Case Farm D: Crop acreages and irrigation water pumpage, Roswell Artesian Basin, New Mexico

Crop	Acres				Irrigation Water Pumped							
					Per Crop				Per Acre			
	1966	1967	1968	Average	1966	1967	1968	Average	1966	1967	1968	Average
					(acre-feet)				(acre-feet)			
Cotton	60.6	60.5	81.0	67.4	170.00	182.60	128.41	160.34	2.81	3.02	1.59	2.38
Diverted	32.5	32.5	8.0	24.3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alfalfa	133.7	59.8	100.4	98.0	650.00	318.00	492.19	486.73	4.86	5.32	4.90	4.97
Seedling alfalfa	0.0	40.6[1]	30.7[2]	23.8[3]	0.00	189.60	10.17	66.59	0.00	4.67	0.33	2.80
Corn silage	59.2	69.7	11.0	46.6	120.00	139.40	15.40	91.60	2.03	2.00	1.40	1.97
Sudex	4.0	40.6	40.6	28.4	10.00	82.10	64.44	52.18	2.50	2.02	1.59	1.84
Barley	33.8[4]	57.3[5]	49.6	46.9[6]	60.00	124.60	95.76	93.45	1.78	2.17	1.93	1.99
Hegari	12.4	0.0	34.5[7]	15.6[8]	25.00	0.00	25.63	16.88	2.02	0.00	0.74	1.08
Fallow	1.3	0.0	13.1	4.8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	303.7	303.7	303.7	303.7	1,035.00	1,036.30	832.00	967.77	3.41	3.41	2.74	3.19

1. Spring planted.
2. Fall planted, not included in total, 15.1 acres was barley, 4.6 acres was diverted, and 11.0 acres was corn silage acreage.
3. Not included in total, 10.2 acres.
4. Not included in total, was diverted and fallow acreage.
5. Not included in total, was corn silage acreage.
6. Not included in total, 30.4 acres.
7. Not included in total, was barley acreage.
8. Not included in total, 11.5 acres.

acre, the sudex received 1.84 acre-feet per acre, the barley received 1.99 acre-feet per acre, and hegari received 1.08 acre-feet per acre.

Table 31. Case Farm D: Crops and yields per acre, Roswell Artesian Basin, New Mexico.

Crop	Unit	Yield per Acre 1966	1967	1968	Average
Cotton planted	lb.				
Lint	lb.	703.5	612.0	581.0	632.2
Seed	ton	0.53	0.46	0.44	0.48
Alfalfa	ton	8.0	5.7	6.7	6.8
Corn silage	ton	18.0	15.0	20.0	17.7
Sudex	ton	40.0	20.0	25.4	28.5
Barley					
Seed	bu.	61.8	----	61.8	61.8
Hay	ton	----	3.9	----	3.9
Hegari	ton	18.0	----	7.7	12.85

Irrigation Efficiency

The typical irrigation efficiency by crops is reported in table 32 and yearly estimates in table C4. Irrigation efficiency on cotton ranged from 53.39 to 96.02 with an average of 63.34 percent; on alfalfa, from 45.46 to 51.80 with an average of 48.59 percent; on barley from 50.23 to 75.22 with an average of 63.01 percent. Forage crops, corn, sudex, and hegari averaged 64.32, 51.88, and 78.56 percent respectively (table C4).

Table 32. Case Farm D: Typical consumptive irrigation requirement, irrigation water applied, and farm irrigation efficiency.

Crop	Consumptive Irrigation Requirement (acre-inches)	Irrigation Water Applied (acre-inches)	Farm Irrigation Efficiency (percent)
Cotton	18.80	29.68	63.34
Alfalfa	29.31	60.32	48.59
Corn	13.97	21.72	64.32
Sudex	12.68	24.44	51.88
Barley	14.82	23.52	63.01
Hegari	13.01	16.56	78.56

ECONOMIC ANALYSIS

Financial Summary

The typical per-acre net return to land and management for each crop is reported in table 33 with the yearly figures reported in table D4. The net farm returns for all crops produced on Farm D were $24,434.84 in 1966, $23,188.32 in 1967, and $25,621.23 in 1968 (table E4).

Table 33. Case Farm D: Typical per-acre returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns per Acre (dollars)	Gross Expenses per Acre (dollars)	Net Returns to Land and Management per Acre (dollars)
Cotton planted	316.75	140.47	176.28
Cotton diverted	90.04	9.80	80.24
Alfalfa	167.70	109.65	58.05
Corn silage	114.92	69.46	45.46
Sudex	113.87	52.94	60.93
Barley	66.99	54.59	12.40
Hegari	74.69	52.06	22.63
Weighted average	160.39	87.94	72.45

A typical whole farm budget was completed for Case Farm D on the basis of typical costs, prices, and yields (table 34). This typical whole farm budget will be used to compare with the linear programming solutions to determine the effect of different levels of irrigation water diversions on net farm returns. The annual whole farm budgets are presented in appendix E (table E4).

Table 34. Case Farm D: Typical whole farm returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns	Gross Expenses	Net Returns to Land and Management
		(dollars)	(dollars)	(dollars)
Cotton planted	67.4	21,348.95	9,467.68	11,881.27
Cotton diverted	24.3	2,187.97	238.14	1,949.83
Alfalfa	121.8	20,425.86	13,355.37	7,070.49
Corn silage	46.6	5,355.27	3,236.84	2,118.43
Sudex	28.4	3,233.91	1,503.50	1,730.41
Barley	46.9	3,141.83	2,560.27	581.56
Hegari	15.6	1,165.18	812.14	353.04
Total	351.0	56,858.97	31,173.94	25,685.03

Linear Programming Solutions--Model A

The coefficients and constraints for model A are presented below:

$$1X_1 + 1X_2 + 1X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 1X_8 + 1X_9 + 1X_{10} + 1X_{11} + 1X_{12} \leq 303.7 \text{ acres}$$

$$1X_1 + 1X_2 + 1X_3 + 0X_4 + 0X_5 + 0X_6 + 0X_7 + 0X_8 + 0X_9 + 0X_{10} + 0X_{11} + 0X_{12} \leq 91.7 \text{ acres of cotton}$$

$$1.55X_1 + 1.90X_2 + 2.26X_3 + 4.97X_4 + 0X_5 + 5.33X_6 + 6.00X_7 + 1.97X_8 + 1.84X_9 + 2.30X_{10} + 1.99X_{11} + 1.08X_{12} \leq 782 \text{ acre-feet of irrigation water}$$

The X variables are identified in table 35.

Table 35. Case Farm D: Whole farm budget and linear programming solutions, models A, B, and C, Roswell Artesian Basin, New Mexico.

Variable	Crop	Whole Farm Budget			Linear Programming Solutions																				
					2.50 acre feet per acre			2.75 acre feet per acre			3.00 acre feet per acre			3.25 acre feet per acre			3.50 acre feet per acre			3.75 acre feet per acre			4.00 acre feet per acre		
		Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars
	MODEL A																								
X_1	Cotton (65)																								
X_2	Cotton (80)	91.70	160.34	13,831.10																					
X_3	Cotton (95)				91.70	207.24	15,724.72	91.70	207.24	15,724.72	91.70	207.24	15,724.72	91.70	207.24	15,724.72	91.70	207.24	15,724.72	91.70	207.24	15,724.72	91.70	207.24	15,724.72
X_4	Alfalfa (A)	121.80[1]	553.32	7,070.49																					
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)				44.51	267.07	3,420.15	63.32	379.93	4,865.51	82.13	492.79	6,310.87	100.94	605.65	7,756.23	119.75	718.51	9,201.59	138.56	831.37	10,646.95	157.37	944.23	12,092.31
X_8	Corn Silage	46.60	91.60	2,118.43																					
X_9	Sudex	28.40	52.18	1,730.41	167.49	308.19	10,205.17	148.68	273.58	9,059.07	129.87	238.97	7,912.98	111.06	204.36	6,766.89	92.25	169.75	5,620.79	73.44	135.14	4,474.70	54.63	100.53	3,328.61
X_{10}	Grain Sorghum																								
X_{11}	Barley	46.90[2]	93.45	581.56																					
X_{12}	Hegari	15.60[3]	16.88	353.04																					
	Fallow	3.50	0.00	0.00																					
	Total	302.40	967.77	25,685.03	303.70	782.50	29,350.04	303.70	860.75	29,649.30	303.70	939.00	29,948.57	303.70	1,017.25	30,247.84	303.70	1,095.50	30,547.10	303.70	1,173.75	30,846.37	303.70	1,252.00	31,145.64
	MODEL B																								
X_1	Cotton (65)																								
X_2	Cotton (80)	91.70	160.34	13,831.10																					
X_3	Cotton (95)				91.70	197.16	15,724.72	91.70	197.16	15,724.72	91.70	197.16	15,724.72	91.70	197.16	15,724.72	91.70	197.16	15,724.72	91.70	197.16	15,724.72	91.70	197.16	15,724.72
X_4	Alfalfa (A)	121.80[1]	553.32	7,070.49																					
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)				54.26	309.28	4,169.34	74.07	422.20	5,691.54	93.88	535.12	7,213.74	113.70	648.08	8,736.71	133.51	761.00	10,258.91	153.32	873.91	11,781.11	173.13	986.83	13,303.31
X_8	Corn Silage	46.60	91.60	2,118.43																					
X_9	Sudex	28.40	52.18	1,730.41	157.74	276.06	9,611.10	137.93	241.39	8,404.07	118.12	206.72	7,197.05	98.30	172.01	5,972.97	78.49	137.34	4,782.40	58.68	102.68	3,575.37	38.87	68.01	2,368.35
X_{10}	Grain Sorghum																								
X_{11}	Barley	46.90[2]	93.45	581.56																					
X_{12}	Hegari	15.60[3]	16.88	353.04																					
	Fallow	3.50	0.00	0.00																					
	Total	302.40	967.77	25,685.03	303.70	782.50	29,505.16	303.70	860.75	29,820.33	303.70	939.00	30,135.51	303.70	1,017.25	30,434.40	303.70	1,095.50	30,766.03	303.70	1,173.75	31,081.20	303.70	1,252.00	31,396.38
	MODEL C																								
X_1	Cotton (65)																								
X_2	Cotton (80)	91.70	160.34	13,831.10																					
X_3	Cotton (95)				91.70	207.24	15,724.72	91.70	207.24	15,724.72	91.70	207.24	15,724.72	91.70	207.24	15,724.72	91.70	207.24	15,724.72	91.70	207.24	15,724.72	91.70	207.24	15,724.72
X_4	Alfalfa (A)	121.80[1]	553.32	7,070.49	100.00	497.00	5,805.00	100.00	497.00	5,805.00	20.34	101.09	1,180.74												
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)										79.66	424.59	5,334.83												
X_7	Alfalfa (D)													100.94	605.65	7,756.23	119.75	718.51	9,201.59	138.56	831.37	10,646.95	157.37	944.23	12,092.31
X_8	Corn Silage	46.60	91.60	2,118.43																					
X_9	Sudex	28.40	52.18	1,730.41	42.53	78.26	2,591.35	85.06	156.51	5,182.71	112.00	206.08	6,824.16	111.06	204.36	6,766.89	92.25	169.75	5,620.79	73.44	135.14	4,474.20	54.63	100.53	3,328.61
X_{10}	Grain Sorghum																								
X_{11}	Barley	46.90[2]	93.45	581.56																					
X_{12}	Hegari	15.60[3]	16.88	353.04																					
	Fallow	3.50	0.00	0.00	69.47	0.00	0.00	26.94	0.00	0.00															
	Total	302.40	967.77	25,685.03	303.70	782.50	24,121.07	303.70	860.75	26,712.43	303.70	939.00	29,064.45	303.70	1,017.25	30,247.84	303.70	1,095.50	30,547.10	303.70	1,173.75	30,846.37	303.70	1,252.00	31,145.64

1 Not included in total, 10.2 acres

2 Not included in total, 30.4 acres

3 Not included in total, 11.5 acres

The parameter changes in irrigation water diversion (Qt), where Q = 782.50 acre-feet of irrigation water and t = 78.25 acre-feet result in the following irrigation water constraints:

2.75 acre-feet per water-right acre = 860.75 acre-feet
3.00 acre-feet per water-right acre = 939.00 acre-feet
3.25 acre-feet per water-right acre = 1,017.25 acre-feet
3.50 acre-feet per water-right acre = 1,095.50 acre-feet
3.75 acre-feet per water-right acre = 1,173.75 acre-feet
4.00 acre-feet per water-right acre = 1,252.00 acre-feet

In table 35 the whole farm budget for the typical crop year is compared with the results of model A. The linear programming solutions presented in table 35 indicate the optimal net farm returns and the combinations of eleven crops that would be produced if there were no assumed crop rotation program on Case Farm D.

In table 35 the net farm return obtained from the linear programming solutions is also contrasted with $25,685.03, which was obtained from the typical crop year with 967.77 acre-feet of irrigation water (3.20 acre-feet acre). The net farm return for the typical crop year would have been increased about 14 percent with the combination of crop enterprises that is indicated in model A with 2.50 acre-feet of irrigation water; about 15 percent with 2.75 acre-feet; about 17 percent with 3.00 acre-feet; about 18 percent with 3.25 acre-feet; about 19 percent with 3.50 acre-feet; about 20 percent with 3.75 acre-feet; and about 21 percent with 4.00 acre-feet.

The lower net farm return for the typical crop year can be attributed primarily to the production of cotton at the 73.5 percent level of the allotment, and to the production of barley and forage sorghum. Even at low levels (2.50 acre-feet per water-right acre) of irrigation water diversions, cotton would be produced on the maximum number of acres allowed under the cotton program, or about 29 percent of the water-right acres. About 15 percent of the water-right acres would be devoted to the production of alfalfa at the "D" level and the remaining tillable acres (56 percent of water-right acres) would be devoted to sudex. The above combination of enterprises would result in a net farm income of approximately $29,350 which is about 14 percent above the whole farm budget.

As more irrigation water becomes available, alfalfa D substitutes for grain sorghum at a rate of 18.81 acres per one-fourth acre-foot of irrigation water per water-right acre until 1,479.24 acre-feet of irrigation water is pumped (4.87 acre-feet per water-right acre) where only cotton 95 and alfalfa D are produced on the cropable acres. If more than 1,479.24 acre-feet were available, net farm returns to land and management would not increase, but would remain at $32,014.80 which is 24.6 percent above the whole farm budget.

Although the above combinations of crop enterprises result in the maximum returns for each quantity of irrigation water, they do not specifically allow for a crop rotation program. Crop yields, and therefore returns, would be reduced if these combinations of crop enterprises were produced for extended time periods at the lower levels of irrigation water pumpage.

Linear Programming Solutions--Model B

The coefficients and constraints for model B are the same as for model A except that irrigation water coefficients have been reduced by 5 percent. The irrigation water coefficient and the first irrigation water constraint for model B are listed below:

$1.47X_1 + 1.81X_2 + 2.15X_3 + 4.72X_4 + 0X_5 + 5.06X_6 + 5.70X_7 + 1.87X_8$

$+ 1.75X9 + 2.19X_{10} + 1.89X_{11} + 1.02X_{12} \leq 782.48$ acre-feet of irrigation water

The X variables are identified in table 35.

In table 35 the whole farm budget for the typical crop year is compared with the results of model B. These solutions presented in table 35 indicate the optimal net farm returns and the combinations of crops that would be produced if there were no assumed crop rotation program on Case Farm D.

In table 35 the net farm return obtained from the linear programming solutions is also contrasted with $25,685.03, which was obtained from the typical crop year with 967.77 acre-feet of irrigation water (3.20 acre-feet per water-right acre). The net farm return for the typical crop year would have been increased about 15 percent with the combination of crop enterprises that is indicated in model B with 2.50 acre-feet of irrigation water; about 16 percent with 2.75 acre-feet; about 17 percent with 3.00 acre-feet; about 18 percent with 3.25 acre-feet; about 20 percent with 3.50 acre-feet; about 21 percent with 3.75 acre-feet; and about 22 percent with 4.00 acre-feet.

The solutions for model B reflect a 5 percent increase in irrigation water efficiency on each crop. If 782.50 acre-feet of irrigation water (2.50 acre-feet per water-right acre) were available, cotton would comprise about 29 percent of the water-right acres, sudex about 51 percent, alfalfa about 17 percent, and the remaining 3 percent would be diverted or fallow. As more irrigation water becomes available, alfalfa D substitutes for grain sorghum at a rate of 19.81 acres per one-fourth acre-foot or irrigation water per water-right acre until 1,405.56 acre-feet (4.63 acre-feet per acre) are pumped. If more than 1,405.56 acre-feet were available net farm return would not be increased, but would remain at $32,014.80. This is about 25 percent above the typical whole farm budget. A 5 percent increase in irrigation efficiency increased the optimal net farm return by an average of 1 percent.

Linear Programming Solutions--Model C

The coefficients and constraints for model C are the same as for model A except that an additional constraint was placed on a minimum amount of alfalfa being produced. The coefficients and the added constraint are listed below:

$$0X_1 + 0X_2 + 0X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 0X_8 + 0X_9 + 0X_{10} + 0X_{11} + 0X_{12} \geq 100 \text{ acres of alfalfa}$$

The X variables are identified in table 35.

In table 35 the whole farm budget for the typical crop year is compared with the results of model C. These solutions, presented in table 35, indicate the optimal net farm returns and the combinations of crops that would be produced if a minimum of one-third of the water-right acres were devoted to alfalfa production, which is the assumed crop rotation program on Case Farm D.

In table 35 the net farm return obtained from the linear programming solutions is also contrasted with $25,685.03, which was obtained from the typical crop year with 967.77 acre-feet of irrigation water (3.20 acre-feet per water-right acre). The net farm return for the typical crop year would have been decreased about 6 percent with the combination of crop enterprises that is indicated in model C with 2.50 acre-feet of irrigation water; increased about 4 percent with 2.75 acre-feet; increased about 13 percent with 3.00 acre-feet; increased about 18 percent with 3.25 acre-feet; increased about 19 percent with 3.50 acre-feet; increased about 20 percent with 3.75 acre-feet; and increased about 21 percent with 4.00 acre-feet.

The primary reason for the lower return figure at 2.50 acre-feet of irrigation water per water-right acre is the requirement that about one-third of the farm be planted in alfalfa. In order to have enough water for alfalfa approximately one-fifth of the farm must be left fallow. Also, alfalfa A should be produced, which requires 4.97 acre-feet of irrigation per acre.

As more irrigation water becomes available more acres would be devoted to alfalfa and sudex. At the 2.75 level of irrigation water diversion, alfalfa A remained unchanged and sudex acreage increased from 42.53 to 85.06 acres. At the 3.00 acre-feet irrigation water diversion level, alfalfa A acreage would decrease to 20.34 acres and alfalfa D would be produced on 79.66 acres. Sudex would be increased to 112 acres. With 3.25 acre-feet of irrigation water available per water-right acre, the maximum net farm return is obtained with 87.12 acres of planted cotton, 100.94 acres of alfalfa D, and 111.06 acres of sudex.

The optimal solutions and cropping patterns for 3.50, 3.75, and 4.00 acre-feet per water-right acre are reported in table 35.

The immediate economic effect of forcing a crop rotation of about one-third of the farm into alfalfa is a reduction in net farm returns at irrigation water diversion of less than 1,017.25 acre-feet (3.25 acre-feet per water-right acre). This effect can be estimated by comparing solutions from model A with solutions from model C. Net farm return would be reduced by $5,228.97 (21.7 percent) at 2.50 acre-feet per water-right acre, $2,936.87 (11 percent) at 2.75 acre-feet per water-right acre, and $883.12 (3.0 percent) at 3.00 acre-feet per water-right acre.

The results obtained from the three linear programming models are graphically summarized in figure 13. This graph indicates the effects of the seven quantities of irrigation water on the net farm return. In model A, as irrigation water is increased from 782.50 acre-feet to 1,479.24 acre-feet (2.50 to 4.87 acre-feet per water-right acre), and in model B from 782.50 to 1,405.56 acre-feet (2.50 to 4.63 acre-feet per water-right acre) the net farm return increases at a constant rate. Beyond 1,479.24 and 1,405.56 acre-feet for models A and B respectively, the size of farm (cultivated acres) and cropping enterprises considered in this study become the factors that restrict net farm returns.

In model C, as irrigation water is increased from 782.50 acre-feet to 939.0 acre-feet (2.50 to 3.00 acre-feet per water-right acre), the net return per water-right acre increases at almost a constant rate. From 939.0 to 1,017.25 acre-feet (3.00 to 3.25 acre-feet) the rate of increase is at a decreasing rate, and beyond 1,017.25 acre-feet (3.25 acre-feet per water-right acre) models A and C are identical.

Optimal Quantity of Irrigation Water

The shadow prices (marginal value products) for an additional acre-foot of irrigation water are presented in table 36. The optimal level of irrigation water diversion for each model can be determined by equating the shadow price with the cost of pumping an acre-foot of irrigation water, which was $7.68. For model A the optimal quantity of water was between 547.75 and 626.0 acre-feet (1.75 and 2.00 acre-feet per water-right acre); for model B, between 547.75 and 626.0 acre-feet (1.75 and 2.00 acre-feet per water-right acre); and for

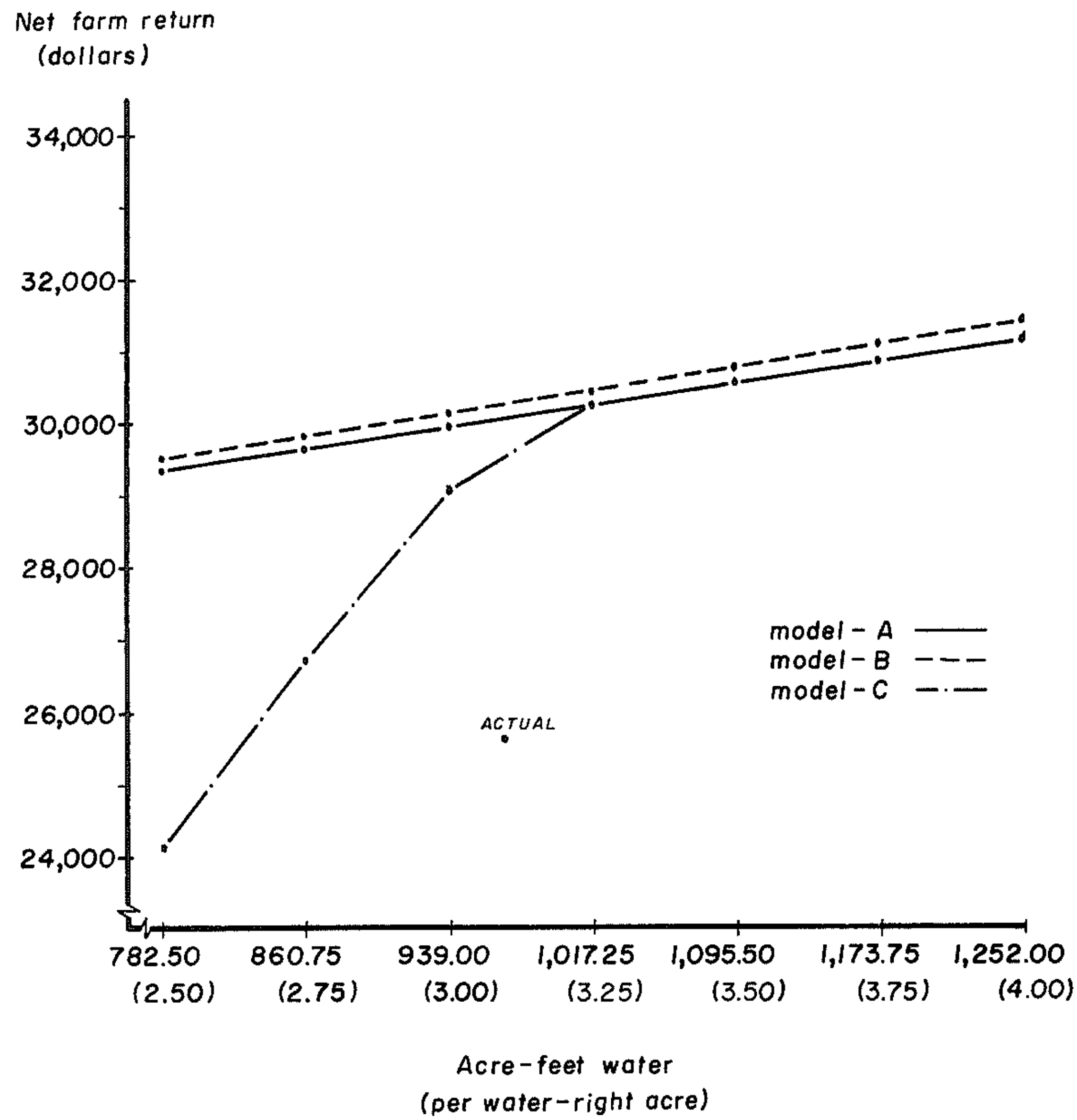


Figure 13. Case Farm D: Net farm return for seven quantities of irrigation water, Roswell Artesian Basin, New Mexico.

model C, between 939.0 and 1,017.25 acre-feet (3.00 and 3.25 acre-feet per water-right acre).

It would appear that 939.0 acre-feet (3.00 acre-feet per water-right acre) would be a sufficient quantity under the conditions of models A and B. However, in model C, if irrigation water diversion were limited to 939.0 acre-feet (3.00 acre-feet per water-right acre) instead of the optimal quantity, net farm returns would have been reduced as much as $1,183.39 or approximately 4 percent. It would appear that Case Farm D was being operated above the optimal cropping program for maximum return under conditions of model A and B, and near the optimal cropping program for model C.

Table 36. Case Farm D: Shadow prices for seven quantities of irrigation water diversion, Roswell Artesian Basin, New Mexico.

Quantity of Irrigation Water Diverted (acre-feet)	Shadow Price Model A (dollars)	Shadow Price Model B (dollars)	Shadow Price Model C (dollars)
782.00	3.82	4.03	33.11
860.75	3.82	4.03	33.11
939.00	3.82	4.03	24.78
1,017.25	3.82	4.03	3.82
1,095.50	3.82	4.03	3.82
1,173.75	3.82	4.03	3.82
1,252.00	3.82	4.03	3.82

CASE FARM E

GENERAL DESCRIPTION

Case Farm E was a partnership farm with 280.0 acres of artesian water rights. This farm was located in the Roswell-East Grand Plains Area (figure 2) and it was in the study for only two years, 1967 and 1968.

Soils

The soils included on Case Farm E were primarily Reagan Loams with over 95 percent classified as Reagan Silty Loam, 4 percent as Reagan Silty Clay Loam, and the remaining 1 percent as Cave Gravelly Loam. The Reagan Silty Loam was SCS Soil Capability Class I, Reagan Silty Clay Loam, Class II, and Cave Gravelly Loam, Class IV (figure 14). These soils are further described in appendix A.

Irrigation Water

Case Farm E had two artesian wells, which produced an average of about 2,500 and 1,200 gallons per minute each. Both of these wells were developed to approximately 500 feet deep, but had pumping lifts of less than 200 feet. Average total soluble salt content of the water from these wells was about 877 millimhos and the average sodium adsorption ratio was about 0.89 for the two-year period 1967 and 1968 (2). The quality classification of this water was Class 2.

Irrigation System

Two artesian wells and two reservoirs were used on Case Farm E. Each artesian well pumped into a reservoir which in turn drained into approximately 11,340 feet of concrete-lined ditch, and about 23,200 feet of earthen primary and secondary lateral ditch (figure 14).

Most of the cropland on Farm E had been leveled. Field 1 and most of field 2 were unleveled. Borders were not employed in the irrigation of the alfalfa fields. The approximate lengths of irrigation water runs for the different fields are reported in table 37.

Crops Produced

The principal crops grown on Case Farm E were cotton, alfalfa, grain sorghum, and barley. Case Farm E had an 80.5-acre cotton allotment. In 1967 there were 75.3 acres of cotton, and in 1968

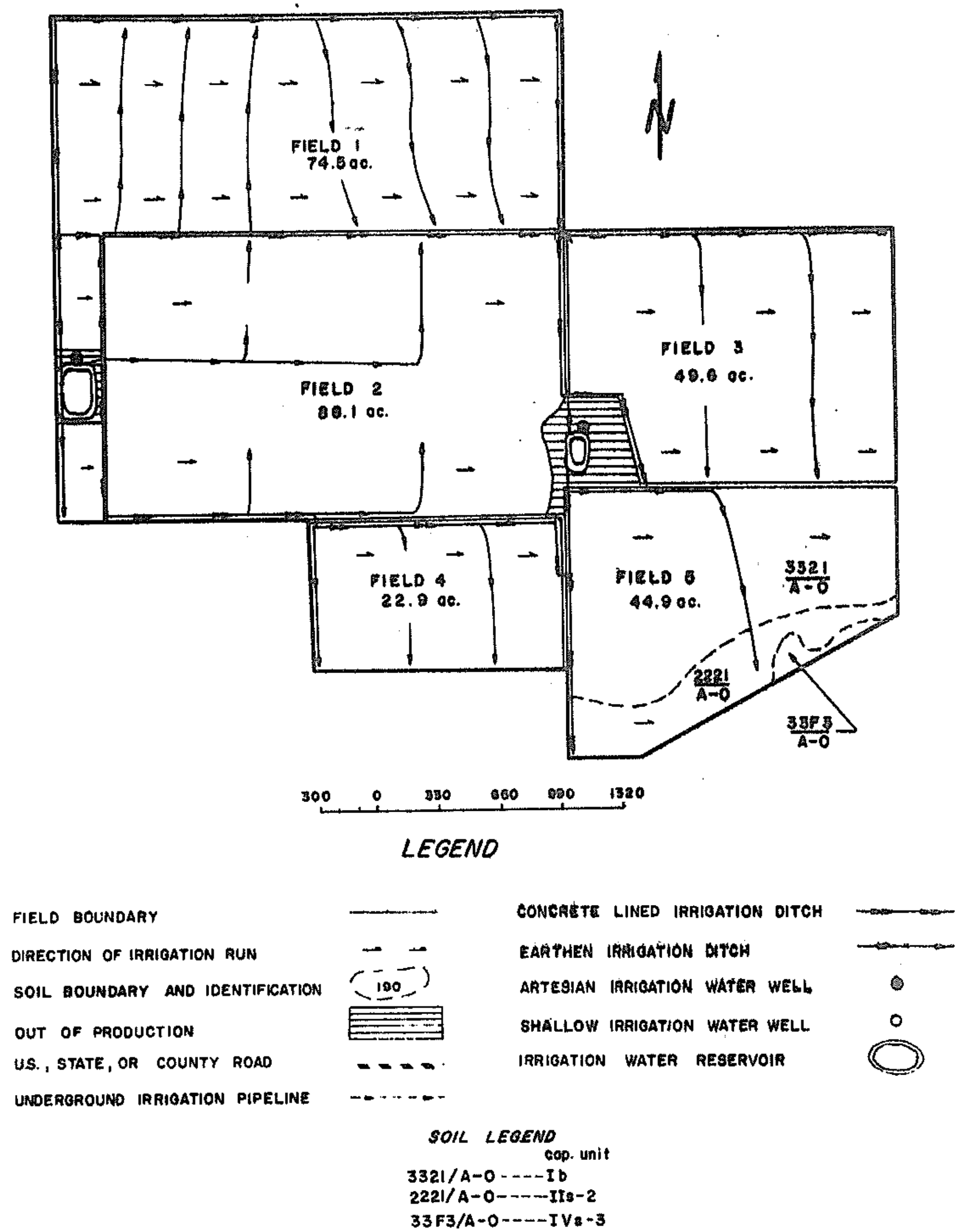


Figure 14. Map of Case Farm E.

Table 37. Case Farm E: Crops planted and approximate lengths of irrigation water runs by field, Roswell Artesian Basin, New Mexico.

Field Number	Crops Planted 1967	Crops Planted 1968	Length of Run (feet)
1	Barley Alfalfa	Alfalfa	220-530
2	Cotton Grain sorghum Diverted Fallow	Grain sorghum	740-920
3	Alfalfa	Cotton Barley	400-740
4	Alfalfa	Alfalfa	400-500
5	Cotton	Cotton Barley	790-950

there were 76.5 acres of cotton (table 38). The diversion rate was 35 percent in 1967, and 5 percent in 1968. Projected yields by ASC were 960 pounds in 1967, and 925 pounds in 1968. Actual per-acre yields were 857 pounds in 1967, and zero in 1968, because the cotton was destroyed by hail (table 39).

Alfalfa was produced on 147.0 acres in 1967 and on 97.4 acres in 1968 (table 37). In the fall of 1967, there were 74.5 acres seeded. The yields were adjusted to 6.6 tons to allow for the lower yield that is obtained in the first year of the assumed five-year production period (table 39).

Grain sorghum was produced on 28.4 acres in 1967, and on 58.3 acres in 1968. As this crop was also damaged by hail in 1968, the yield was adjusted to 6,500 pounds per acre (table 39).

Barley was produced on 74.5 acres in 1967, and on 94.5 acres in 1968. This crop was harvested for grain in 1967, and was used as pasture in 1968 (table 39).

Table 38. Case Farm E: Crop acreages and irrigation water pumpage, Roswell Artesian Basin, New Mexico

Crop	Acres			Irrigation Water Pumped					
				Per Crop			Per Acre		
	1967	1968	Average	1967	1968	Average	1967	1968	Average
				(acre-feet)			(acre-feet)		
Cotton	75.3	76.5[1]	75.9[2]	214.84	92.06	153.45	2.85	1.20	2.03
Diverted	29.3	4.0[1]	16.7[3]	0.00	0.00	0.00	0.00	0.00	0.00
Alfalfa	72.5	97.4	85.0	346.55	390.00	368.28	4.78	4.12	4.45
Seedling alfalfa	74.5[4]	0.0	37.2[4]	166.80	0.00	83.40	2.24	0.00	1.12
Grain sorghum	28.4	88.1	58.3	72.50	111.86	92.18	2.55	1.27	1.91
Barley	74.5	94.5	84.5	157.20	176.78	166.99	2.11	1.87	1.99
Fallow	0.0	14.0[1]	7.0[1]	0.00	0.00	0.00	0.00	0.00	0.00
Total	280.0	280.0	280.0	957.89	770.70	864.30	3.42	2.75	3.09

1. Not included in total, was planted to barley after cotton was hailed out.
2. Not included in total, 38.3 acres.
3. Not included in total, 2.00 acres.
4. Fall planted, not included in total, was barley acreage.

Table 39. Case Farm E: Crops and yields per acre, Roswell Artesian Basin, New Mexico.

Crop	Unit	Yield per Acre 1966	1967	1968	Average
Cotton planted					
Lint	lb.	950.0	857.0	0.0[1]	903.5
Seed	ton	0.71	0.70	0.0[1]	70.5
Alfalfa					
Hay	ton		7.6	5.6	6.6
Grain sorghum					
Grain	lb.		7,000	6,500[2]	6,750
Barley					
Grain	bu.		75.0	----	75.0
Pasture	a.u.m.		----	5.7	5.7

1. Hail damage to cotton, resulted in 95 percent loss, July 13, 1968.
2. Grain sorghum yield adjusted because of hail damage, estimated at 50 percent.

Irrigation Water Pumped

A total of 957.89 acre-feet of irrigation water were pumped in 1967 and 770.70 acre-feet in 1968 (table 38). Diversions per acre varied by two-thirds of an acre-foot during the two-year period. This difference can be partially explained by climatic conditions, including the hail damage to the cotton crop on July 13, 1968.

The average per-acre diversion for cotton for the two-year period was 2.03 acre-feet per acre. Alfalfa received an average of 4.45 acre-feet per acre on the established stand. The seedling alfalfa which was planted in the fall received an average of 1.12 acre-feet per acre. The grain sorghum received an average of 1.91 acre-feet per acre, and the barley received 1.99 acre-feet per acre.

The average quantity of water diverted on Case Farm E in 1967 was higher than the average quantity of irrigation water diverted on farms in the Roswell-East Grand Plains Area. The average irrigation water diversion on Farm E was 3.42 acre-feet per water-right acre, 3.42 acre-feet per cultivated acre, and 3.82 acre-feet per cropped acre. The average irrigation water diversion for all farms in the vicinity of Case Farm E was 2.66 acre-feet per water-right acre, 2.94 acre-feet per cultivated acre, and 3.39 acre-feet per cropped acre (9, p. 130).

In 1968 the average irrigation water diversion on Farm E was 2.75 acre-feet per water-right acre, 0.40 acre-feet per acre more than the average for the Roswell-East Grand Plains Area (12).

Irrigation Efficiency

The typical irrigation efficiency by crops is reported in table 40 and yearly estimates in table C5. Irrigation efficiency on cotton averaged 77.53 percent for the two years (table 40). The consumptive irrigation requirement for cotton in 1968 was not meaningful because the cotton enterprise was destroyed by hail in July (table C5). Alfalfa irrigation efficiency remained almost constant at 54.04 and 54.07 percent (table C5), and averaged 54.06 percent, and grain sorghum averaged 77.84 percent. Barley averaged 63.94 percent.

Table 40. Case Farm E: Typical consumptive irrigation requirement, irrigation water applied, and farm irrigation efficiency by crops.

Crop	Consumptive Irrigation Requirement	Irrigation Water Applied	Farm Irrigation Efficiency
	(acre-inches)	(acre-inches)	(percent)
Cotton	18.84	24.30	77.53
Alfalfa	28.87	53.40	54.06
Grain sorghum	17.84	22.92	77.84
Barley	15.27	23.88	63.94

ECONOMIC ANALYSIS

Financial Summary

The typical per-acre net returns by crops are reported in table 41 and yearly figures are reported in table D5. The net farm return for the period was $36,208.76 and $30,587.45, for 1967 and 1968 respectively (table E5). The primary reasons for the large variation in net farm return were the favorable prices and yields for cotton and alfalfa in 1967, and the unfavorable price and lower acreage of alfalfa in 1968.

Table 41. Case Farm E: Typical per-acre returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns per Acre (dollars)	Gross Expenses per Acre (dollars)	Net Returns to Land and Management per Acre (dollars)
Cotton planted	367.79	188.89	178.90
Cotton diverted	100.05	9.17	90.88
Alfalfa	176.40	110.79	65.61
Grain sorghum	124.75	54.92	69.83
Barley	56.21	44.10	12.11
Weighted average	176.64	97.75	78.88

Because of these wide variations in yields, prices, acreage, and net farm returns, a typical whole farm budget was computed using typical yields, prices, acreage, and costs (table 42). This typical whole farm budget will be used to compare with the linear programming solutions to determine the effect of different levels of irrigation water diversions on net farm returns. The annual whole farm budgets are presented in appendix E (table E5).

Table 42. Case Farm E: Typical whole farm returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
Cotton planted	75.9	27,915.26	14,336.37	13,578.89
Cotton diverted	16.7	1,670.84	153.14	1,517.70
Alfalfa	122.2	21,556.08	13,538.54	8,017.54
Grain sorghum	58.3	7,272.93	3,201.84	4,071.09
Barley	84.5	4,749.75	3,226.45	1,023.30
Total	357.6	63,164.86	34,956.34	28,208.52

Linear Programming Solutions--Model A

The coefficients and constraints for model A are presented below:

$1X_1 + 1X_2 + 1X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 1X_8 + 1X_9 \leq 280$ acres

$1X_1 + 1X_2 + 1X_3 + 0X_4 + 0X_5 + 0X_6 + 0X_7 + 0X_8 + 0X_9 \leq 92.50$ acres of cotton

$1.71X_1 + 2.10X_2 + 2.50X_3 + 4.45X_4 + 0X_5 + 5.33X_6 + 6.00X_7 + 1.91X_8 + 1.99X_9 \leq 700$ acre-feet of irrigation water

The X variables are identified in table 43.

The parameter changes in irrigation water diversion (Qt), where Q = 770.00 acre-feet of irrigation water and t = 70.00 acre-feet result in the following irrigation water constraints:

2.75 acre-feet per water-right acre = 770.00 acre-feet
3.00 acre-feet per water-right acre = 840.00 acre-feet
3.25 acre-feet per water-right acre = 910.00 acre-feet
3.50 acre-feet per water-right acre = 980.00 acre-feet
3.75 acre-feet per water-right acre = 1,050.00 acre-feet
4.00 acre-feet per water-right acre = 1,120.00 acre-feet

In table 43 the whole farm budget for the typical crop year is compared with the results of model A. The linear programming solutions presented in table 43 indicate the optimal net farm returns and the combinations of the eight crops that would be produced if there were no assumed crop rotation program on Case Farm E.

In table 43 the net farm return obtained from the linear programming solutions is also contrasted with $28,208.52, which was obtained from the typical crop year with 864.30 acre-feet of irrigation water (3.09 acre-feet per water-right acre). The net farm return for the typical crop year would have been increased about 5 percent with the combination of crop enterprises that is indicated in model A with 2.50 acre-feet of irrigation water; about 6 percent with 2.75 acre-feet; about 6 percent with 3.00 acre-feet; about 7 percent with 3.25 acre-feet; about 8 percent with 3.50 acre-feet; about 9 percent with 3.75 acre-feet; and about 9 percent with 4.00 acre-feet.

The lower net farm return for the typical crop year can be attributed primarily to the production of cotton at the 82 percent level of the allotment and to the production of barley. Even at low levels (2.50 acre-feet of water per water-right acre) of irrigation water diversions, cotton would be produced on the maximum number of acres allowed under the cotton program, or about 31 percent

Table 43. Case Farm E: Whole farm budget and linear programming solutions, models A, B, and C, Roswell Artesian Basin, New Mexico.

		Whole Farm Budget			Linear Programming Solutions																				
					2.50 acre feet per acre			2.75 acre feet per acre			3.00 acre feet per acre			3.25 acre feet per acre			3.50 acre feet per acre			3.75 acre feet per acre			4.00 acre feet per acre		
Vari-able	Crop	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars
													MODEL A												
X_1	Cotton (65)																								
X_2	Cotton (80)	92.50[1]	153.45	15,096.59																					
X_3	Cotton (95)				92.50	231.25	16,141.25	92.50	231.25	16,141.25	92.50	231.25	16, 141.25	92.50	231.25	16,141.25	92.50	231.25	16,141.25	92.50	231.25	16,141.25	92.50	231.25	16,141.25
X_4	Alfalfa (A)	122.20[2]	451.68	8,017.54																					
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)				27.05	162.30	2,223.51	44.16	264.97	3,629.96	61.28	367.68	5,037.22	78.39	470.35	6,443.66	95.51	573.05	7,850.92	112.62	675.72	9,257.36	129.74	778.44	10,664.46
X_8	Grain Sorghum	58.30	92.18	4,071.09	160.45	306.45	11,204.22	143.34	273.78	10,009.43	126.22	241.07	8,813.94	109.11	208.40	7,619.15	91.99	175.70	6,423.66	74.88	143.03	5,228.87	57.76	110.31	4,033.38
X_9	Barley	84.50	166.99	1,023.30																					
	Fallow	7.20[3]	0.00	0.00																					
	Total	280.00	864.30	28,208.52	280.00	700.00	29,568.98	280.00	770.00	29,780.63	280.00	840.00	29,992.41	280.00	910.00	30,204.06	280.00	980.00	30,415.83	280.00	1,050.00	30,627.48	280.00	1,120.00	30,839.09
													MODEL B												
X_1	Cotton (65)																								
X_2	Cotton (80)	92.50[1]	153.45	15,096.59																					
X_3	Cotton (95)				92.50	220.15	16,141.25	92.50	220.15	16,141.25	92.50	220.15	16,141.25	92.50	220.15	16,141.25	92.50	220.15	16,141.25	92.50	220.15	16,141.25	92.50	220.15	16,141.25
X_4	Alfalfa (A)	122.20[2]	451.68	8,017.54																					
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)				36.11	205.83	2,968.24	54.11	308.42	4,447.84	72.10	410.98	5,926.62	90.10	513.56	7,406.22	108.09	616.12	8,885.00	126.09	718.70	10,364.60	144.08	821.26	11,843.38
X_8	Grain Sorghum	58.30	92.18	4,071.09	151.39	274.02	10,571.56	133.39	241.43	9,314.62	115.40	208.87	8,058.38	97.40	176.29	6,801.44	79.41	143.73	5,545.20	61.41	111.15	4,288.26	43.42	78.59	3,032.02
X_9	Barley	84.50	166.99	1,023.30																					
	Fallow	7.20[3]	0.00	0.00																					
	Total	280.00	864.30	28,208.52	280.00	700.00	29,681.05	280.00	770.00	29,903.71	280.00	840.00	30,126.25	280.00	910.00	30,348.91	280.00	980.00	30,571.45	280.00	1,050.00	30,794.11	280.00	1,120.00	31,016.65
													MODEL C												
X_1	Cotton (65)				92.50	158.18	13,699.25																		
X_2	Cotton (80)	92.50[1]	153.45	15,096.59				92.50	194.25	14,920.25															
X_3	Cotton (95)										92.50	231.25	16,141.25	92.50	231.25	16,141.25	92.50	231.25	16,141.25	92.50	231.25	16,141.25	92.50	231.25	16,141.25
X_4	Alfalfa (A)	122.20[2]	451.68	8,017.54	92.00	409.40	6,036.12	92.00	409.36	6,036.12	72.74	323.69	4,772.47												
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)										19.26	102.66	1,470.50	83.07	442.76	6,342.39									
X_7	Alfalfa (D)													8.93	53.58	734.05	95.51	573.05	7,850.92	112.62	675.72	9,257.36	129.74	778.44	10,664.46
X_8	Grain Sorghum	58.30	92.18	4,071.09	69.33	132.42	4,841.31	87.12	166.39	6,083.59	95.50	182.40	6,668.76	95.50	182.41	6,668.76	91.99	175.70	6,423.66	74.88	143.03	5,228.87	57.76	110.31	4,033.38
X_9	Barley	84.50	166.99	1,023.30																					
	Fallow	7.20[3]	0.00	0.00	26.17	0.00	0.00	8.38	0.00	0.00															
	Total	280.00	864.30	28,208.52	280.00	700.00	24,576.68	280.00	770.00	27,039.96	280.00	840.00	29,052.98	280.00	910.00	29,886.45	280.00	980.00	30,415.83	280.00	1,050.00	30,627.48	280.00	1,120.00	30,839.09

1 Not included in total, 40.3 acres

2 Not included in total, 37.2 acres

3 Not included in total

of the water-right acres. About 10 percent of the water-right acres would be devoted to the production of alfalfa at the "D" level and the remaining tillable acres, 57 percent of the water-right acres, would be devoted to grain sorghum. The above combination of enterprises would result in a net farm return of approximately $29,568.98.

As more irrigation water becomes available, alfalfa D substitutes for grain sorghum at a rate of 17.11 acres per one-fourth acre-foot of irrigation water per water-right acre until 4.84 acre-feet of irrigation water is pumped per water-right acre, where only cotton and alfalfa are produced on the cropable acres. If more than 4.84 acre-feet were available net farm returns to land and management would not increase, but would remain at $31,533.75 which is 11.9 percent above the typical whole farm budget.

Although the above combinations of crop enterprises result in the maximum returns for each quantity of irrigation water, they do not specifically allow for a crop rotation program. Crop yields, and therefore returns, would be reduced if these combinations of crop enterprises were produced for extended time periods at the lower levels of irrigation water pumpage.

Linear Programming Solutions--Model B

The coefficients and constraints for model B are the same as for model A except that irrigation water coefficients have been reduced by 5 percent. The irrigation water coefficients and the first irrigation water constraint for model B are listed below:

$$1.62X_1 + 2.00X_2 + 2.38X_3 + 4.23X_4 + 0X_5 + 5.06X_6 + 5.70X_7 + 1.81X_8$$

$$+ 1.89X_9 \leq 700 \text{ acre-feet of irrigation water}$$

The X variables are identified in table 43.

In table 43 the whole farm budget for the typical crop year is compared with the results of model B. These solutions presented in table 43 indicate the optimal net farm returns and the combinations of crops that would be produced if there were no assumed crop rotation program on Case Farm E.

In table 43 the net farm return obtained from the linear programming solutions is also contrasted with $28,208.52, which was obtained from the typical crop year with 864.30 acre-feet of irrigation water (3.09 acre-feet per water-right acre). The net farm return for the typical crop year would have been increased about 5 percent with the combination of crop enterprises that is indicated in model B with 2.50 acre-feet of irrigation water; about 6 percent with 2.75

acre-feet; about 7 percent with 3.00 acre-feet; about 8 percent with 3.25 acre-feet; about 8 percent with 3.50 acre-feet; about 9 percent with 3.75 acre-feet; and about 10 percent with 4.00 acre-feet.

The solutions for model B reflect a 5 percent increase in irrigation water efficiency on each crop. If 2.50 acre-feet of irrigation water per water-right acre were available, cotton would comprise about 31 percent of the water-right acres, grain sorghum about 54 percent, alfalfa D about 13 percent, and the remaining 2 percent would be diverted. As more irrigation water becomes available alfalfa D substitutes for grain sorghum at a rate of 18 acres per one-fourth acre-foot of irrigation water per water-right acre until 4.60 acre-feet per acre are pumped. If more than 4.60 acre-feet were available net farm income would not be increased, but would remain at $31,553.75. This is 11.8 percent above the typical whole farm budget. A 5 percent increase in irrigation efficiency increased the optimal net farm returns to land and management by an average of 0.47 percent.

Linear Programming Solutions--Model C

The coefficients and constraints for model C are the same as for model A except that an additional constraint was placed on a minimum amount of alfalfa being produced. The coefficients and the added constraint are listed below:

$$0X_1 + 0X_2 + 0X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 0X_8 + 0X_9 \geq 92.0 \text{ acres}$$

of alfalfa

The X variables are identified in table 43.

In table 43 the whole farm budget for the typical crop year is compared with the results of model C. These solutions, presented in table 43, indicate the optimal net farm returns and the combinations of crops that would be produced if a minimum of one-third of the water-right acres were devoted to alfalfa production, which is the assumed crop rotation program.

In table 43 the net farm return obtained from the linear programming solutions is also contrasted with $28,208.52, which was obtained from the typical crop year with 864.30 acre-feet of irrigation water (3.09 acre-feet per water-right acre). The net farm return for the typical crop year would have been decreased about 13 percent with the combination of crop enterprises that is indicated in model C with 2.50 acre-feet of irrigation water; decreased about 4 percent with 2.75 acre-feet; increased about 3 percent with 3.00 acre-feet; increased about 6 percent with 3.25 acre-feet; increased about 8 percent with 3.50 acre-feet; increased about 9 percent with 3.75 acre-feet; and increased slightly over 9 percent with 4.00 acre-feet. The maximum diversion would be the same as for model A, 4.84 acre-feet of irrigation water diversion per water-right acre with a net farm return of $31,553.75.

The primary reason for the lower return figure at 2.50 acre-feet of irrigation water per water-right acre is the requirement that about one-third of the farm be planted in alfalfa. In order to have enough water for alfalfa, cotton would be produced on only 65 percent of the base (60.12 acres). Alfalfa A would be produced on 92 acres, which require 4.45 acre-feet of irrigation water per acre, grain sorghum on 69.33 acres, and 26.17 acres would not be cropped.

As more irrigation water becomes available more acres would be devoted to alfalfa A and grain sorghum. At the 2.75 level of irrigation water diversion, planted cotton acreage would shift from 60.12 to 74 acres (cotton 80), and alfalfa A acreage would remain constant. The fallow land would move into grain sorghum production. At the 3.00 acre-feet irrigation water diversion level, planted cotton acreage would shift to 87.88 acres (cotton 95), alfalfa A and C would be produced on 72.74 and 19.26 acres respectively, and grain sorghum would be produced on 95.50 acres. With 3.25 acre-feet of irrigation water available per water-right acre, the maximum net farm return to land and management is obtained with 87.88 acres of planted cotton (cotton 95), 83.07 acres of alfalfa A, 8.93 acres of alfalfa D, and 95.50 acres of grain sorghum.

The optimal solutions and cropping patterns for 3.50, 3.75, and 4.00 acre-feet per water-right acre are the same as for model A and are reported in table 43.

The immediate economic effect of forcing in a crop rotation of about one-third of the farm into alfalfa is a reduction in net farm returns at irrigation water diversion levels of less than 3.50 acre-feet per water-right acre. This effect can be estimated by comparing solutions from model A with solutions from model C. Net farm return would be reduced by $5,309.77 (22 percent) at 2.50 acre-feet per water-right acre, $3,375.87 (12 percent) at 2.75 acre-feet per water-right acre, $1,574.50 (5 percent) at 3.00 acre-feet per water-right acre, and $317.61 (1 percent) at 3.25 acre-feet per water-right acre.

The results obtained from the three linear programming models are graphically summarized in figure 15. This graph indicates the effects of the seven quantities of irrigation water on the net farm return. In models A and B, as irrigation water is increased from 700.00 acre-feet to 1,355.20 acre-feet (2.50 to 4.84 acre-feet per water-right acre), and 700.00 to 1,288.00 acre-feet (2.50 to 4.60

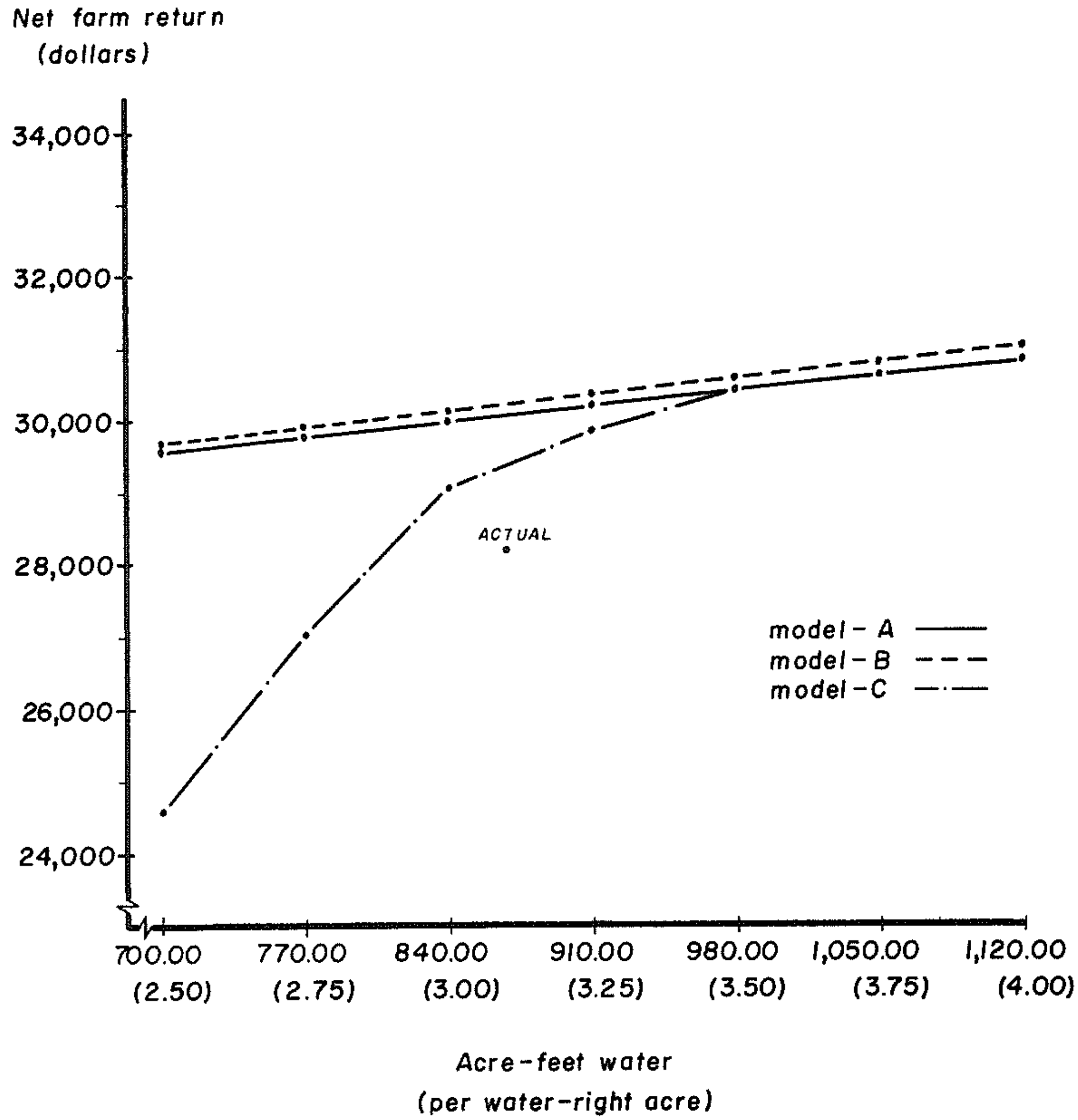


Figure 15. Case Farm E: Net farm return for seven quantities of irrigation water, Roswell Artesian Basin, New Mexico.

acre-feet per water-right acre) the net farm return increases at a constant rate. Beyond 1,355.20 and 1,288.00 acre-feet for models A and B respectively, the size of farm (cultivated acres) and cropping enterprises considered in this study become the factors that restrict net farm returns.

In model C, as irrigation water is increased from 700.00 acre-feet to 840.00 acre-feet (2.50 to 3.00 acre-feet per water-right acre), the net return per water-right acre increases at almost a constant rate. From 840.00 to 980.00 acre feet (3.00 to 3.50 acre-feet) the rate of increase is at a lower constant rate, and beyond 980.00 acre-feet (3.50 acre-feet per water-right acre) the size of the farm (cultivated acres) and cropping enterprises considered become the limiting factors.

Optimal Quantity of Irrigation Water

The shadow prices (marginal value products) for an additional acre-foot of irrigation water are presented in table 44. The optimal level of irrigation water diversion for each model can be determined by equating the shadow price with the cost of pumping an acre-foot of irrigation water. The estimated cost of pumping an acre-foot of irrigation water was $7.68. For models A and B the optimal quantity of water was below 2.50 acre-feet per water-right acre. For model A it was between 560 and 630 acre-feet (2.00 and 2.25 acre-feet per water-right acre), and for model B it was between 490 and 560 acre-feet (1.75 and 2.00 acre-feet per water-right acre). For model C, the optimal quantity was between 910 and 980 acre-feet (3.25 and 3.50 acre-feet per water-right acre). It would appear that 840 acre-feet (3.00 acre-feet per water-right acre) would be a sufficient quantity of irrigation water to maximize returns under conditions of models A and B.

In model C, if irrigation water diversions were limited to 840 acre-feet (3.00 acre-feet per water-right acre) instead of the optimal quantity, net farm returns would have been reduced between $833.47 and $1,362.85 or approximately 3 percent to 5 percent.

It would appear that Case Farm E was being operated far above the optimal cropping program under conditions of models A and B, but below the optimal cropping program for maximum return under the conditions of model C.

Table 44. Case Farm E: Shadow prices for seven quantities of irrigation water diversion, Roswell Artesian Basin, New Mexico.

Quantity of Irrigation Water Diverted (acre-feet)	Shadow Price Model A (dollars)	Shadow Price Model B (dollars)	Shadow Price Model C (dollars)
700.00	3.02	3.18	36.56
770.00	3.02	3.18	33.85
840.00	3.02	3.18	12.20
910.00	3.02	3.18	8.73
980.00	3.02	3.18	3.02
1,050.00	3.02	3.18	3.02
1,120.00	3.02	3.18	3.02

CASE FARM F

GENERAL DESCRIPTION

Case Farm F was an owner-operator farm with 204.4 acres of artesian water rights and 195.6 acres of shallow water rights. This farm was part of a large commercial farming operation and was located in the Dexter-Hagerman Area of the Roswell Artesian Basin (figure 2).

Soils

The soils included on Case Farm F were Reagan Loam, Reeves Loam, and Reeves Loam, Shallow. The location of these soils is shown in figure 16. The Reagan Loam comprised about 69 percent of the irrigated cropland, Reeves Loam about 17 percent, and Reeves Loam, Shallow about 14 percent (figure 16). The Reagan Loam was Capability Class I, Reeves Loam was Class II, and Reeves Loam, Shallow was Class IV. Soils are described further in appendix A.

Irrigation Water

Case Farm F had two artesian wells and one shallow well. The two artesian wells produced about 1,000 gallons per minute each, and the shallow well produced about 80 gallons per minute. Because of the low volume of pumpage from the shallow well, irrigation water was considered to be a limiting factor on this farm where nearly half of the water rights were from shallow source. Average soluble salt content of the water from these wells was about 925 millimhos and the average adsorption ratio was about 0.93 during the period of this study (2). The quality classification of the water was Class 2.

Irrigation System

One reservoir was used on Farm F. Water for this reservoir was pumped from one of the artesian wells and the shallow well (figure 16). The other artesian well was pumped directly into an earthen ditch and served about 140 acres. The reservoir drained into a concrete-lined ditch approximately 6,000 feet in total length. About 22,000 feet of primary and secondary earthen laterals were also included in the irrigation system.

In 1966 and 1967, all of the farmland had been leveled except for 140 acres in fields 4, 5, 6, and 7. Fields 4 and 5 were leveled prior to the 1968 crop year. The leveled cropland sloped from west to east (figure 16). The approximate lengths of irrigation water

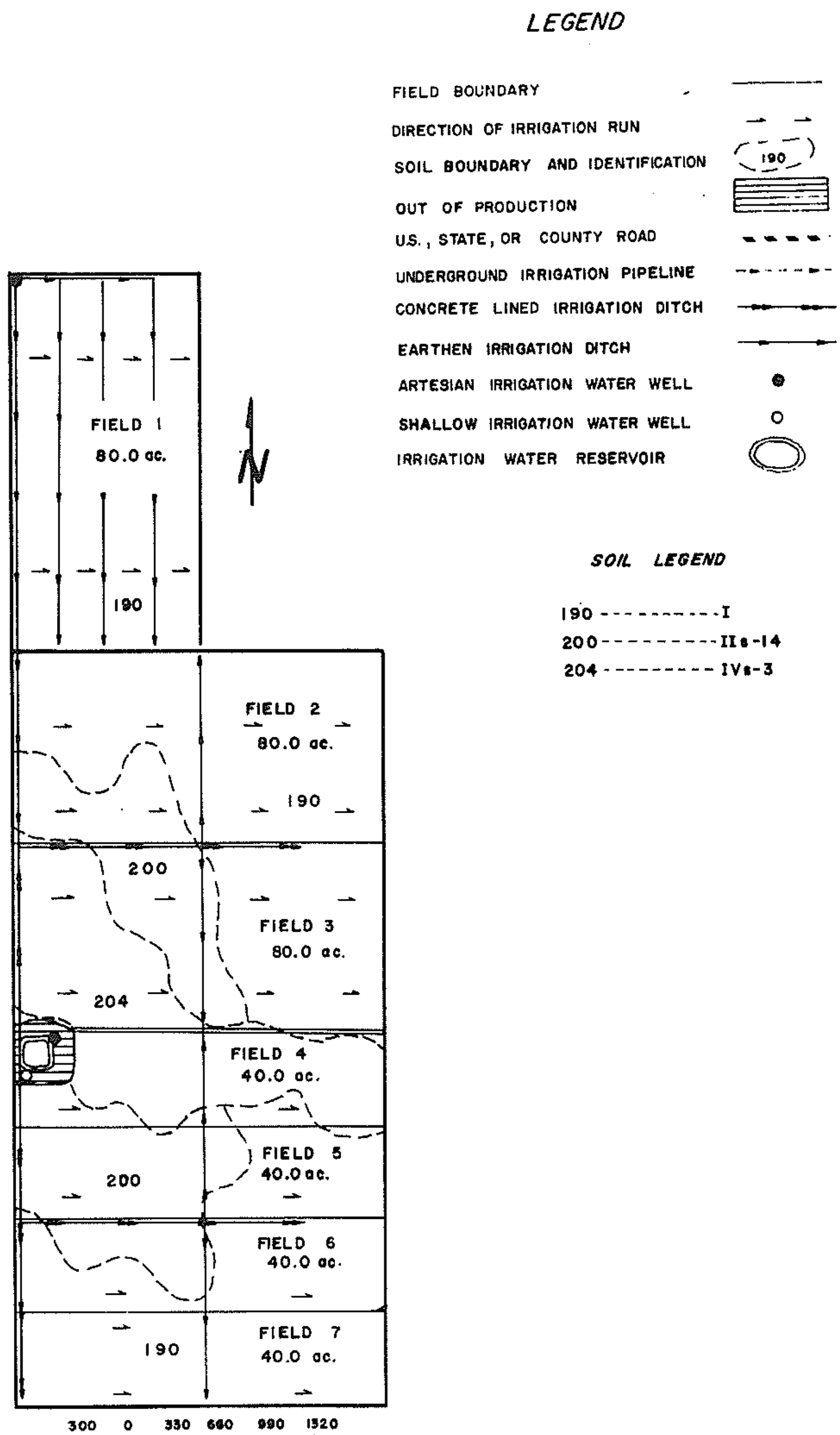


Figure 16. Map of Case Farm F.

runs for the different fields are reported in table 45.

Table 45. Case Farm F: Crops planted and approximate lengths of irrigation water runs by fields, Roswell Artesian Basin, New Mexico.

Field Number	Crops Planted 1966	1967	1968	Length of Run (feet)
1	Alfalfa	Alfalfa	Alfalfa	320
2	Cotton Diverted	Cotton Diverted	Cotton Diverted	1,320
3	Cotton Diverted	Corn	Cotton Diverted	1,320
4	Corn	Corn Diverted Fallow	Cotton Diverted	630
5	Corn	Cotton Diverted Fallow	Cotton Diverted	630
6	Corn	Corn Diverted Fallow	Cotton Diverted Oats	630
7	Corn	Diverted Fallow	Cotton Diverted Oats	630

Crops Produced

Cotton, alfalfa, corn silage, and small grains were produced on Farm F. The cotton allotment was 439.9 acres for Case Farm F and another farm operated by the same owner. In 1966 cotton was produced on 140.0 acres, in 1967 on 80.02 acres, and in 1968 on 262.3 acres (table 46). In 1966 there were 20.0 acres diverted under provisions of the Upland Cotton Program, 43.08 acres in 1967, and 17.7 acres in 1968. The projected per-acre yield by ASC was 780 pounds in 1966, 810 pounds in 1967, and 780 pounds in 1968. The actual per-acre yields in pounds were 428.6 in 1966, 613.0 in 1967, and 610.7 in 1968 (table 47).

Table 46. Case Farm F: Crop acreages and irrigation water pumpage, Roswell Artesian Basin, New Mexico

Crop	Acres				Irrigation Water Pumped: Per Crop (acre-feet)				Irrigation Water Pumped: Per Acre (acre-feet)			
	1966	1967	1968	Average	1966	1967	1968	Average	1966	1967	1968	Average
Cotton	140.0	80.02	262.3	160.77	352.00	144.04	387.46	294.50	2.51	1.80	1.48	1.83
Diverted	20.0	43.08	17.7	26.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alfalfa	80.0	80.00	80.0	80.00	27.20	180.00	103.84	103.68	0.34	2.25	1.29	1.30
Corn silage	160.0	140.00	0.0	100.00	220.80	175.00	0.00	131.93	1.38	1.25	0.00	1.32
Barley	80.0[1]	0.00	0.0	26.67[1]	24.00	0.00	0.00	8.00	0.30	0.00	0.00	0.30
Oats	0.0	0.00	40.0	13.33	0.00	0.00	71.69	23.90	0.00	0.00	1.79	1.79
Fallow	0.0	56.90	0.0	18.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	400.0	400.00	400.0	400.00	624.00	499.04	562.99	562.01	1.56	1.25	1.41	1.41

1. Not included in total, was cover crop on seed alfalfa.

Alfalfa seed was produced during all three years on 80.0 acres. The yields are reported in table 47. Corn silage was produced on 160.0 acres in 1966, and 140 acres in 1967. Barley was produced in 1966 primarily as a cover crop for the alfalfa. Oats were produced in 1968 on 40.0 acres.

Table 47. Case Farm F: Crops and yields per acre, Roswell Artesian Basin, New Mexico.

Crop	Unit	Yield per Acre			
		1966	1967	1968	Average
Cotton planted					
Lint	lb.	428.6	613.0	610.7	550.77
Seed	ton	0.30	0.43	0.43	0.382
Alfalfa					
Seed	lb.	----	32.5	26.6	22.73
Hay (mixed)	ton	0.30	2.0	1.93	1.41
Corn silage	ton	18.0	15.8	----	16.9
Oats					
Hay	ton	----	----	3.35	3.35

Irrigation Water Pumped

Pumpage for the three years was 624.00 acre-feet in 1966, 499.04 acre-feet in 1967, and 562.99 acre-feet in 1968 (table 46). Diversions were 1.56, 1.25, and 1.41 acre-feet per water-right acre, respectively.

The average per-acre diversion for cotton for the three-year period was 1.83 acre-feet per acre. Alfalfa received an average of 1.30 acre-feet per acre. Corn silage received an average of 1.32 acre-feet per acre. The barley received an average of 0.30 acre-feet per acre, and the oats received 1.79 acre-feet per acre.

In 1967 the average quantity of water diverted was greater on all farms in the Dexter-Hagerman Area. The average irrigation water diversion on Farm F was 1.25 acre-feet per water-right acre, 1.25 acre-feet per cultivated acre, and 1.66 acre-feet per cropped acre. The average irrigation water diversion for all farms in the Dexter-Hagerman Area was 2.83 acre-feet per water-right acre, 3.06 acre-feet per cultivated acre, and 3.39 acre-feet per cropped acre (9, p. 130).

In 1968, the average irrigation water diversion for Farm F was 1.41 acre-feet per water-right acre, 1.10 acre-feet per acre less than the average diversion for all farms in the Dexter-Hagerman Area which was 2.51 acre-feet per water-right acre (12).

Irrigation Efficiency

The typical irrigation efficiency by crops is reported in table 48 and yearly estimates in table C6. Irrigation efficiency on cotton ranged from 62.15 to 103.15 percent with an average of 81.17 percent (table C6). Because an estimate of consumptive use for seed alfalfa was not available, irrigation efficiency for alfalfa was not computed. Because estimates of irrigation water applied on barley for the 1965 calendar year were not available, irrigation efficiency for the 1966 barley was not computed. In 1968 irrigation efficiency on oats was estimated to be 81.10 percent (table 48).

Table 48. Case Farm F: Typical consumptive irrigation requirement, irrigation water applied, and farm irrigation efficiency.

Crop	Consumptive Irrigation Requirement (acre-inches)	Irrigation Water Applied (acre-inches)	Farm Irrigation Efficiency (percent)
Cotton	18.80	23.16	81.17
Alfalfa[1]			
Corn Silage	14.32	15.78	90.75
Barley[2]			
Oats	17.42	21.48	81.10

1. Seed alfalfa, no estimate for CIR.
2. Estimate of irrigation water applied during the fall and winter of 1965 and 1966 was unavailable.

ECONOMIC ANALYSIS

Financial Summary

The typical per-acre net returns by crops are reported in table 49 and yearly figures are reported in table D6. The net farm return for the three years was $24,384.80, $26,225.03, and $45,008.51 respecively (table E6). The primary reason for the wide variations in net farm returns were the different prices, yields, and acreages over the three years.

Table 49. Case Farm F: Typical per-acre returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns per Acre (dollars)	Gross Expenses per Acre (dollars)	Net Returns to Land and Management per Acre (dollars)
Cotton planted	291.06	111.06	180.00
Cotton diverted	84.38	11.42	72.96
Alfalfa (hay & seed)	45.55	39.53	6.02
Corn silage	124.38	78.28	46.10
Barley	12.50	10.22	2.28
Oats	67.00	59.21	7.79
Weighted average	155.56	70.82	84.74

Because of these wide variations, a typical whole farm budget was computed using typical prices, yields, acreages, and costs (table 50). This typical whole farm budget will be used to compare with the linear programming solutions to determine the effect of different levels of irrigation water diversions on net farm returns. The annual whole farm budgets are presented in appendix E (table E6).

Table 50. Case Farm F: Typical whole farm returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
Cotton planted	160.77	46,793.72	17,855.12	28,938.60
Cotton diverted	26.93	2,272.35	307.54	1,964.81
Alfalfa (hay & seed)	80.00	3,644.00	3,162.40	481.60
Corn silage	100.00	12,438.00	7,828.00	4,610.00
Barley	26.67	333.38	272.57	60.81
Oats	13.33	893.11	789.27	103.84
Fallow	18.97	0.00	0.00	0.00
Total	426.67	66,374.56	30,214.90	36,159.66

Linear Programming Solutions--Model A

The coefficients and constraints for model A are presented below:

$1X_1 + 1X_2 + 1X_3 + 1X_4 + 1X_5 + 1X_6 + 1X_7 + 1X_8 + 1X_9 + 1X_{10} + 1X_{11}$

$\leq$ 400 acres

$1X_1 + 1X_2 + 1X_3 + 0X_4 + 0X_5 + 0X_6 + 0X_7 + 0X_8 + 0X_9 + 0X_{10} + 0X_{11}$

$\leq$ 123.1 acres of cotton

$1.19X_1 + 1.46X_2 + 1.74X_3 + 4.71X_4 + 1.30X_5 + 5.33X_6 + 6.00X_7 + 1.32X_8$

$+ 2.00X_9 + 0.3X_{10} + 1.79X_{11}$ $\leq$ 1,000 acre-feet of irrigation water

The X variables are identified in table 51.

The parameter changes in irrigation water diversion (Qt), where Q = 1,000.00 acre-feet of irrigation water and t = 100.00 acre-feet result in the following irrigation water constraints:

2.75 acre-feet per water-right acre = 1,100.00 acre-feet
3.00 acre-feet per water-right acre = 1,200.00 acre-feet
3.25 acre-feet per water-right acre = 1,300.00 acre-feet
3.50 acre-feet per water-right acre = 1,400.00 acre-feet
3.75 acre-feet per water-right acre = 1,500.00 acre-feet
4.00 acre-feet per water-right acre = 1,600.00 acre-feet

In table 51 the whole farm budget for the typical crop year is compared with the results of model A. The linear programming solutions presented in table 51 indicate the optimal net farm returns and the combinations of the eleven crops that would be produced if there were no assumed crop rotation program on Case Farm F.

In table 51 the net farm return obtained from the linear programming solutions is also contrasted with $36,159.66, which was obtained from the typical crop year with 562.01 acre-feet of irrigation water (1.41 acre-feet per water-right acre). The net farm return for the typical crop year would have been increased about 29 percent with the combination of crop enterprises that is indicated in model A with 2.50 acre-feet of irrigation water; about 30 percent with 2.75 acre-feet; about 30 percent with 3.00 acre-feet; about 31 percent with 3.25 acre-feet; about 32 percent with 3.50 acre-feet; about 33 percent with 3.75 acre-feet; and about 33 percent with 4.00 acre-feet.

The lower net farm return to land and management for the typical crop year can be attributed primarily to the production of cotton at the 81.7 percent level of the allotment, and to the production of alfalfa seed (B). Even at low levels (2.50 acre-feet of water per water-right acre) of irrigation water diversions, cotton would be

Table 51. Case Farm F: Whole farm budget and linear programming solutions, models A, B, and C, Roswell Artesian Basin, New Mexico.

		Whole Farm Budget			Linear Programming Solutions																				
					2.50 acre feet per acre			2.75 acre feet per acre			3.00 acre feet per acre			3.25 acre feet per acre			3.50 acre feet per acre			3.75 acre feet per acre			4.00 acre feet per acre		
Variable	Crop	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars
	MODEL A																								
X_1	Cotton (65)																								
X_2	Cotton (80)	187.70	294.50	30,903.41																					
X_3	Cotton (95)				187.70	326.60	32,832.48	187.70	326.60	32,832.48	187.70	326.60	32,832.48	187.70	326.60	32,832.48	187.70	326.60	32,832.48	187.70	326.60	32,832.48	187.70	326.60	32,832.48
X_4	Alfalfa (A)																								
X_5	Alfalfa (B)	80.00	103.68	481.60																					
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)				62.20	373.20	4,508.88	87.20	523.20	6,321.13	112.20	673.20	8,133.38	137.20	823.20	9,945.63	162.20	973.20	11,757.88	187.20	1,123.20	13,570.13	212.20	1,273.20	15,382.38
X_8	Corn Silage	100.00	131.93	4,610.00																					
X_9	Grain Sorghum				150.10	300.20	9,322.71	125.10	250.20	7,769.96	100.10	200.20	6,217.21	75.10	150.20	4,664.46	50.10	100.20	3,111.71	25.10	50.20	1,558.96	0.10	0.20	6.21
X_{10}	Barley	26.67[1]	8.00	60.81																					
X_{11}	Oats	13.33	23.90	103.84																					
	Fallow	18.97	0.00	0.00																					
	Total	400.00	562.01	36,159.66	400.00	1,000.00	46,664.07	400.00	1,100.00	46,923.57	400.00	1,200.00	47,183.07	400.00	1,300.00	47,442.57	400.00	1,400.00	47,702.07	400.00	1,500.00	47,961.57	400.00	1,600.00	48,221.07
	MODEL B																								
X_1	Cotton (65)																								
X_2	Cotton (80)	187.70	294.50	30,903.41																					
X_3	Cotton (95)				187.70	309.71	32,832.48	187.70	309.71	32,832.48	187.70	309.71	32,832.48	187.70	309.71	32,832.48	187.70	309.71	32,832.48	187.70	309.71	32,832.48	187.70	309.71	32,832.48
X_4	Alfalfa (A)																								
X_5	Alfalfa (B)	80.00	103.68	481.60																					
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)				75.51	430.40	5,473.72	101.82	580.37	7,380.93	128.14	730.40	9,288.87	154.45	880.37	11,196.08	180.77	1,030.38	13,104.02	207.09	1,180.39	15,011.95	212.30	1,210.11	15,389.63
X_8	Corn Silage	100.00	131.93	4,610.00																					
X_9	Grain Sorghum				136.79	259.89	8,496.03	110.48	209.92	6,861.91	84.16	159.89	5,227.18	57.83	109.92	3,593.06	31.53	59.91	1,958.33	5.21	9.90	323.59			
X_{10}	Barley	26.67[1]	8.00	60.81																					
X_{11}	Oats	13.33	23.90	103.84																					
	Fallow	18.97	0.00	0.00																					
	Total	400.00	562.01	36,159.66	400.00	1,000.00	46,802.23	400.00	1,100.00	47,075.32	400.00	1,200.00	47,348.53	400.00	1,300.00	47,621.62	400.00	1,400.00	47,894.83	400.00	1,500.00	48,168.02	400.00	1,519.82	48,222.11
	MODEL C																								
X_1	Cotton (65)																								
X_2	Cotton (80)	187.70	294.50	30,903.41																					
X_3	Cotton (95)				187.70	326.60	32,832.48	187.70	326.60	32,832.48	187.70	326.60	32,832.48	187.70	326.60	32,832.48	187.70	326.60	32,832.48	187.70	326.60	32,832.48	187.70	326.60	32,832.48
X_4	Alfalfa (A)				48.64	229.09	1,853.18																		
X_5	Alfalfa (B)	80.00	103.68	481.60																					
X_6	Alfalfa (C)				83.36	444.31	5,211.67	132.00	703.56	8,252.64	118.21	630.06	7,390.49												
X_7	Alfalfa (D)										13.79	82.74	999.64	137.20	823.20	9,945.63	162.20	973.20	11,757.88	187.20	1,123.20	13,570.13	212.20	1,273.20	15,382.38
X_8	Corn Silage	100.00	131.93	4,610.00				52.91	69.84	2,439.15															
X_9	Grain Sorghum										80.30	160.60	4,987.43	75.10	150.20	4,664.46	50.10	100.20	3,111.71	25.10	50.20	1,558.96	0.10	0.20	6.21
X_{10}	Barley	26.67[1]	8.00	60.81																					
X_{11}	Oats	13.33	23.90	103.84																					
	Fallow				80.30	0.00	0.00	27.39	0.00	0.00															
	Total	400.00	562.01	36,159.66	400.00	1,000.00	39,897.33	400.00	1,100.00	43,524.27	400.00	1,200.00	46,210.04	400.00	1,300.00	47,422.57	400.00	1,400.00	47,702.07	400.00	1,500.00	47,961.57	400.00	1,600.00	48,221.07

1 Not included in total

produced on the maximum number of acres allowed under the cotton program (cotton 95), or about 45 percent of the water-right acres. About 15.6 percent of the water-right acres would be devoted to the production of alfalfa at the "D" level, and the remaining tillable acres (38 percent of the water-right acres) would be devoted to grain sorghum. The above combination of enterprises would result in a net farm income of approximately $46,664.

As more irrigation water becomes available, alfalfa D substitutes for grain sorghum at a rate of 25.00 acres per one-fourth acre-foot of irrigation water per water-right acre until 4.00 acre-feet of irrigation water is pumped per water-right acre, where only cotton 95 and alfalfa D are produced on the water-right acres. If more than 4.00 acre-feet were available, net farm returns to land and management would not increase, but would remain at $48,222.11 which is 33.4 percent above the typical whole farm budget.

Although the above combinations of crop enterprises result in the maximum returns for each quantity of irrigation water, they do not specifically allow for a crop rotation program. Crop yields, and therefore returns, would be reduced if these combinations of crop enterprises were produced for extended time periods at the lower levels of irrigation water pumpage.

Linear Programming Solutions--Model B

The coefficients and constraints for model B are the same as for model A except that irrigation water coefficients have been reduced by 5 percent. The irrigation water coefficients and the first irrigation water constraint for model B are listed below:

$$1.13X_1 + 1.39X_2 + 1.65X_3 + 4.47X_4 + 1.24X_5 + 5.06X_6 + 5.70X_7 + 1.25X_8$$

$$+ 1.90X_9 + 0.29X_{10} + 1.70X_{11} \leq 1{,}000 \text{ acre-feet of irrigation water}$$

The X variables are identified in table 51.

In table 51 the whole farm budget for the typical crop year is compared with the results of model B. These solutions presented in table 51 indicate the optimal net farm returns and the combinations of crops that would be produced if there were no assumed crop rotation program on Case Farm F.

In table 51 the net farm return obtained from the linear programming solutions is also contrasted with $36,159.66, which was obtained from the typical crop year with 562.01 acre-feet of irrigation water (1.41 acre-feet per water-right acre). The net farm return for the typical crop year would have been increased about 29 percent with the combination of crop enterprises that is indicated in model B with 2.50 acre-feet of irrigation water; about 30 percent with 2.75 acre-feet; about 31 percent with 3.00 acre-feet; about 32 percent with 3.25 acre-feet; about 32 percent with 3.50 acre-feet; about 33 percent with 3.75 acre-feet; and about 33 percent with 4.00 acre-feet.

The solutions for model B reflect a 5 percent increase in irrigation water efficiency on each crop. If 2.50 acre-feet of irrigation water per water-right acre were available, cotton 95 would comprise about 45 percent of the water-right acres, grain sorghum about 34 percent, alfalfa D about 19 percent, and the remaining 2 percent would be diverted. As more irrigation water becomes available alfalfa D substitutes for grain sorghum at a rate of 26.31 acres per one-fourth acre-foot of irrigation water per water-right acre until 3.80 acre-feet per acre are pumped. If more than 3.80 acre-feet were available net farm return would not be increased, but would remain at $48,222.11. This is 33.4 percent above the typical whole farm budget. A 5 percent increase in irrigation efficiency increased the optimal net farm returns by an average of 0.35 percent.

Linear Programming Solutions--Model C

The coefficients and constraints for model C are the same as for model A except that an additional constraint was placed on a minimum amount of alfalfa being produced. The coefficients and the added constraint are listed below:

$$0X_1 + 0X_2 + 0X_3 + 1X_4 + 1X_5 + 1X_6 + 1X_7 + 0X_8 + 0X_9 + 0X_{10} + 0X_{11}$$

$\geq$ 132 acres of alfalfa

The X variables are identified in table 51.

In table 51 the whole farm budget for the typical crop year is compared with the results of model C. These solutions, presented in table 51, indicate the optimal net farm returns and the combinations of crops that would be produced if a minimum of one-third of the water-right acres were devoted to alfalfa production, which is the assumed crop rotation program on Case Farm F.

In table 51 the net farm return obtained from the linear programming solutions is also contrasted with $36,159.66, which was obtained from the typical crop year with 562.01 acre-feet of irrigation water (1.41 acre-feet per water-right acre). The net farm return for the typical crop year would have been increased about 10 percent with the combination of crop enterprises that is indicated in model C with 2.50 acre-feet of irrigation water; increased about 20 percent with 2.75 acre-feet; increased about 28 percent with 3.00 acre-feet; increased about 31 percent with 3.25 acre-feet; increased about 32 percent with 3.50 acre-feet; increased about 33 percent with 3.75 acre-feet; and increased about 33 percent with 4.00 acre-feet.

The primary reason for the lower return figure at 2.50 acre-feet of irrigation water per water-right acre is the requirement that about one-third of the farm be planted in alfalfa. In order to have enough water for alfalfa approximately one-fifth of the farm must be left fallow. Also, alfalfa A and C would be produced, which require 4.47 and 5.33 acre-feet of irrigation water per acre respectively.

As more irrigation water becomes available more acres would be devoted to alfalfa C and corn silage. At the 2.75 level of irrigation water diversion, alfalfa A shifts to corn silage and alfalfa C acreage should increase from 83.36 to 132.00 acres. At the 3.00 acre-feet irrigation water diversion level, alfalfa C and D should be produced on 118.21 and 13.79 acres respectively. Grain sorghum would be produced on 80.3 acres. With 3.25 acre-feet of irrigation water available per water-right acre, the maximum net farm return to land and management is obtained with 178.32 acres of planted cotton, 137.2 acres of alfalfa D, and 75.1 acres of grain sorghum.

The optimal solutions and cropping patterns for 3.50, 3.75, and 4.00 acre-feet per water-right acre are reported in table 52.

The immediate economic effect of forcing in a crop rotation of about one-third of the farm into alfalfa is a reduction in net farm returns at irrigation water diversion less than 3.25 acre-feet per water-right acre. This effect can be estimated by comparing solutions from model A with solutions from model C. Net farm return would be reduced by $6,766.74 (17 percent) at 2.50 acre-feet per water-right acre, $3,399.50 (8 percent) at 2.75 acre-feet per water-right acre, $973.03 (2 percent) at 3.00 acre-feet per water-right acre.

The results obtained from the three linear programming models are graphically summarized in figure 17. This graph indicates the effects of the seven quantities of irrigation water on the net farm return. In models A and B, as irrigation water is increased from 1,000 acre-feet to 1,600 acre-feet (2.50 to 4.00 acre-feet per water-right acre), and 1,000 to 1,520 acre-feet (2.50 to 3.80 acre-feet per water-right acre) the net farm return increases at a constant rate. Beyond 1,600 and 1,520 acre-feet for models A and B respectively, the size of farm (water-right acres) and cropping enterprises considered in this study become the factors that restrict net farm returns.

In model C, as irrigation water is increased from 1,000 acre-feet to 1,200 acre-feet (2.50 to 3.00 acre-feet per water-right acre), the net return per water-right acre increases at almost a constant rate. From 1,200 to 1,600 acre-feet (3.00 to 4.00 acre-feet) the rate of increase is at a lower constant rate, and beyond

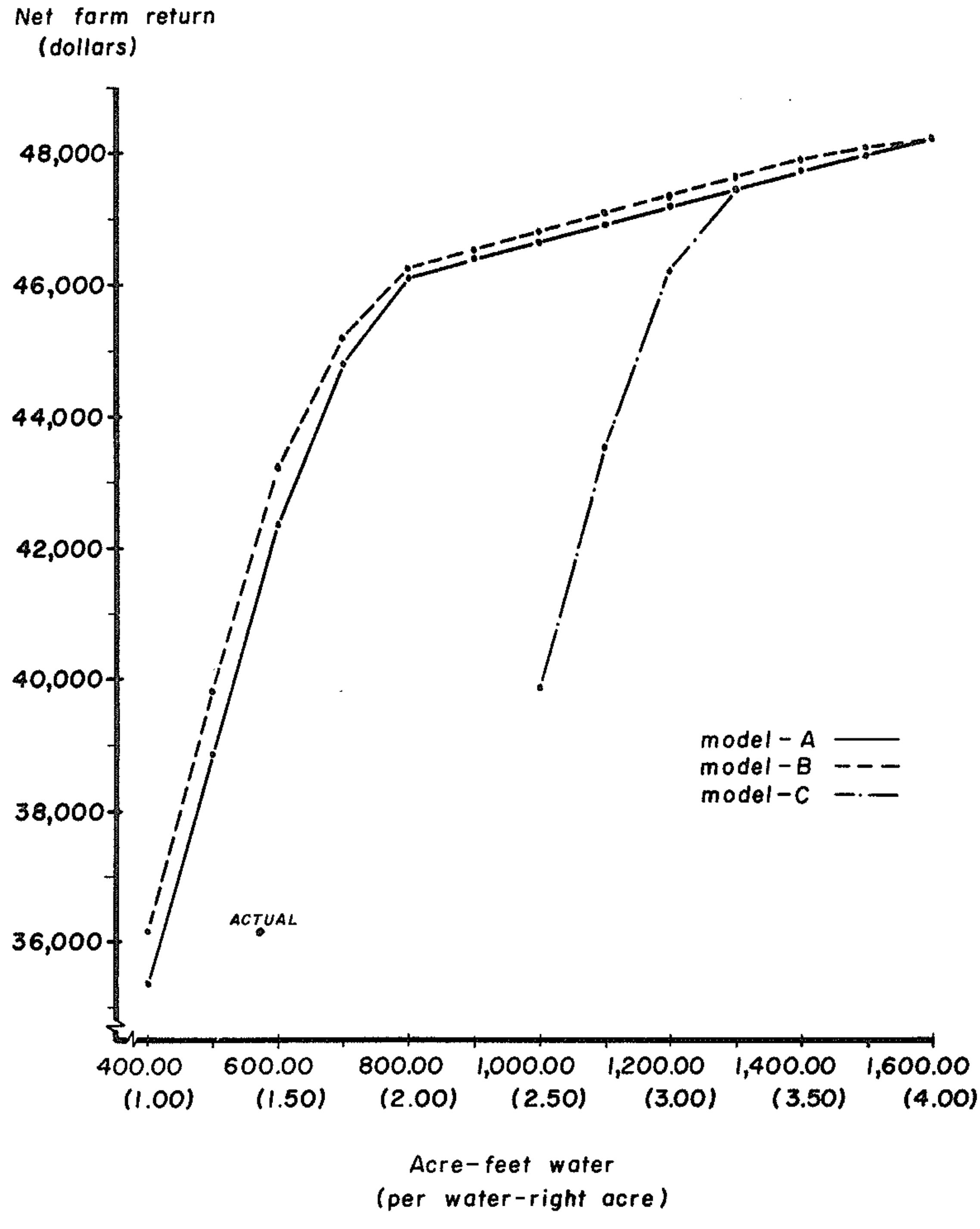


Figure 17. Case Farm F: Net farm return for thirteen quantities of irrigation water, Roswell Artesian Basin, New Mexico.

1,600 acre-feet (4.00 acre-feet per water-right acre) the size of the farm (cultivated acres) and cropping enterprises considered become the limiting factors.

Optimal Quantity of Irrigation Water

The shadow prices (marginal value products) for an additional acre-foot of irrigation water are presented in table 52. The optimal level of irrigation water diversion for each model can be determined by equating the shadow price with the cost of pumping an acre-foot of irrigation water. The estimated cost of pumping an acre-foot of irrigation water was $7.68. For models A and B the optimal quantity of water was below 2.50 acre-feet per water-right acre; for both models it was between 700 and 800 (1.75 and 2.00 acre-feet per water-right acre), and for model C it was between 1,200 and 1,300 acre-feet (3.00 and 3.25 acre-feet per water-right acre).

In model C, if irrigation water diversions were limited to 3.00 acre-feet per water-right acre instead of the optimal quantity, net farm returns would have been reduced by as much as $1,232.50 (2.6 percent).

It would appear that Case Farm F was being operated at near the optimal cropping program under conditions of models A and B, but far below the optimal cropping program for maximum return under the conditions of model C.

Table 52. Case Farm F: Shadow prices for seven quantities of irrigation water diversion, Roswell Artesian Basin, New Mexico.

Quantity of Irrigation Water Diverted (acre-feet)	Shadow Price Model A (dollars)	Shadow Price Model B (dollars)	Shadow Price Model C (dollars)
1,000	2.60	2.73	39.39
1,100	2.60	2.73	34.92
1,200	2.60	2.73	14.88
1,300	2.60	2.73	2.60
1,400	2.60	2.73	2.60
1,500	2.60	2.73	2.60
1,600	2.60	0.00	2.60

CASE FARM G

GENERAL DESCRIPTION

Case Farm G was an owner-operator farm with 187.2 acres of shallow water rights. This farm was part of a 450-acre farming unit. Farm G was located in the Dexter-Hagerman Area of the Roswell Artesian Basin (figure 2).

Soils

The principal irrigated soils included on Case Farm G were Reagan Loams with 0-1 percent slopes and with 1-3 percent slopes. Approximately 96.3 percent of the cropland had soil with a 0-1 percent slope, and 3.7 percent had soil with a slope of 1-3 percent (figure 18). The Reagan Loam, 0-1 percent slopes, was SCS Capability Class I, and the Reagan Loam, 1-3 percent slopes, was SCS Capability Class II. A further description of the soils is included in appendix A.

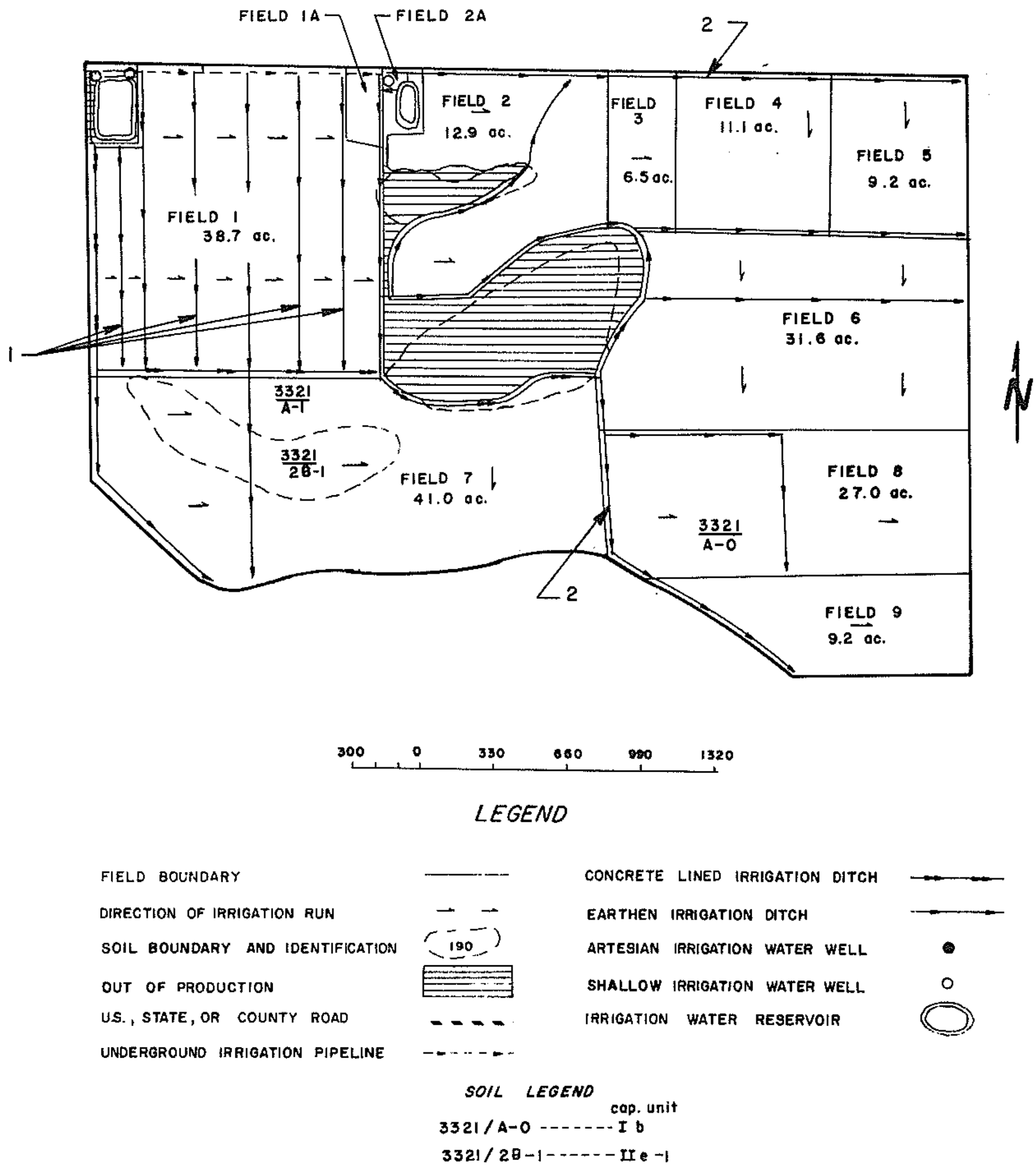
Irrigation Water

During the three-year period, Case Farm G had three shallow wells producing 150 to 350 gallons per minute with a total production of approximately 750 gallons per minute. Because of the low total production from the three irrigation wells, irrigation water was considered to be a limiting factor on this farm and partially had dictated the cropping program. The water had an average total soluble salt content of 1,741 millimhos and the average sodium adsorption ratio was 0.89 for the period of the study (2). This water was classified as Class 2.

Irrigation System

In 1966 and 1967, two reservoirs were used on Farm G. In 1967, one of the reservoirs was removed, leaving the reservoir in the northwest corner of the farm (figure 18). These reservoirs were normally used simultaneously in irrigating a large part of the farm because of the low quantity of water produced by each well.

The larger reservoir in the northwest corner of the farm was supplied with water from the two adjacent wells, and was drained into both an underground pipeline and a concrete ditch during most of 1967 and 1968, and into earthen ditches in 1966. The smaller reservoir was supplied from the adjacent well and was drained into earthen ditches during the 1966 and part of the 1967 crop years. Approximately 1,320 feet of underground pipeline, 4,420 feet of



1 Ditches removed when field 1 was planted in rye.
2 Concrete lined in spring of 1968.

Figure 18. Map of Case Farm G.

concrete ditch, and 22,380 feet of earthen ditch were used in 1967 and 1968; all ditches were earthen in 1966. Approximately 3,370 feet of previously earthen ditch was concrete-lined during 1967 and 1968 (figure 18).

Part of the cropland on Farm G had been leveled. Borders were not employed in the irrigation of the alfalfa but irrigation water runs were short (less than 700 feet). The approximate lengths of irrigation water runs for the different fields are reported in table 53.

Table 53. Case Farm G: Crops planted and approximate lengths of irrigation water runs by field, Roswell Artesian Basin, New Mexico.

Field Number	Crops Planted 1966	1967	1968	Length of Run (feet)
1	Alfalfa	Alfalfa	Alfalfa Rye	100- 240
1a	Out	Out	Rye	----
2	Diverted	Barley Diverted	Barley Rye	200- 820
2a	Reservoir	Reservoir	Barley Rye	----
3	Oats	Barley Diverted	Diverted Rye	300
4	Oats	Barley	Cotton	660- 690
5	Oats Alfalfa	Alfalfa	Alfalfa	660- 690
6	Alfalfa	Alfalfa	Alfalfa	290- 580
7	Cotton	Cotton	Cotton	1,000-1,290
8	Cotton	Barley	Barley Alfalfa	790- 840
9	Fallow	Fallow	Fallow Alfalfa	770-1,320

Crops Produced

The principal crops produced on Farm G were cotton, alfalfa, and small grains. The farm had a cotton allotment of 80.9 acres in 1966, and 60.4 acres in 1967 and 55.0 acres in 1968. In 1966 there were 68.0 acres planted to cotton and the remainder was diverted under provisions of the Upland Cotton Program. The planted acreage of cotton was 41.0 acres in 1967 and 52.1 acres in 1968 (table 54). Projected per-acre yields by ASC were 750 pounds in 1966, 780 pounds in 1967, and 755 pounds in 1968. The actual per-acre yields in pounds were 568.0 in 1966, 738.0 in 1967, and 547.2 in 1968 (table 55).

Alfalfa was produced primarily for hay and one seed crop in 1966, for pasture in 1967, and for hay in 1968. In 1966 alfalfa was produced on 29.5 acres of which 9.2 acres were fall seeded. In 1967 alfalfa was produced on 79.5 acres, and in 1968 on 114.3 acres of which 36.2 acres were fall seeded (table 54). The alfalfa yields were adjusted to allow for the lower yields obtained the first year of the assumed five-year production period and are reported in table 55.

Barley was produced for seed and pasture in 1967 and 1968 on 38.1 acres and 44.9 acres respectively. Oats were produced on 26.8 acres in 1966, primarily for hay. In the fall of 1968, rye was planted on 58.1 acres for pasture (table 54).

Irrigation Water Pumped

During 1966 a total of 516.12 acre-feet of irrigation water were pumped, in 1967 the total was 480.35 acre-feet, or about 36 acre-feet less, and in 1967 a total of 509.16 acre-feet of irrigation water was pumped (table 54). Irrigation water diversion was 2.76 acre-feet per water-right acre in 1966, 2.57 acre-feet in 1967, and 2.72 acre-feet in 1968 (table 54).

The average per-acre diversion for cotton for the three-year period was 2.70 acre-feet per acre. Alfalfa received an average of 3.72 acre-feet per acre on the established stand. The seedling alfalfa which was planted in the fall received an average of 0.47 acre-feet per acre. The barley received an average of 1.61 acre-feet per acre, oats received 1.51 acre-feet per acre, and rye received 0.45 acre-feet per acre.

In 1967 the average quantity of irrigation water used on Case Farm G was lower than the average for the Dexter-Hagerman Area. The average diversion for Farm G was 2.57 acre-feet per water-right acre, 2.57 acre-feet per cultivated acre, and 3.03 acre-feet per cropped acre. The average diversion for all farms in the Dexter-Hagerman

Table 54. Case Farm G: Crop acreages and irrigation water pumpage, Roswell Artesian Basin, New Mexico

Crop	Acres				Irrigation Water Pumped							
					Per Crop				Per Acre			
	1966	1967	1968	Average	1966	1967	1968	Average	1966	1967	1968	Average
					(acre-feet)				(acre-feet)			
Cotton	68.0	41.0	52.1	53.7	197.20	92.76	145.56	145.17	2.90	2.26	2.79	2.70
Diverted	12.9	19.4	2.9	11.7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alfalfa	70.3	79.5	78.1	76.0	267.14	303.66	277.88	282.90	3.80	3.82	3.56	3.72
Seedling alfalfa	9.2[1]	0.0	36.2[2]	15.1[1]	11.28	0.00	10.00	7.09	1.23	0.00	0.28	0.47
Barley	0.0	38.1	44.9[3]	27.7[4]	0.00	83.93	49.56	44.50	0.00	2.20	1.10	1.61
Oats	26.8	0.0	0.0	8.9	40.50	0.00	0.00	13.50	1.51	0.00	0.00	1.51
Rye	0.0	0.0	58.1[5]	19.4[6]	0.00	0.00	26.16	8.72	0.00	0.00	.45	.45
Fallow	9.2	9.2	9.2	9.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	187.2	187.2	187.2	187.2	516.12	480.35	509.16	501.88	2.76	2.57	2.72	2.68

1. Fall planted, oats, not included in total.
2. Fall planted, not included in total, 27 acres barley, 9.2 acres fallow.
3. Were not irrigated in 1968, 6.5 acres.
4. Not irrigated, 14.97 acres.
5. Not included in total, 38.7 acres alfalfa, 19.4 acres barley.
6. Not included in total.

Table 55. Case Farm G: Crops and yields per acre, Roswell Artesian Basin, New Mexico.

Crop	Unit	Yield per Acre			
		1966	1967	1968	Average
Cotton planted					
Lint	lb.	568.0	738.0	547.2	617.7
Seed	ton	0.43	0.55	0.61	0.53
Alfalfa					
Hay	ton	5.5	2.0	4.1	3.87
Seed	lb.	133.8	----	----	113.8
Straw	ton	0.28	----	----	0.28
Pasture	a.u.m.	----	10.25	----	10.25
Barley					
Seed	bu.	----	17.1	41.7	29.4
Pasture	a.u.m.	----	6.0	4.0	5.0
Oats					
Hay	ton	3.3	----	----	3.3
Rye					
Pasture	a.u.m.	----	----	4.0	4.0

Area was 2.83 acre-feet per water-right acre, 3.06 acre-feet per cultivated acre, and 3.39 acre-feet per cropped acre (9).

In 1968 Case Farm G was slightly above the average irrigation water diversion of farms in the Dexter-Hagerman Area. Case Farm G pumped 2.72 acre-feet per water-right acre, compared with 2.52 acre-feet per water-right acre in the Dexter-Hagerman Area (12).

Irrigation Efficiency

The typical irrigation efficiency by crops is reported in table 56 and yearly estimates in table C7. Irrigation efficiency on cotton ranged from 53.79 to 71.35 percent with an average of 59.12 percent; on alfalfa, from 62.57 to 67.63 percent with an average of 65.54; and on small grains from 93.94 to 100.44 percent, averaging 97.51 percent (tables 56 and C7).

Table 56. Case Farm G: Typical consumptive irrigation requirement, irrigation water applied, and farm irrigation efficiency.

Crop	Consumptive Irrigation Requirement (acre-inches)	Irrigation Water Applied (acre-inches)	Farm Irrigation Efficiency (percent)
Cotton	18.80	31.80	59.12
Alfalfa	29.31	44.72	65.54
Barley	18.60	19.80	93.94
Oats	18.20	18.12	100.44
Rye	5.30	5.40	98.14

ECONOMIC ANALYSIS

Financial Summary

The typical per-acre net returns by crops are reported in table 57 and annual figures are presented in table D7. The net farm return for the three years was $16,547.78, $12,586.95, and $9,165.65 respectively (table E7).

Table 57. Case Farm G: Typical per-acre returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns per Acre (dollars)	Gross Expenses per Acre (dollars)	Net Returns to Land and Management per Acre (dollars)
Cotton planted	302.07	139.85	162.22
Cotton diverted	81.36	10.40	70.96
Alfalfa	110.90	72.87	38.03
Barley	48.80	42.08	6.72
Oats	71.72	35.32	36.40
Rye	10.80	18.88	- 8.08
Weighted average	132.95	72.69	60.26

Because of the wide variations in yields, prices, and net farm returns, a typical whole farm budget was computed for Farm G using typical yields, prices, and costs (table 58). This typical whole farm budget will be used to compare with the linear programming solutions to determine the effect of different levels of irrigation water diversions on net farm returns. The annual whole farm budgets are presented in appendix E (table E7).

Table 58. Case Farm G: Typical whole farm returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
Cotton planted	53.7	15,221.16	7,509.95	8,711.21
Cotton diverted	11.7	951.91	121.68	830.23
Alfalfa	91.1	10,102.99	6,638.46	3,464.53
Barley	27.7	1,351.76	1,165.62	186.14
Oats	8.9	638.31	314.35	323.96
Rye	19.4	209.52	366.27	- 156.75
Fallow	9.2	0.00	0.00	0.00
Total	221.7	29,475.65	16,116.33	13,359.32

Linear Programming Solutions--Model A

The coefficients and constraints for model A are presented below:

$$1X_1 + 1X_2 + 1X_3 + 1X_4 + 1X_5 + 1X_6 + 1X_7 + 1X_8 + 1X_9 + 1X_{10} + 1X_{11}$$

$\leq$ 187.2 acres

$$1X_1 + 1X_2 + 1X_3 + 0X_4 + 0X_5 + 0X_6 + 0X_7 + 0X_8 + 0X_9 + 0X_{10} + 0X_{11}$$

$\leq$ 65.4 acres of cotton

$$1.76X_1 + 2.16X_2 + 2.57X_3 + 4.71X_4 + 4.04X_5 + 5.33X_6 + 6.00X_7 + 2.10X_8$$

$+ 1.61X_9 + 1.51X_{10} + 0.45X_{11} \leq$ 468.00 acre-feet of irrigation water

The X variables are identified in table 59.

The parameter changes in irrigation water diversion (Qt), where Q = 468.00 acre-feet of irrigation water and t = 46.80 acre-feet result

Table 59. Case Farm G: Whole farm budget and linear programming solutions, models A, B, and C, Roswell Artesian Basin, New Mexico.

		Whole Farm Budget			Linear Programming Solutions																							
					2.50 acre feet per acre			2.75 acre feet per acre			3.00 acre feet per acre			3.25 acre feet per acre			3.50 acre feet per acre			3.75 acre feet per acre			4.00 acre feet per acre		
Variable	Crop	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars
	MODEL A																								
X_1	Cotton (65)																								
X_2	Cotton (80)	65.40	145.17	9,541.44																					
X_3	Cotton (95)				65.40	168.08	10,310.96	65.40	168.08	10,310.96	65.40	168.08	10,310.96	65.40	168.08	10,310.96	65.40	168.08	10,310.96	65.40	168.08	10,310.96	65.40	168.08	10,310.96
X_4	Alfalfa (A)																								
X_5	Alfalfa (B)	91.10[1]	289.99	3,464.53																					
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)				11.32	67.92	820.02	23.32	139.92	1,689.30	35.32	211.92	2,558.58	47.32	283.92	3,427.86	59.32	355.92	4,297.14	71.32	427.92	5,166.42	83.32	499.92	6,035.70
X_8	Grain Sorghum				110.48	232.00	5,582.55	98.48	206.80	4,976.19	86.48	181.60	4,369.83	74.48	156.40	3,763.47	62.48	131.20	3,157.11	50.48	106.00	2,550.75	38.48	80.80	1,944.39
X_9	Barley	27.70	44.50	186.14																					
X_{10}	Oats	8.90	13.50	323.96																					
X_{11}	Rye	19.40[2]	8.72	-156.75																					
	Fallow	9.20	0.00	0.00																					
	Total	187.20	501.88	13,359.32	187.20	468.00	16,713.53	187.20	514.80	16,976.45	187.20	561.60	17,239.37	187.20	608.40	17,502.29	187.20	655.20	17,765.21	187.20	702.00	18,028.13	187.20	748.80	18,291.05
	MODEL B																								
X_1	Cotton (65)																								
X_2	Cotton (80)	65.40	145.17	9,541.44																					
X_3	Cotton (95)				65.40	159.58	10,310.96	65.40	159.58	10,310.96	65.40	159.58	10,310.96	65.40	159.58	10,310.96	65.40	159.58	10,310.96	65.40	159.58	10,310.96	65.40	159.58	10,310.96
X_4	Alfalfa (A)																								
X_5	Alfalfa (B)	91.10[1]	289.99	3,464.53																					
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)				17.52	99.86	1,269.15	30.17	171.97	2,185.51	42.82	244.07	3,101.88	55.47	316.17	4,018.25	68.11	388.23	4,933.89	80.76	460.33	5,850.25	93.41	532.44	6,766.62
X_8	Grain Sorghum				104.28	208.56	5,269.27	91.63	183.25	4,630.06	78.98	157.95	3,990.86	66.33	132.65	3,351.65	53.69	107.39	2,712.96	41.04	82.09	2,073.75	28.39	56.78	1,434.55
X_9	Barley	27.70	44.50	186.14																					
X_{10}	Oats	8.90	13.50	323.96																					
X_{11}	Rye	19.40[2]	8.72	-156.75																					
	Fallow	9.20	0.00	0.00																					
	Total	187.20	501.88	13,359.32	187.20	468.00	16,849.38	187.20	514.80	17,126.53	187.20	561.60	17,403.70	187.20	608.40	17,680.86	187.20	655.20	17,957.81	187.20	702.00	18,234.96	187.20	748.80	18,512.13
	MODEL C																								
X_1	Cotton (65)																								
X_2	Cotton (80)	65.40	145.17	9,541.44																					
X_3	Cotton (95)				65.40	168.08	10,310.96	65.40	168.08	10,310.96	65.40	168.08	10,310.96	65.40	168.08	10,310.96	65.40	168.08	10,310.96	65.40	168.08	10,310.96	65.40	168.08	10,310.96
X_4	Alfalfa (A)																								
X_5	Alfalfa (B)	91.10[1]	289.99	3,464.53	62.00	250.49	2,543.24	62.00	250.48	2,543.24	48.46	195.78	1,987.83	12.18	49.21	499.62									
X_6	Alfalfa (C)										13.54	72.17	845.03	49.82	265.54	3,109.27	15.61	83.20	974.22						
X_7	Alfalfa (D)																46.39	278.34	3,360.49	71.32	427.92	5,166.42	83.32	499.92	6,035.70
X_8	Grain Sorghum				23.54	49.43	1,189.48	45.83	96.24	2,315.79	59.80	125.57	3,021.69	59.80	125.57	3,021.69	59.80	125.58	3,021.69	50.48	106.00	2,550.75	38.48	80.80	1,944.39
X_9	Barley	27.70	44.50	186.14																					
X_{10}	Oats	8.90	13.50	323.96																					
X_{11}	Rye	19.40[2]	8.72	-156.75																					
	Fallow	9.20	0.00	0.00	36.26	0.00	0.00	13.97	0.00	0.00															
	Total	187.20	501.88	13,359.32	187.20	468.00	14,043.68	187.20	514.80	15,169.99	187.20	561.60	16,165.51	187.20	608.40	16,941.54	187.20	655.20	17,667.36	187.20	702.00	18,028.13	187.20	748.80	18,291.05

1 Not included in total, 15.1 acres

2 Not included in total

in the following irrigation water constraints:

2.75 acre-feet per water-right acre = 514.80 acre-feet
3.00 acre-feet per water-right acre = 561.60 acre-feet
3.25 acre-feet per water-right acre = 608.40 acre-feet
3.50 acre-feet per water-right acre = 655.20 acre-feet
3.75 acre-feet per water-right acre = 702.00 acre-feet
4.00 acre-feet per water-right acre = 728.80 acre-feet

In table 59 the whole farm budget for the typical crop year is compared with the results of model A. The linear programming solutions presented in table 59 indicate the optimal net farm returns and the combinations of the eleven crops that would be produced if there were no assumed crop rotation program on Case Farm G.

In table 59 the net farm return obtained from the linear programming solutions is also contrasted with $13,359.32, which was obtained from the typical crop year with 501.88 acre-feet of irrigation water (2.68 acre-feet per water-right acre). The net farm return for the typical crop year would have been increased about 25 percent with the combination of crop enterprises that is indicated in model A with 2.50 acre-feet of irrigation water; about 27 percent with 2.75 acre-feet; about 29 percent with 3.00 acre-feet; about 31 percent with 3.25 acre-feet; about 33 percent with 3.50 acre-feet; about 35 percent with 3.75 acre-feet; and about 37 percent with 4.00 acre-feet.

The lower net farm return for the typical crop year can be attributed primarily to the production of cotton at the 82.1 percent level of the allotment, and to the production of barley. Even at low levels (2.50 acre-feet of water per water-right acre) of irrigation water diversions, cotton would be produced on the maximum number of acres allowed under the cotton program, or about 33 percent of the water-right acres. About 6.0 percent of the water-right acres would be devoted to the production of alfalfa at the "D" level and the remaining tillable acres (59 percent of water-right acres) would be devoted to grain sorghum. The above combination of enterprises would result in a net farm return of approximately $16,714.

As more irrigation water becomes available, alfalfa D substitutes for grain sorghum at a rate of 12.00 acres per one-fourth acre-foot of irrigation water per water-right acre until 898.88 acre-feet (4.80 acre-feet per water-right acre) of irrigation water is pumped, where only cotton 95 and alfalfa D are produced on the water-right acres. If more than 898.88 acre-feet (4.80 acre-feet per water-right acre) were available net farm returns to land and management would not increase, but would remain at $19,134.15.

Although the above combinations of crop enterprises result in the maximum returns for each quantity of irrigation water, they do not specifically allow for a crop rotation program. Crop yields, and therefore returns, would be reduced if these combinations of crop enterprises were produced for extended periods at the lower levels of irrigation water pumpage.

Linear Programming Solutions--Model B

The coefficients and constraints for model B are the same as for model A except that irrigation water coefficients have been reduced by 5 percent. The irrigation water coefficients and the first irrigation water constraint for model B are listed below:

$$1.67X_1 + 2.05X_2 + 2.44X_3 + 4.47X_4 + 3.84X_5 + 5.06X_6 + 5.70X_7 + 2.00X_8$$

$$+ 1.53X_9 + 1.43X_{10} + 0.43X_{11} \leq 468.00 \text{ acre-feet of irrigation water}$$

The X variables are identified in table 59.

In table 59 the whole farm budget for the typical crop year is compared with the results of model B. These solutions presented in table 59 indicate the optimal net farm returns and the combinations of crops that would be produced if there were no assumed crop rotation program on Case Farm G.

In table 59 the net farm return obtained from the linear programming solutions is also contrasted with $13,359.32, which was obtained from the typical crop year with 501.88 acre-feet of irrigation water (2.68 acre-feet per water-right acre). The net farm return for the typical crop year would have been increased about 26 percent with the combination of crop enterprises that is indicated in model B with 2.50 acre-feet of irrigation water; about 28 percent with 2.75 acre-feet; about 30 percent with 3.00 acre-feet; about 32 percent with 3.25 acre-feet; about 34 percent with 3.50 acre-feet; about 36 percent with 3.75 acre-feet; and about 39 percent with 4.00 acre-feet.

The solutions for model B reflect a 5 percent increase in irrigation water efficiency on each crop. If 2.50 acre-feet of irrigation water per water-right acre were available, cotton 95 would comprise about 33 percent of the water-right acres, grain sorghum about 59 percent, alfalfa D about 6 percent, and the remaining 2 percent would be diverted. As more irrigation water becomes available alfalfa D substitutes for grain sorghum at a rate of 12.65 acres per one-fourth acre-foot of irrigation water per water-right acre until 853.84 acre-feet (4.56 acre-feet per acre) are pumped until only cotton 95 and alfalfa D is produced on the water-right acres.

If more than 853.84 acre-feet (4.56 acre-feet per water-right acre) were available net farm return would not be increased, but would remain at $19,134.15. This is about 43 percent above the typical whole farm budget. A 5 percent increase in irrigation efficiency increased the optimal net farm returns by an average of 1 percent.

Linear Programming Solutions--Model C

The coefficients and constraints for model C are the same as for model A except that an additional constraint was placed on a minimum amount of alfalfa being produced. The coefficients and the added constraint are listed below:

$$0X_1 + 0X_2 + 0X_3 + 1X_4 + 1X_5 + 1X_6 + 1X_7 + 0X_8 + 0X_9 + 0X_{10} + 0X_{11}$$

$\geq$ 62.0 acres of alfalfa

The X variables are identified in table 59.

In table 59 the whole farm budget for the typical crop year is compared with the results of model C. These solutions, presented in table 59, indicate the optimal net farm returns and the combinations of crops that would be produced if a minimum of one-third of the water-right acres were devoted to alfalfa production, which is the assumed crop rotation program.

In table 59 the net farm return obtained from the linear programming solutions is also contrasted with $13,359.32, which was obtained from the typical crop year with 501.88 acre-feet of irrigation water (2.68 acre-feet per water-right acre). The net farm return for the typical crop year would have been increased about 5 percent with the combination of crop enterprises that is indicated in model C with 2.50 acre-feet of irrigation water; increased about 14 percent with 2.75 acre-feet; increased about 21 percent with 3.00 acre-feet; increased about 27 percent with 3.25 acre-feet; increased about 32 percent with 3.50 acre-feet; increased about 35 percent with 3.75 acre-feet; and increased about 37 percent with 4.00 acre-feet.

The primary reason for the lower return figure at 2.50 acre-feet of irrigation water per water-right acre is the level of alfalfa production and fallow land. In order to have enough water for alfalfa, even at a low level, alfalfa B would be produced on the required 62 acres. Cotton 95 and grain sorghum would be produced on 65.40 and 45.83 acres respectively, and alfalfa B on 62.00 acres.

As more irrigation water becomes available more acres would be devoted to grain sorghum. At the 2.75 level of irrigation water diversion, alfalfa B acreage would remain the same and grain sorghum would increase from 23.54 to 45.83 acres with a corresponding decrease in fallow acreage. At the 3.00 acre-feet irrigation water diversion level, planted cotton acreage would be produced on 62.13 acres and alfalfa shifts slightly to 48.46 acres of alfalfa (B) and 13.54 acres of alfalfa C. With 3.25 acre-feet of irrigation water available per water-right acre the maximum net farm return is obtained with 62.13 acres of planted cotton, 12.18 acres of alfalfa (B), 49.82 acres of alfalfa C, and 59.80 acres of grain sorghum.

At 3.50 acre-feet of irrigation water available per water-right acre the maximum net farm return is obtained with 62.13 acres of planted cotton, 15.61 acres of alfalfa (C), 46.39 acres of alfalfa (D), and 59.80 acres of grain sorghum. At 3.75 acre-feet per water-right acre alfalfa D substitutes for alfalfa C and grain sorghum, and at 4.00 acre-feet model C is the same as model A.

The results obtained from the three linear programming models are graphically summarized in figure 19. This graph indicates the effects of the seven quantities of irrigation water on the net farm return. In models A and B, as irrigation water is increased from 468.0 acre-feet to 748.8 acre-feet (2.50 to 4.00 acre-feet per water-right acre) the net farm return increases at a constant rate and would continue at a constant rate until 898.56 and 853.63 acre-feet (4.80 and 4.56 acre-feet per water-right acre) respectively were pumped. Beyond 898.56 and 853.63 acre-feet for models A and B respectively, the size of farm (water-right acres) and cropping enterprises considered in this study become the factors that restrict net farm returns.

In model C, as irrigation water is increased from 468.00 acre-feet to 561.6 acre-feet (2.50 to 3.00 acre-feet per water-right acre), the net return per water-right acre increases at almost a constant rate. From 561.6 to 702.0 acre-feet (3.50 to 3.75 acre-feet) the rate of increase is at a lower constant rate. At 702.0 acre-feet model C is the same as model A. Beyond 898.56 acre-feet (4.80 acre-feet per water-right acre) the size of farm (water-right acres) and cropping enterprises considered become the limiting factors.

Optimal Quantity of Irrigation Water

The shadow prices (marginal value products) for an additional acre-foot of irrigation water are presented in table 60. The optimal level of irrigation water diversion for each model can be determined by equating the shadow price with the cost of pumping an acre-foot of irrigation water. The estimated cost of pumping an acre-foot of irrigation water was $7.68. For model A and B the optimal quantity of water was below 2.50 acre-feet per water-right acre; for model A it was between 421.2 and 468.0 (2.25 and 2.50 acre-feet per water-right acre), and for model B it was between 374.4 and 421.2 (2.00

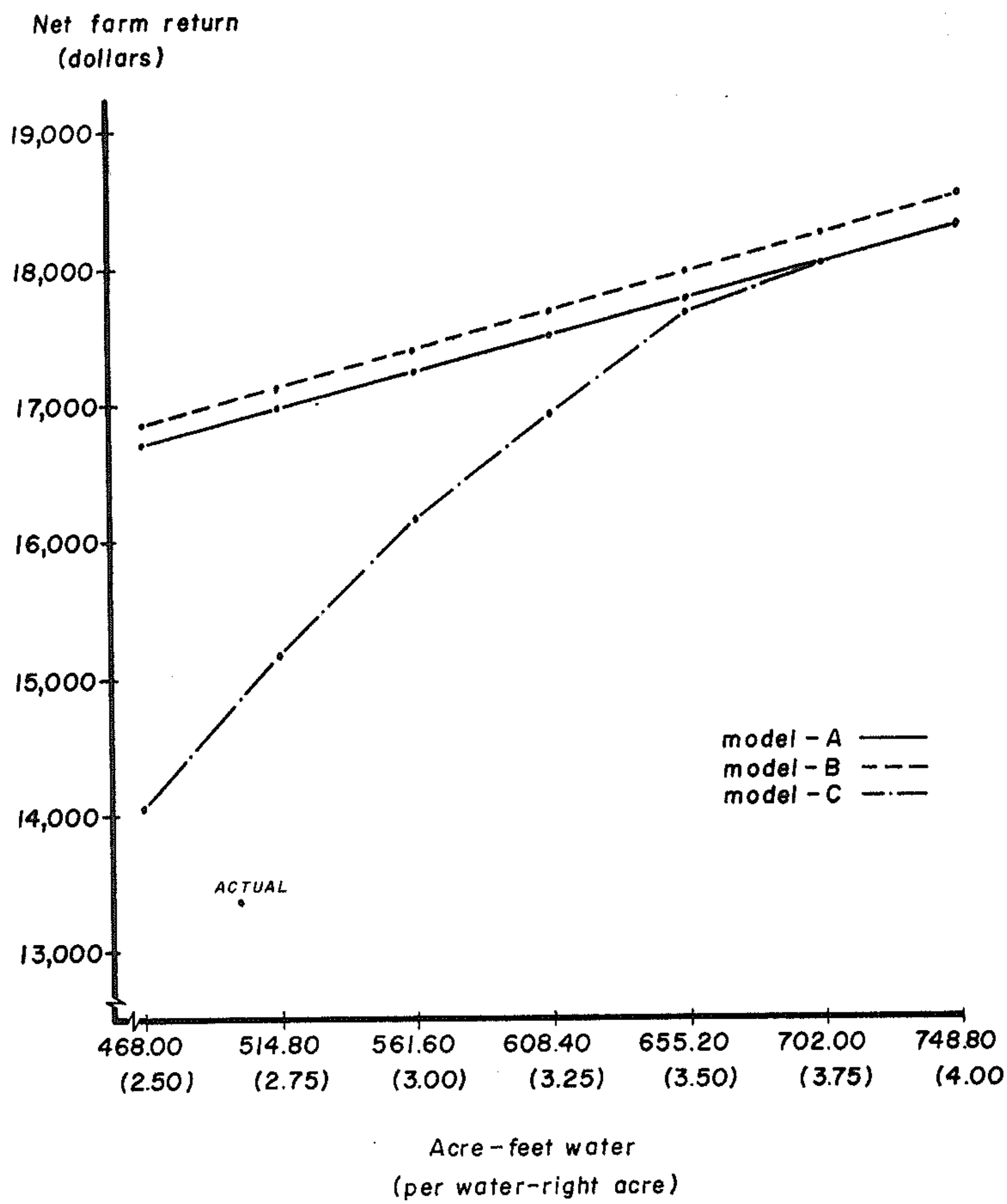


Figure 19. Case Farm G: Net farm return for seven quantities of irrigation water, Roswell Artesian Basin, New Mexico.

and 2.25 acre-feet per water-right acre). For model C, the optimal quantity of water was between 655.2 and 702.0 acre-feet (3.50 and 3.75 acre-feet per water-right acre).

In model C, if irrigation water diversions were limited to 561.6 acre-feet (3.00 acre-feet per water-right acre) instead of the optimal quantity, net farm returns would be reduced between $1,501.85 to $1,862.62 (9 percent to 11.5 percent).

It would appear that Case Farm G was being operated at above the optimal cropping program under conditions of models A and B, but far below the optimal cropping program for maximum return under the conditions of model C.

Table 60. Case Farm G: Shadow prices for seven quantities of irrigation water diversion, Roswell Artesian Basin, New Mexico.

Quantity of Irrigation Water Diverted (acre-feet)	Shadow Price Model A (dollars)	Shadow Price Model B (dollars)	Shadow Price Model C (dollars)
468.0	5.62	5.92	24.06
514.8	5.62	5.92	24.06
561.6	5.62	5.92	16.58
608.4	5.62	5.92	16.58
655.2	5.62	5.92	14.97
702.0	5.62	5.92	5.62
748.8	5.62	5.92	5.62

CASE FARM H

GENERAL DESCRIPTION

Case Farm H was an owner-operator farm with 174.0 acres of surface water rights with an annual allotment of 2.5 acre-feet per water-right acre from the Pecos River. The farm was located in the Dexter-Hagerman Area of the Roswell Artesian Basin (figure 2). This farm cooperated in the study for only two years, 1967 and 1968.

Soils

The principal soils included on Case Farm H were Reagan Loam, Reagan Silty Loam, Reagan Silty Clay Loam, and Vinton Loamy Fine Sand (figure 20). The Reagan Loam comprised approximately 30 percent, Reagan Silty Loam about 29.5 percent, Reagan Silty Clay Loam about 30 percent, and the Vinton Loamy Fine Sand about 10.5 percent of the irrigated cropland (figure 20). The Reagan Loam and Reagan Silty Loam were SCS Capability Class I, and the Reagan Silty Clay Loam and Vinton Loamy Fine Sand were Class II. These soils are further described in appendix A.

Irrigation Water

Irrigation water used on Farm H was pumped from the Pecos River. Since the quality of the river water varies from day to day no attempt was made to analyze the irrigation water quality for this farm.

Irrigation System

Approximately one mile of concrete-lined ditch was used to convey irrigation water from the Pecos River to the northwest boundary of the farm. There were approximately 8,000 feet of concrete-lined ditch and about 4,950 feet of earthen primary and secondary lateral ditches on the farm (figure 20).

All of the cropland on Case Farm H had been grade leveled. Borders were employed in the irrigation of all alfalfa fields. The approximate length of irrigation water runs for the different fields are reported in table 61.

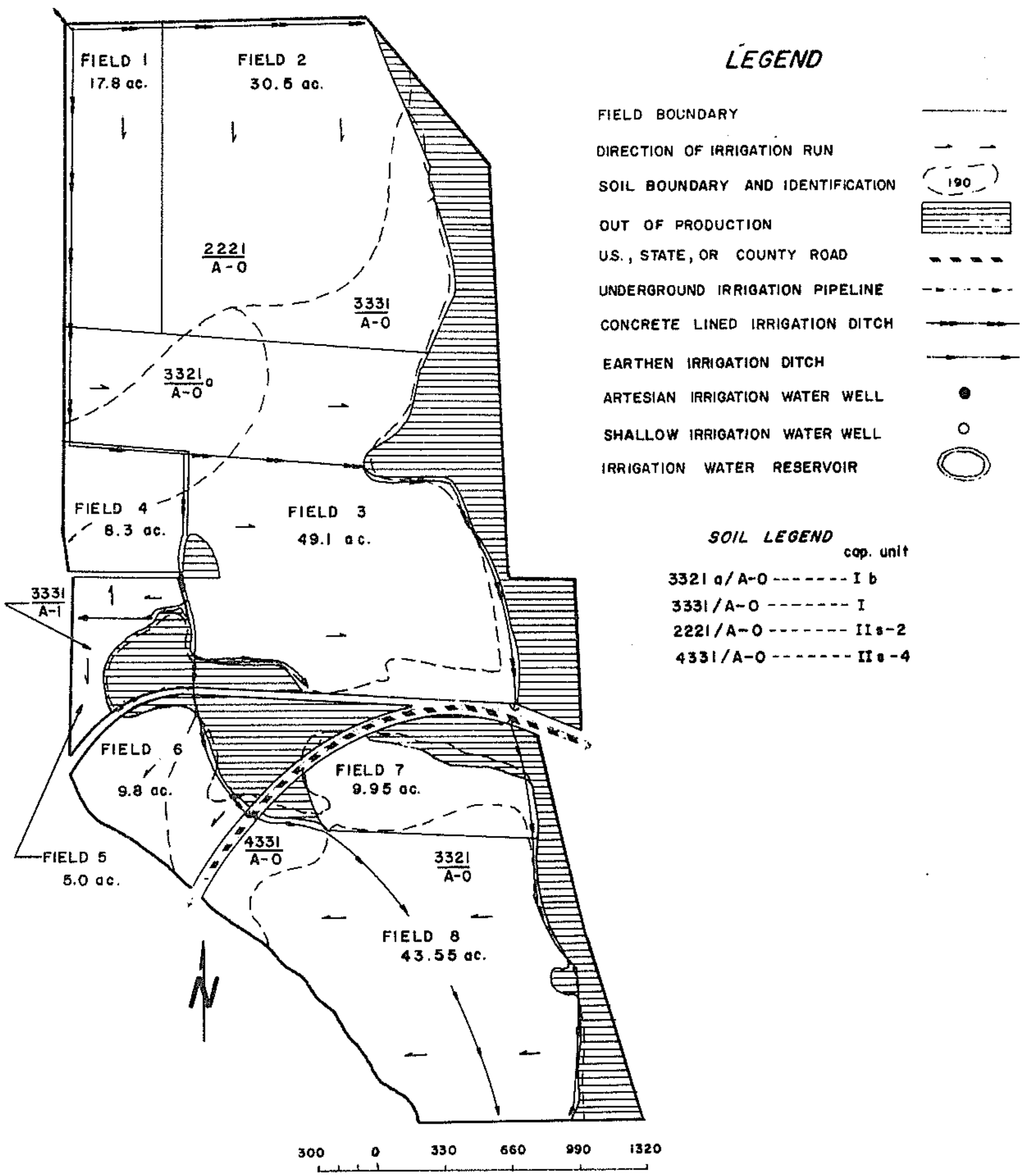


Figure 20. Map of Case Farm H.

Table 61. Case Farm H: Crops planted and approximate length of irrigation water runs by field, Roswell Artesian Basin, New Mexico.

Field Number	Crops Planted 1967	Crops Planted 1968	Length of Run (feet)
1	Cotton	Cotton Forage sorghum Alfalfa	1,480-1,500
2	Alfalfa	Cotton Alfalfa	1,500-1,600
3	Alfalfa	Alfalfa	530-1,690
4	Cotton	Cotton	580- 630
5	Alfalfa	Cotton	200- 660
6	Alfalfa	Alfalfa	450- 710
7	Diverted	Diverted Fallow	----
8	Cotton	Cotton	400- 980

Crops Produced

Cotton and alfalfa were the primary crops produced on Case Farm H. The cotton allotment was 110.8 acres for Case Farm H and another farm together. In 1967 cotton was produced on 69.65 acres on Case Farm H, and on 71.60 acres in 1968 (table 62). The diversion under the Upland Cotton Program was 9.95 acres in 1967 and 5.60 acres in 1968. The projected per-acre yields by ASC were 915 pounds in 1967, and 995 pounds in 1968. The actual per-acre yields were 908.0 pounds in 1967, and 888.6 pounds in 1968 (table 63).

In 1967 alfalfa was produced on 94.4 acres, of which 49.1 acres were used to produce hay and the remaining 45.3 acres were used to produce seed alfalfa. In 1968 alfalfa was produced on 92.45 acres of which 6.5 were planted in the fall. The yields were adjusted to allow for the lower yield obtained in the first year of the assumed five-year production period (table 63). In 1968 forage sorghum was produced for pasture on 6.5 acres. The yield is reported in table 63.

Table 62. Case Farm H: Crop acreages and irrigation water pumpage, Roswell Artesian Basin, New Mexico

Crop	Acres			Irrigation Water Pumped[1]					
				Per Crop			Per Acre		
	1967	1968	Average	1967	1968	Average	1967	1968	Average
				(acre-feet)			(acre-feet)		
Cotton	69.65	71.60	70.62	221.49	306.69	264.09	3.18	4.28	3.74
Diverted	9.95	5.60	7.77	0.00	0.00	0.00	0.00	0.00	0.00
Alfalfa	94.40	85.95	90.18	430.46	559.95	495.20	4.56	6.51	5.49
Seedling alfalfa	0.00	6.50[2]	3.25[3]	0.00	13.42	6.71	0.00	2.06	2.06
Forage sorghum	0.00	6.50	3.25	0.00	18.59	9.30	0.00	2.86	2.86
Fallow	0.00	4.35	2.18	0.00	0.00	0.00	0.00	0.00	0.00
Total	174.00	174.00	174.00	651.95	898.65	775.30	3.75	5.16	4.46

1. Also includes rainfall, actual pumpage for 1967 was 516.9 acre-feet and for 1968, 573.5 acre-feet. Rainfall for 1967 was 9.9 inches and for 1968, 23.2 inches.
2. Not included in total, was forage sorghum.
3. Not included in total.

Table 63. Case Farm H: Crops and yields per acre, Roswell Artesian Basin, New Mexico.

Crop	Unit	Yield per Acre 1966	1967	1968	Average
Cotton planted					
Lint	lb.	1,114.7	908.0	888.6	970.4
Seed	ton	0.84	0.71	0.67	0.74
Alfalfa					
Hay	ton	----	6.7	7.0	6.85
Seed	lb.	----	21.6	----	21.6
Forage sorghum	a.u.m.	----	----	7.2	7.2

Irrigation Water Pumped

The irrigation water pumpage for this farm was 516.9 acre-feet in 1967. Of this 516.9 acre-feet, 423.8 acre-feet were pumped under a public water right, and 93.1 acre-feet were pumped under a private water right (or drain pool right). In 1968 a total of 573.5 acre-feet of irrigation water was pumped from the Pecos River. Included in this total were 403.6 acre-feet from the public source, and 169.9 acre-feet from the private (drain pool) source. In addition to this pumped water, 135.05 acre-feet in 1967, and 325.15 acre-feet in 1968 were from rainfall. This water was included in the total irrigation water primarily because the irrigation system was installed in a manner to allow for the use of rainfall for irrigation (table 62).

The average per-acre diversion for cotton for the two-year period was 3.74 acre-feet per acre. Alfalfa received an average of 5.49 acre-feet per acre on the established stand. The seedling alfalfa which was planted in the fall received an average of 2.06 acre-feet per acre. The forage sorghum received an average of 2.86 acre-feet per acre.

The average quantity of irrigation water diverted on Case Farm H during 1967 was higher than the average quantity diverted in the Dexter-Hagerman Area of the Roswell Artesian Basin. The average irrigation water diversion on Farm H was 3.75 acre-feet per water-right and cultivated acre, and 3.97 per cropped acre. The average irrigation water diversion for all farms in the Dexter-Hagerman Area was 2.83 acre-feet per water-right acre, 3.06 acre-feet per cultivated acre, and 3.39 acre-feet per cropped acre in 1967 (9).

In 1968 the average irrigation water diversion for Farm H was 5.16 acre-feet per water-right acre, this was considerably above the average for all farms in the Dexter-Hagerman Area of 2.52 acre-feet per water-right acre (12).

Irrigation Efficiency

The irrigation efficiency by crops is reported in table 64, and yearly estimates in table C8. Irrigation efficiency on cotton ranged from 35.67 to 50.71 percent with an average of 42.09 percent; on alfalfa from 34.22 to 56.65 with an average of 43.47 percent; on forage sorghum, 34.94 percent (table C8).

Table 64. Case Farm H: Typical consumptive irrigation requirement, irrigation water applied, and farm irrigation efficiency.

Crop	Consumptive Irrigation Requirement (acre-inches)	Irrigation Water Applied (acre-inches)	Farm Irrigation Efficiency (percent)
Cotton	18.44	44.76	42.09
Alfalfa	28.87	66.42	43.47
Forage sorghum	11.99	34.32	34.94

ECONOMIC ANALYSIS

Financial Summary

The typical per-acre net returns by crops are reported in table 65 and annual net returns in appendix D (table D8). The net farm return was $27,584.76 in 1967 and $22,416.16 in 1968 (table E8).

Table 65. Case Farm H: Typical per-acre returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns per Acre (dollars)	Gross Expenses per Acre (dollars)	Net Returns to Land and Management per Acre (dollars)
Cotton planted	428.16	142.72	285.44
Cotton diverted	98.11	8.95	89.16
Alfalfa	155.00	116.26	38.74
Forage sorghum	19.39	49.82	- 30.43
Weighted average	256.95	119.45	137.50

Because of the variations in yields, prices, and net farm returns a typical whole farm budget was computed using typical yields, prices, and costs (table 66). This typical whole farm budget will be used to compare with the linear programming solutions to determine the effect of different levels of irrigation water diversions on net farm returns. The annual whole farm budgets are presented in appendix E (table E8).

Table 66. Case Farm H: Typical whole farm returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
Cotton planted	70.62	30,236.66	10,078.89	20,157.77
Cotton diverted	7.77	762.31	69.54	692.77
Alfalfa	93.43	14,481.65	10,862.17	3,619.48
Forage sorghum	3.25	63.02	161.92	- 98.90
Fallow	2.18	0.00	0.00	0.00
Total	177.25	45,543.64	21,172.52	24,371.12

Linear Programming Solutions--Model A

The coefficients and constraints for model A are presented below:

$1X_1 + 1X_2 + 1X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 1X_8 + 1X_9 \leq 174$ acres

$1X_1 + 1X_2 + 1X_3 + 0X_4 + 0X_5 + 0X_6 + 0X_7 + 0X_8 + 0X_9 \leq 78.39$ acres of cotton

$2.43X_1 + 2.99X_2 + 3.55X_3 + 4.71X_4 + 0X_5 + 5.33X_6 + 6.00X_7 + 2.50X_8 + 2.86X_9 \leq 435.00$ acre-feet or irrigation water

The X variables are identified in table 67.

The parameter changes in irrigation water diversion (Qt), where Q = 435.00 acre-feet of irrigation water and t = 43.50 acre-feet result in the following irrigation water constraints:

2.75 acre-feet per water-right acre = 478.50 acre-feet
3.00 acre-feet per water-right acre = 522.00 acre-feet
3.25 acre-feet per water-right acre = 565.50 acre-feet
3.50 acre-feet per water-right acre = 609.00 acre-feet
3.75 acre-feet per water-right acre = 652.50 acre-feet
4.00 acre-feet per water-right acre = 696.00 acre-feet

In table 67 the whole farm budget for the typical crop year is compared with the results of model A. The linear programming solutions presented in table 67 indicate the optimal net farm returns and the combinations of the eight crops that would be produced if there were no assumed crop rotation program on Case Farm H.

In table 67 the net farm return obtained from the linear programming solutions is also contrasted with $24,371.12, which was obtained from the typical crop year with 775.30 acre-feet of irrigation water (4.46 acre-feet of irrigation water per water-right acre). The net farm return for the typical crop year would have been increased about 5 percent with the combination of crop enterprises that is indicated in model A with 2.50 acre-feet of irrigation water; about 9 percent with 2.75 acre-feet; about 13 percent with 3.00 acre-feet; about 14 percent with 3.25 acre-feet; about 15 percent with 3.50 acre-feet; about 16 percent with 3.75 acre-feet; and about 16 percent with 4.00 acre-feet.

The lower net farm return for the typical crop year can be attributed primarily to the production of alfalfa at the "A" level and to production of forage sorghum. Even at low levels (2.50 acre-feet of water per water-right acre) of irrigation water diversions,

Table 67. Case Farm H: Whole farm budget and linear programming solution, models A, B, and C, Roswell Artesian Basin, New Mexico.

		Whole Farm Budget			Linear Programming Solutions																				
					2.50 acre feet per acre			2.75 acre feet per acre			3.00 acre feet per acre			3.25 acre feet per acre			3.50 acre feet per acre			3.75 acre feet per acre			4.00 acre feet per acre		
Variable	Crop	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars
	MODEL A																								
x_1	Cotton (65)																								
x_2	Cotton (80)																								
x_3	Cotton (95)	78.39	264.09	20,850.54	78.39	278.28	21,606.64	78.39	278.28	21,606.64	78.39	278.28	21,606.64	78.39	278.28	21,606.63	78.39	278.28	21,606.63	78.39	278.28	21,606.63	78.39	278.28	21,606.63
x_4	Alfalfa (A)	93.43	501.91	3,619.48																					
x_5	Alfalfa (B)																								
x_6	Alfalfa (C)																								
x_7	Alfalfa (D)										1.34	8.04	104.65	13.77	82.62	1,075.44	26.20	157.21	2,046.22	38.63	231.78	3,016.22	51.05	306.31	3,987.00
x_8	Grain Sorghum				62.69	156.72	3,886.78	80.09	200.22	4,965.58	94.27	235.68	5,844.68	81.84	204.60	5,074.08	69.41	173.51	4,303.42	56.98	142.44	3,532.76	44.56	111.41	2,762.72
x_9	Forage Sorghum	3.25[1]	9.30	-98.90																					
	Fallow	2.18	0.00	0.00	32.92	0.00	0.00	15.52	0.00	0.00															
	Total	174.00	775.30	24,371.12	174.00	435.00	25,493.42	174.00	478.50	26,572.22	174.00	522.00	27,555.97	174.00	565.50	27,756.15	174.00	609.00	27,956.27	174.00	652.50	28,155.61	174.00	696.00	28,356.35
	MODEL B																								
x_1	Cotton (65)																								
x_2	Cotton (80)																								
x_3	Cotton (95)	78.39	264.09	20,850.54	78.39	264.17	21,606.63	78.39	264.17	21,606.63	78.39	264.17	21,606.63	78.39	264.17	21,606.63	78.39	264.17	21,606.63	78.39	264.17	21,606.63	78.39	264.17	21,606.63
x_4	Alfalfa (A)	93.43	501.91	3,619.48																					
x_5	Alfalfa (B)																								
x_6	Alfalfa (C)																								
x_7	Alfalfa (D)										9.12	51.98	712.27	22.22	126.65	1,735.38	35.32	201.33	2,758.49	48.43	276.05	3,782.38	61.53	350.72	4,805.49
x_8	Grain Sorghum				71.78	170.83	4,450.36	90.05	214.33	5,583.10	86.49	205.85	5,362.38	73.39	174.68	4,550.18	60.29	143.50	3,737.98	47.18	112.28	2,925.16	34.08	81.11	2,112.96
x_9	Forage Sorghum	3.25[1]	9.30	-98.90																					
	Fallow	2.18	0.00	0.00	23.83	0.00	0.00	5.56	0.00	0.00															
	Total	174.00	775.30	24,371.12	174.00	435.00	26,056.99	174.00	478.50	27,189.73	174.00	522.00	27,681.28	174.00	565.50	27,892.19	174.00	609.00	28,103.10	174.00	652.50	28,314.17	174.00	696.00	28,525.08
	MODEL C																								
x_1	Cotton (65)				78.39	190.49	16,990.25																		
x_2	Cotton (80)							78.39	234.39	19,298.05															
x_3	Cotton (95)	78.39	264.09	20,850.54							78.39	278.28	21,606.63	78.39	278.28	21,606.63	78.39	278.28	21,606.63	78.39	278.28	21,606.63	78.39	278.28	21,606.63
x_4	Alfalfa (A)	93.43	501.91	3,619.48	44.06	207.52	1,706.88	44.71	210.58	1,732.07	45.35	213.60	1,756.86												
x_5	Alfalfa (B)																								
x_6	Alfalfa (C)				6.94	36.99	437.57	6.29	33.53	396.58	5.65	30.12	356.23	51.00	271.83	3,215.55	51.00	271.83	3,215.55	51.00	271.83	3,215.55			
x_7	Alfalfa (D)																						51.05	306.31	3,987.00
x_8	Grain Sorghum													6.15	15.39	381.30	23.55	58.89	1,460.10	40.95	102.39	2,538.90	44.56	111.41	2,762.72
x_9	Forage Sorghum	3.25[1]	9.30	-98.90																					
	Fallow	2.18	0.00	0.00	44.61	0.00	0.00	44.61	0.00	0.00	44.61	0.00	0.00	38.46	0.00	0.00	21.06	0.00	0.00	3.66	0.00	0.00			
	Total	174.00	775.30	24,371.12	174.00	435.00	19,134.70	174.00	478.50	21,426.70	174.00	522.00	23,719.72	174.00	565.50	25,203.48	174.00	609.00	26,282.28	174.00	652.50	27,361.08	174.00	696.00	28,356.35

1 Not included in total acres

cotton would be produced on the maximum number of acres allowed under the cotton program (cotton 95), or about 41 percent of water-right acres. About 46 percent of the water-right acres would be devoted to the production of grain sorghum and the remaining acres (18.9 percent of water-right acres) would be left fallow. The above combinations of enterprises would result in a net farm return of approximately $25,493.42.

As more irrigation water becomes available, at 2.75 acre-feet of water per water-right acre grain sorghum acreage increases to 80.09 acres. At 3.00 acre-feet of irrigation water per water-right acre, alfalfa at the "D" level begins to substitute for grain sorghum at a rate of 12.42 acres per one-fourth acre-foot of irrigation water per water-right acre until 4.90 acre-feet of irrigation water is pumped per water-right acre, where only cotton and alfalfa are produced. The net farm return would be $29,073.55, which is 19.3 percent above the typical whole farm budget.

Although the above combinations of crop enterprises result in the maximum returns for each quantity of irrigation water, they do not specifically allow for a crop rotation program. Crop yields, and therefore returns, may be reduced if these combinations of crop enterprises were produced for extended time periods at the lower levels of irrigation water pumpage.

Linear Programming Solutions--Model B

The coefficients and constraints for model B are the same as for model A except that irrigation water coefficients have been reduced by 5 percent. The irrigation water coefficients and the first irrigation water constraint for model B are listed below:

$$2.31X_1 + 2.84X_2 + 3.37X_3 + 4.47X_4 + 0X_5 + 5.06X_6 + 5.70X_7 + 2.38X_8$$

$$+ 2.27X_9 \leq 435.00 \text{ acre-feet of irrigation water}$$

The X variables are identified in table 67.

In table 67 the whole farm budget for the typical crop year is compared with the results of model B. These solutions presented in table 67 indicate the optimal net farm returns and the combinations of crops that would be produced if there were no assumed crop rotation program on Case Farm H.

In table 67 the net farm return obtained from the linear programming solutions is also contrasted with $24,371.12, which was obtained from the typical crop year with 775.30 acre-feet of irrigation water (4.46 acre-feet of irrigation water per water-right acre). The net farm return for the typical crop year would have been increased about 7 percent with the combination of crop enterprises that is indicated in model B with 2.50 acre-feet of irrigation water; about 12 percent with 2.75 acre-feet; about 14 percent with 3.00 acre-feet; about 14 percent with 3.25 acre-feet; about 15 percent with 3.50 acre-feet; about 16 percent with 3.75 acre-feet; and about 17 percent with 4.00 acre-feet.

The solutions for model B reflect a 5 percent increase in irrigation water efficiency on each crop. If 2.50 acre-feet of irrigation water per water-right acre were available, cotton 95 would comprise about 41 percent of the water-right acres, grain sorghum about 35 percent, and 24 percent would be diverted and fallow. As more irrigation water becomes available the acreage of grain sorghum increases, and at 3.00 acre-feet of irrigation water per water-right acre alfalfa D (5.70 acre-feet) begins to substitute for grain sorghum at a rate of 12.42 acres per one-fourth acre-foot of irrigation water per water-right acre until 4.69 acre-feet per acre are pumped. If more than 4.69 acre-feet were available net farm returns would not be increased, but would remain at $29,073.77. This is 19.3 percent above the typical whole farm budget. A 5 percent increase in irrigation efficiency increased the optimal net farm returns by an average of 1 percent.

Linear Programming Solutions-- Model C

The coefficients and constraints for model C are the same as for model A except that an additional constraint was placed on a minimum amount of alfalfa being produced. The coefficients and the added constraint are listed below:

$$0X_1 + 0X_2 + 0X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 0X_8 + 0X_9 \geq 51.0 \text{ acres of alfalfa}$$

The X variables are identified in table 67.

In table 67 the whole farm budget for the typical crop year is compared with the results of model C. These solutions, presented in table 67, indicate the optimal net farm returns and the combinations of crops that would be produced if a minimum of one-third of the water-right acres were devoted to alfalfa production, which is the assumed crop rotation program.

In table 67 the net farm return obtained from the linear programming solutions is also contrasted with $24,371.12, which was obtained from the typical crop year with 775.3 acre-feet of irrigation water (4.46 acre-feet of irrigation water per water-right acre). The net farm return for the typical crop year would have been decreased about 27 percent with the combination of crop enterprises that is indicated in model C with 2.50 acre-feet of irrigation water; decreased about 12 percent with 2.75 acre-feet; decreased about 3 percent with 3.00 acre-feet; increased about 3 percent with 3.25 acre-feet; increased about 8 percent with 3.50 acre-feet; increased about 12 percent with 3.75 acre-feet; and increased about 16 percent with 4.00 acre-feet.

The primary reason for the lower return figure at 2.50, 2.75, and 3.00 acre-feet of irrigation water per water-right acre is the requirement that about one-third of the farm be planted in alfalfa. In order to have enough water for alfalfa, cotton would be produced on 50.95 acres (cotton 65) for 2.50 acre-feet per water-right acre, and approximately one-third of the farm must be left fallow. Also, alfalfa A and C would be produced on 44.06 and 6.94 acres respectively. These require 4.71 and 5.33 acre-feet of irrigation water per acre respectively.

As more irrigation water becomes available cotton would be produced on 62.71 acres (cotton 80). At the 2.75 level of irrigation water diversion alfalfa A shifts from 44.06 to 44.71 acres, and alfalfa C shifts from 6.94 to 6.29 acres. At the 3.00 level of irrigation water diversion cotton shifts to the 95 percent planted level and alfalfa A acreage shifts slightly to alfalfa C. With 3.25 acre-feet of irrigation water available per water-right acre, the maximum net farm return is obtained with 74.47 acres of planted cotton, 51.0 acres of alfalfa C, 6.15 acres of grain sorghum, and 38.46 acres fallow.

The optimal solutions and cropping patterns for 3.50, 3.75, and 4.00 acre-feet per water-right acre are reported in table 67.

The immediate economic effect of forcing in a crop rotation of about one-third of the farm into alfalfa is a reduction in net farm returns at irrigation water diversion less than 4.00 acre-feet per water-right acre. This effect can be estimated by comparing solutions from model A with solutions from model C. Net farm returns would be reduced by about $6,358.72 (33 percent) at 2.50 acre-feet per water-right acre, $5,173.96 (24 percent) at 2.75 acre-feet per water-right acre, $3,836.25 (16 percent) at 3.00 acre-feet per water-right acre, $2,552.67 (10 percent) at 3.25 acre-feet per water-right acre, $1,673.99 (6 percent) at 3.50 acre-feet per water-right acre, and $794.53 (3 percent) at 3.75 acre-feet per water-right acre.

The results obtained from the three linear programming models are graphically summarized in figure 21. This graph indicates the effect of the seven quantities of irrigation water on net farm return per water-right acre. In models A and B as irrigation water is increased from 348.0 acre-feet to 522.0 acre-feet (2.50 to 3.00 acre-feet per water-right acre), the net return per water-right acre increases at an almost constant rate, and between 522.0 and 852.6 and 816.06 acre-feet (3.00 and 4.90 and 4.69 acre-feet) respectively it increases at a constant rate, but less than at the lower levels. Beyond 4.90 and 4.69 for model A and B respectively, the size of farm and cropping enterprises considered in this study become the factors

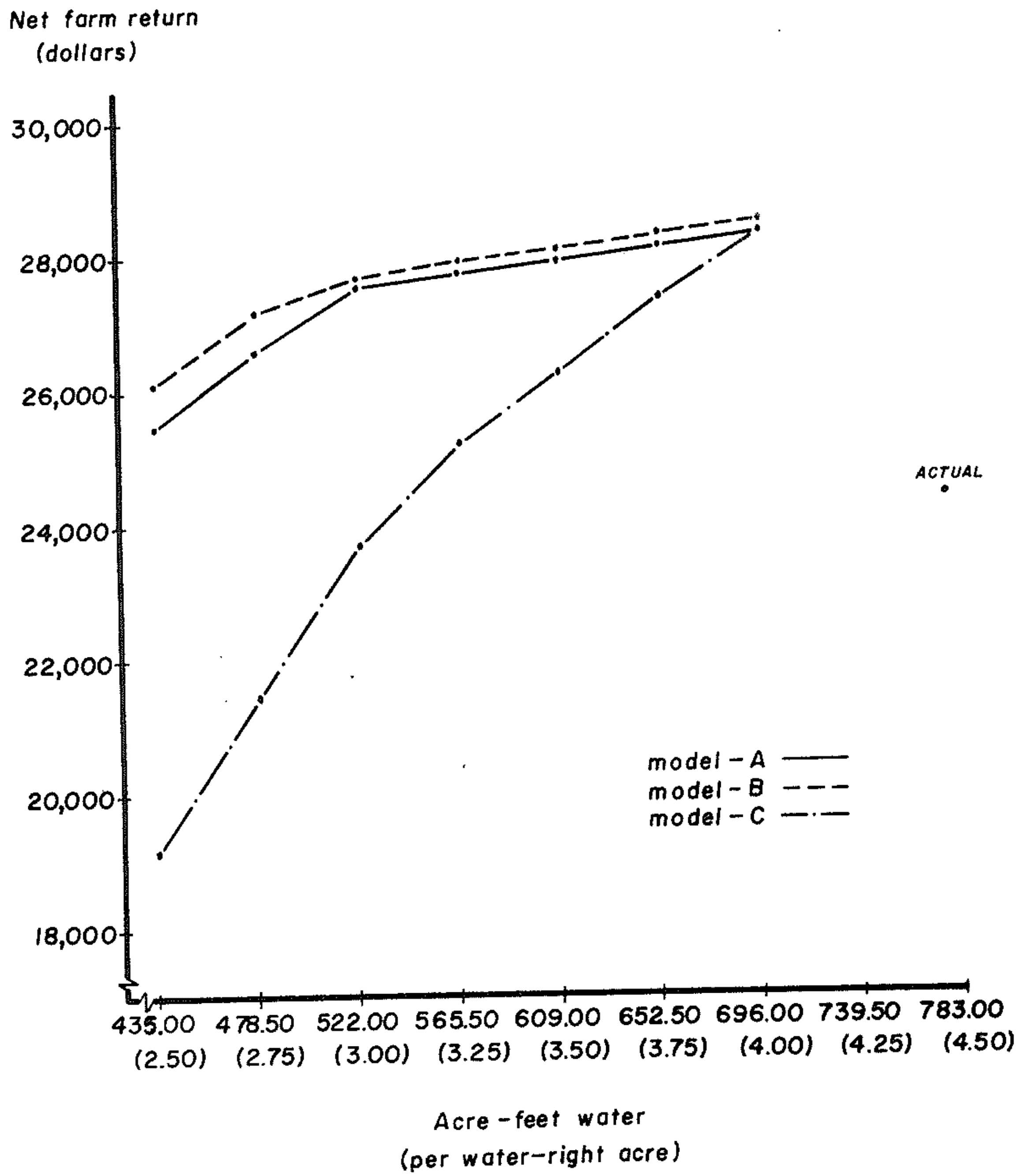


Figure 21. Case Farm H: Net farm return for seven quantities of irrigation water, Roswell Artesian Basin, New Mexico.

that restrict net farm returns.

In model C as irrigation water is increased from 348.0 acre-feet to 522.0 acre-feet (2.50 to 3.00 acre-feet per water-right acre), the net return per water-right acre increases at a constant rate, and from 522.0 to 696.0 acre-feet (3.00 to 4.00 acre-feet) the rate of increase is at a lower constant rate. Beyond 4.00 acre-feet model C is the same as model A until 852.6 acre-feet (4.90 acre-feet per water-right acre) is pumped where farm size and cropping enterprises considered become the limiting factors, as in model A and B.

Optimal Quantity of Irrigation Water

The shadow prices (marginal value products) for an additional acre-foot of irrigation water are presented in table 68. The optimal level of irrigation water diversion for each model can be determined by equating the shadow price with the cost of pumping an acre-foot of irrigation water. The estimated cost of pumping an acre-foot of irrigation water was $7.68. For models A and B the optimal quantity of water was between 478.5 and 522.0 acre-feet (2.75 and 3.00 acre-feet per water-right acre).

It would appear that 3.00 acre-feet per water-right acre would be a sufficient quantity for Case Farm H under the conditions of models A and B. However, in model C, if irrigation water diversion were limited to 3.00 acre-feet per water-right acre instead of the optimal quantity of 3.75 to 4.00 acre-feet per water-right acre, net returns per water-right acre would have been reduced between $20.93 to $26.65. On a whole farm basis net farm returns would have been reduced between $3,641.36 to $4,636.63 or approximately 15.4 to 19.5 percent.

Table 68. Case Farm H: Shadow prices for seven quantities of irrigation water diversion, Roswell Artesian Basin, New Mexico.

Quantity of Irrigation Water Diverted	Shadow Price Model A	Shadow Price Model B	Shadow Price Model C
	(dollars)	(dollars)	(dollars)
435.0	24.80	26.05	52.58
478.5	24.80	26.05	52.58
522.0	4.60	4.84	39.21
565.5	4.60	4.84	24.80
609.0	4.60	4.84	24.80
625.5	4.60	4.84	24.80
696.0	4.60	4.84	4.60

CASE FARM I

GENERAL DESCRIPTION

Case Farm I was an owner-operator farm with 122.2 acres of artesian water rights. This farm was part of a 775-acre farming unit and was located in the Cottonwood Area of the Roswell Artesian Basin (figure 2). This farm was included in the study for two years, 1966 and 1967.

Soils

The soils included on Case Farm I were Reagan Loam, Reeves Loam, and Cottonwood Loam (figure 22). The Reagan Loam comprised approximately 89 percent of the irrigated cropland and the Reeves Loam about 11 percent. The Cottonwood Loam comprised less than 1 percent of the irrigated cropland, and about 5 percent of the farmland, located primarily in the area out of production (figure 22). The Reagan Loam was SCS Capability Class I, the Reeves Loam was Class IV, and the Cottonwood Loam was Class VII. These soils are described further in appendix A.

Irrigation Water

Case Farm I had one artesian well, 1,008 feet deep, producing an average of 540 gallons per minute. The water from this well had an average total soluble salt content of 2,150 millimhos and the average sodium adsorption ratio was 0.52 for the period of the study (2). This water is classified as Class 2.

Irrigation System

The well on Farm I pumped into a reservoir with a capacity of approximately 5 acre-feet, which in turn drained through two outlets into approximately 9,150 feet of underground pipeline. About 3,700 feet of earthen primary and secondary lateral ditch was also included in the irrigation system (figure 22).

All of field number 1 had been bench leveled, and parts of the other fields were grade leveled. The unleveled land was located north of the underground pipeline in fields 3, 4, and 5 (figure 22).

The irrigation water on this farm was supplied to most of the crops from the underground pipeline through the use of rubber tubes. Thus, the irrigation water did not touch the ground until it reached the field. The approximate lengths of irrigation runs for the different fields are reported in table 69.

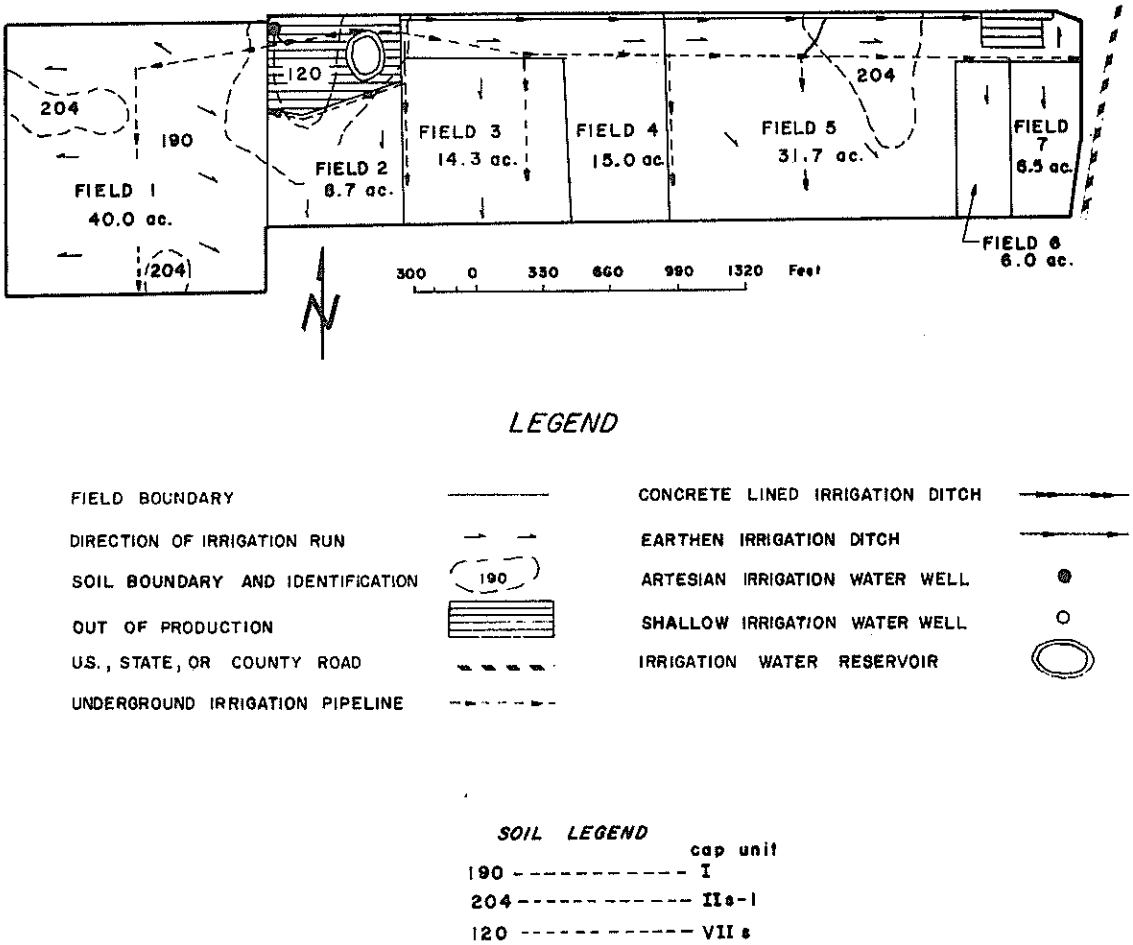


Figure 22. Map of Case Farm I.

Table 69. Case Farm I: Crops planted and approximate length of irrigation water runs by field, Roswell Artesian Basin, New Mexico.

Field Number	Crops Planted		Length of Run (feet)
	1966	1967	
1	Alfalfa	Alfalfa	200-400
2	Cotton	Cotton	530-660
3	Cotton	Cotton	320-450
4	Cotton	Diverted Fallow	185-420
5	Alfalfa	Alfalfa	185-800
6	Cotton	Alfalfa	760
7	Diverted	Oats	760

Crops Produced

The principal crops produced on Case Farm I were cotton and alfalfa. Case Farm I had a cotton allotment of 35.0 acres. In 1966 there were 44.0 acres planted to cotton on Case Farm I. The diverted acreage was 6.5 acres under the Government Upland Cotton Program. In 1967 there were 23.0 acres planted to cotton with 12.4 acres diverted (table 70). The projected per-acre yields were 800 pounds in 1966 and 830 pounds in 1967. The actual per-acre yields were 806.6 pounds and 739.0 pounds for the same period (table 71).

Alfalfa was produced on 71.7 acres in 1966 and on 77.7 acres in 1967. In 1967, 6.0 acres were planted in the spring. The adjusted yields are reported in table 71. Oats were produced on 6.5 acres in 1967, primarily for pasture.

Irrigation Water Pumped

In 1966 a total of 434.82 acre-feet of irrigation water was pumped for irrigation (table 70). The pumpage for 1967 was 439.63 acre-feet. Per-acre irrigation water diversions, 3.56 in 1966 and 3.60 in 1967, remained fairly stable over the two-year period.

Table 70. Case Farm I: Crop acreages and irrigation water pumpage, Roswell Artesian Basin, New Mexico

Crop	Acres			Irrigation Water Pumped					
				Per Crop			Per Acre		
	1966	1967	Average	1966	1967	Average	1966	1967	Average
				(acre-feet)			(acre-feet)		
Cotton	44.0	23.0	33.50	140.80	79.38	110.09	3.20	3.45	3.29
Diverted	6.5	12.4	9.45	0.00	0.00	0.00	0.00	0.00	0.00
Alfalfa	71.7	71.7	71.70	294.02	345.45	319.74	4.10	4.82	4.46
Seedling alfalfa	0.0	6.0[1]	3.00	0.00	12.00	6.00	0.00	2.00	2.00
Oats	0.0	6.5	3.25	0.00	2.80	1.40	0.00	0.43	0.43
Fallow	0.0	2.6	1.30	0.00	0.00	0.00	0.00	0.00	0.00
Total	122.2	122.2	122.2	434.82	439.63	437.23	3.56	3.60	3.58

1. Spring planted.

The average per-acre diversion for cotton for the two-year period was 3.29 acre-feet per acre. Alfalfa received an average of 4.46 acre-feet per acre on the established stand. The seedling alfalfa which was planted in the spring received an average of 2.00 acre-feet per acre. The oats received an average of 0.43 acre-feet per acre.

In 1967 the average quantity of irrigation water diverted on Farm I was higher than the average quantity diverted on all farms in the Cottonwood Area. The average irrigation water diversion on Case Farm I in 1967 was 3.60 acre-feet per water-right acre, 3.60 acre-feet per cultivated acre, and 3.76 acre-feet per cropped acre. The average irrigation water diversion for all farms in the Cottonwood Area was 3.29 acre-feet per water-right acre, 3.44 acre-feet per cultivated acre, and 3.82 acre-feet per cropped acre (12).

Table 71. Case Farm I: Crops and yields per acre for 1966 and 1967, Roswell Artesian Basin, New Mexico.

Crop	Unit	Yield per Acre			
		1966	1967	1968	Average
Cotton planted					
Lint	lb.	806.6	739.0	776.0	773.86
Seed	ton	0.69	0.63	0.58	0.63
Alfalfa					
Hay	ton	6.2	5.9	5.5	5.87
Oats					
Pasture	a.u.m.	----	5.0	----	5.0

Irrigation Efficiency

The typical irrigation efficiency by crops is reported in table 72 and yearly estimates in table C9. Irrigation efficiency on cotton ranged from 50.26 to 58.04 percent with an average of 54.31 percent for the two-year period; and on alfalfa from 62.17 to 63.66 percent with an average of 62.86 percent (table C9).

Table 72. Case Farm I: Typical consumptive irrigation requirement, irrigation water applied, and farm irrigation efficiency.

Crop	Consumptive Irrigation Requirement (acre-inches)	Irrigation Water Applied (acre-inches)	Farm Irrigation Efficiency (percent)
Cotton	21.67	39.90	54.31
Alfalfa	33.64	53.52	62.86
Barley	4.06	5.16	78.77

ECONOMIC ANALYSIS

Financial Summary

The typical per-acre net returns by crops are reported in table 73 and yearly figures are reported in table D9. The net farm return was $10,406.61 and $10,529.42 for 1966 and 1967 respectively (table E9).

Table 73. Case Farm I: Typical per-acre returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns per Acre (dollars)	Gross Expenses per Acre (dollars)	Net Returns to Land and Management per Acre (dollars)
Cotton planted	346.79	156.30	190.49
Cotton diverted	88.31	17.62	70.69
Alfalfa	146.75	116.74	30.01
Oats	13.50	15.22	- 1.72
Weighted average	191.60	115.69	75.91

Because of the wide variations in yields, prices, and net farm return a typical whole farm budget was computed using typical yields, prices, and costs (table 74). This typical whole farm budget will be used to compare with the linear programming solutions to determine the effect of different levels of irrigation water diversions on net farm returns. The annual whole farm budgets for 1966 and 1967 are presented in appendix E (table E9).

Table 74. Case Farm I: Typical whole farm returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
Cotton planted	33.50	11,617.47	5,236.05	6,381.42
Cotton diverted	9.45	834.53	166.51	668.02
Alfalfa	74.70	10,918.20	8,685.46	2,232.74
Oats	3.25	43.88	49.47	- 5.59
Fallow	1.30	0.00	0.00	0.00
Total	122.20	23,414.08	14,137.49	9,276.59

Linear Programming Solutions--Model A

The coefficients and constraints for model A are presented below:

$1X_1 + 1X_2 + 1X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 1X_8 + 1X_9 + 1X_{10} \leq 122.2$

acres

$1X_1 + 1X_2 + 1X_3 + 0X_4 + 0X_5 + 0X_6 + 0X_7 + 0X_8 + 0X_9 + 0X_{10} \leq 42.95$

acres of cotton

$2.14X_1 + 2.63X_2 + 3.13X_3 + 4.46X_4 + 0X_5 + 5.33X_6 + 6.00X_7 + 2.50X_8$

$+ 2.50X_9 + 0.43X_{10} \leq 305.50$ acre-feet of irrigation water

The X variables are identified in table 75.

The parameter changes in irrigation water diversion (Qt), where Q = 305.50 acre-feet of irrigation water and t = 30.55 acre-feet result in the following irrigation water constraints:

2.75 acre-feet per water-right acre = 336.05 acre-feet
3.00 acre-feet per water-right acre = 367.50 acre-feet
3.25 acre-feet per water-right acre = 397.15 acre-feet
3.50 acre-feet per water-right acre = 427.70 acre-feet
3.75 acre-feet per water-right acre = 458.25 acre-feet
4.00 acre-feet per water-right acre = 488.80 acre-feet

Table 75. Case Farm I: Whole farm budget and linear programming solutions, models A, B, and C, Roswell Artesian Basin, New Mexico.

		Whole Farm Budget			Linear Programming Solutions																				
					2.50 acre feet per acre			2.75 acre feet per acre			3.00 acre feet per acre			3.25 acre feet per acre			3.50 acre feet per acre			3.75 acre feet per acre			4.00 acre feet per acre		
Variable	Crop	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars
	MODEL A																								
X_1	Cotton (65)																								
X_2	Cotton (80)	42.95	110.09	7,049.44																					
X_3	Cotton (95)				42.95	134.43	7,924.28	42.95	134.43	7,924.28	42.95	134.43	7,924.28	42.95	134.43	7,924.28	42.95	134.43	7,924.28	42.95	134.43	7,924.28	42.95	134.43	7,924.28
X_4	Alfalfa (A)	74.70	325.74	2,232.74																					
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)							1.00	6.00	78.34	9.73	58.38	762.25	18.45	110.70	1,445.37	27.18	163.08	2,129.28	35.91	215.46	2,813.19	44.64	267.84	3,497.10
X_8	Grain Sorghum																								
X_9	Castor Beans				68.43	171.07	4,282.35	78.25	195.62	4,896.89	69.52	173.79	4,350.56	60.80	152.02	3,804.86	52.07	130.19	3,258.54	43.34	108.36	2,712.22	34.61	86.53	2,165.89
X_{10}	Oats	3.25	1.40	-5.59																					
	Fallow	1.30	0.00	0.00	10.82	0.00	0.00																		
	Total	122.20	437.23	9,276.59	122.20	305.50	12,206.63	122.20	336.05	12 899.51	122.20	366.60	13,037.09	122.20	397.15	13,174.51	122.20	427.70	13,312.10	122.20	458.25	13,449.69	122.20	488.80	13,587.27
	MODEL B																								
X_1	Cotton (65)																								
X_2	Cotton (80)	42.95	110.09	7,049.44																					
X_3	Cotton (95)				42.95	127.56	7,924.28	42.95	127.56	7,924.28	42.95	127.56	7,924.28	42.95	127.56	7,924.28	42.95	127.56	7,924.28	42.95	127.56	7,924.28	42.95	127.56	7,924.28
X_4	Alfalfa (A)	74.70	325.74	2,232.74																					
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)							5.99	34.14	469.26	15.19	86.58	1,189.98	24.39	139.02	1,910.71	33.59	191.46	2,631.44	42.79	243.91	3,352.17	52.00	296.40	4,073.68
X_8	Grain Sorghum																								
X_9	Castor Beans				74.76	177.94	4,678.48	73.26	174.35	4,584.61	64.06	152.46	4,008.87	54.86	130.57	3,433.14	45.66	108.68	2,857.40	36.46	86.78	2,281.67	27.25	64.86	1,705.31
X_{10}	Oats	3.25	1.40	-5.59																					
	Fallow	1.30	0.00	0.00	4.49	0.00	0.00																		
	Total	122.20	437.23	9,276.59	122.20	305.50	12,602.76	122.20	336.05	12,978.15	122.20	366.60	13,123.13	122.20	397.15	13,268.13	122.20	427.70	13,413.12	122.20	458.25	13,558.12	122.20	488.82	13,703.27
	MODEL C																								
X_1	Cotton (65)																								
X_2	Cotton (80)	42.95	110.09	7,049.44	42.95	112.96	7,152.46																		
X_3	Cotton (95)							42.95	134.43	7,924.28	42.95	134.43	7,924.28	42.95	134.43	7,924.28	42.95	134.43	7,924.28	42.95	134.43	7,924.28	42.95	134.43	7,924.28
X_4	Alfalfa (A)	74.70	325.74	2,232.74	23.75	105.93	712.74	13.31	59.36	399.43															
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)				16.25	86.61	966.71	26.69	142.26	1,587.79	11.69	62.31	695.44												
X_7	Alfalfa (D)										28.31	169.86	2,217.81	40.00	240.00	3,133.60	40.00	240.00	3,133.60	40.00	240.00	3,133.60	44.64	267.84	3,497.10
X_8	Grain Sorghum																								
X_9	Castor Beans													9.09	22.72	568.85	21.31	53.27	1,333.58	33.53	83.82	2,098.31	34.61	86.53	2,165.89
X_{10}	Oats	3.25	1.40	-5.59																					
	Fallow	1.30	0.00	0.00	39.25	0.00	0.00	39.25	0.00	0.00	39.25	0.00	0.00	30.16	0.00	0.00	17.94	0.00	0.00	5.72	0.00	0.00			
	Total	122.20	437.23	9,276.59	122.20	305.50	8,831.91	122.20	336.05	9,911.50	122.20	366.60	10,837.53	122.20	397.15	11,626.73	122.20	427.70	12,391.46	122.20	458.25	13,156.19	122.20	488.80	13,587.27

In table 75 the whole farm budget for the typical crop year is compared with the results of model A. The linear programming solutions presented in table 75 indicate the optimal net farm returns and the combinations of the nine crops that would be produced if there were no assumed crop rotation program on Case Farm I.

In table 75 the net farm return obtained from the linear programming solutions is also contrasted with $9,276.59, which was obtained from the typical crop year with 437.48 acre-feet of irrigation water (3.58 acre-feet of irrigation water per water-right acre). The net farm return for the typical crop year would have been increased about 32 percent with the combination of crop enterprises that is indicated in model A with 2.50 acre-feet of irrigation water; about 39 percent with 2.75 acre-feet; about 41 percent with 3.00 acre-feet; about 42 percent with 3.25 acre-feet; about 44 percent with 3.50 acre-feet; about 45 percent with 3.75 acre-feet; and about 46 percent with 4.00 acre-feet.

The lower net farm return for the typical crop year can be attributed primarily to the production of cotton at the 78 percent level of the allotment and to the production of alfalfa (A) and 6.5 acres of oats. Even at low levels (2.50 acre-feet of water per water-right acre) of irrigation water diversions, cotton would be produced on the maximum number of acres allowed under the cotton program (cotton 95) or about 33 percent of the water-right acres. The remaining tillable acres (65 percent of the water-right acres) would be devoted to castor beans. The above combination of enterprises would result in a net farm income of approximately $12,206.63.

As more irrigation becomes available, alfalfa D substitutes for castor beans at a rate of 8.75 acres per one-fourth acre-foot of irrigation water per water-right acre until 5.01 acre-feet of irrigation water is pumped per water-right acre, where only cotton and alfalfa are produced on the cropable acres. If more than 5.01 acre-feet were available net farm returns would not increase, but would remain at $14,156.23 or about 53 percent above the typical whole farm budget.

Although the above combinations of crop enterprises result in the maximum returns for each quantity of irrigation water, they do not specifically allow for a crop rotation program. Crop yields, and therefore returns, would be reduced if these combinations of crop enterprises were produced for extended time periods at the lower levels of irrigation water pumpage.

Linear Programming Solutions--Model B

The coefficients and constraints for model B are the same as for model A except that irrigation water coefficients have been reduced by 5 percent. The irrigation water coefficients and the first irrigation water constraint for model B are listed below:

$$2.03X_1 + 2.50X_2 + 2.97X_3 + 4.24X_4 + 0X_5 + 5.06X_6 + 5.70X_7 + 2.38X_8$$

$$+ 2.38X_9 + 0.41X_{10} \leq 305.50 \text{ acre-feet of irrigation water}$$

The X variables are identified in table 75.

In table 75 the whole farm budget for the typical crop year is compared with the results of model B. These solutions presented in table 75 indicate the optimal net farm returns and the combinations of crops that would be produced if there were no assumed crop rotation program on Case Farm I.

In table 75 the net farm return obtained from the linear programming solutions is also contrasted with $9,276.59, which was obtained from the typical crop year with 437.48 acre-feet of irrigation water (3.58 acre-feet of irrigation water per water-right acre). The net farm return for the typical crop year would have been increased about 36 percent with the combination of crop enterprises that is indicated in model B with 2.50 acre-feet of irrigation water; about 40 percent with 2.75 acre-feet; about 41 percent with 3.00 acre-feet; about 43 percent with 3.25 acre-feet; about 45 percent with 3.50 acre-feet; about 46 percent with 3.75 acre-feet; and about 48 percent with 4.00 acre-feet.

Case Farm I would not use more than 4.47 acre-feet of irrigation water per water-right acre under conditions of this study. The maximum cropping program of cotton 95 and alfalfa D is reached at this level of irrigation water diversion.

The solutions for model B reflect a 5 percent increase in irrigation water efficiency on each crop. If 2.50 acre-feet of irrigation water per water-right acre were available, cotton 95 would comprise about 33 percent of the water-right acres, and castor beans about 61 percent, and the remaining 6 percent would be diverted or out of production. As more irrigation water becomes available alfalfa D (5.70 acre-feet) substitutes for castor beans at a rate of 9.20 acres per one-fourth acre-foot per water-right acre until 4.74 acre-feet per acre are pumped. If more than 4.74 acre-feet were available net farm returns would not be increased, but would remain at $14,156.23. This is about 53 percent above the typical whole farm budget. A 5 percent increase in irrigation efficiency increases the optimal net farm returns by an average of 1 percent.

Linear Programming Solutions--Model C

The coefficients and constraints for model C are the same as for model A except that an additional constraint was placed on a minimum amount of alfalfa being produced. The coefficients and the added constraint are listed below:

$0X_1 + 0X_2 + 0X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 0X_8 + 0X_9 + 0X_{10} \geq 40.0$

acres of alfalfa

The X variables are identified in table 75.

In table 75 the whole farm budget for the typical crop year is compared with the results of model C. These solutions, presented in table 75, indicate the optimal net farm returns and the combinations of crops that would be produced if a minimum of one-third of the water-right acres were devoted to alfalfa production, which is the assumed crop rotation program.

In table 75 the net farm return obtained from the linear programming solutions is also contrasted with $9,276.59, which was obtained from the typical crop year with 3.58 acre-feet of irrigation water per water-right acre. The net farm return for the typical crop year would have been decreased about 5 percent with the combination of crop enterprises that is indicated in model C with 2.50 acre-feet of irrigation water; increased about 7 percent with 2.75 acre-feet; increased about 17 percent with 3.00 acre-feet; increased about 25 percent with 3.25 acre-feet; increased about 34 percent with 3.50 acre-feet; increased about 42 percent with 3.75 acre-feet; and increased about 46 percent with 4.00 acre-feet.

The primary reason for the lower return figure at 2.50, 2.75, and 3.00 acre-feet of irrigation water per water-right acre is the level of cotton production. In order to have enough water for alfalfa at the low level (2.50 acre-feet), cotton would be planted on 80 percent or 34.4 acres of the cotton allotment of 42.95 acres, alfalfa A and C on 40 acres and 39 acres left fallow. At the 2.75 acre-feet level, cotton would be planted on 95 percent or 40.8 acres. Also, 13.31 acres of alfalfa A and 26.69 acres of alfalfa C would be produced which require 4.46 and 5.33 acre-feet of irrigation per acre respectively with 39.25 acres left fallow. At the 3.00 acre-feet level cotton would remain at the 95 level, 28.31 acres of alfalfa D would be produced in addition to 11.69 acres of alfalfa C, and 39.25 acres would remain fallow.

At the 3.25 level of irrigation water diversion, planted cotton would be produced on 40.8 acres (cotton 95) and alfalfa D acreage would increase from 28.31 to 40.0 acres with a corresponding decrease in fallow and alfalfa C, and the addition of 9.09 acres of castor beans.

The optimal solution and cropping pattern for the 4.00 acre-feet per water-right acre level is the same as model A and is reported in table 75.

The immediate economic effect of forcing in a crop rotation of about one-third of the farm into alfalfa is a reduction in net farm returns at irrigation water diversions less than 4.00 acre-feet per water-right acre. This effect can be estimated by comparing solutions from model A with solutions from model C. Net farm returns would be reduced by $3,374.72 (38 percent) at 2.50 acre-feet per water-right acre, $2,988.01 (30 percent) at 2.75 acre-feet per water-right acre, $2,199.56 (20 percent) at 3.00, $1,547.78 (13 percent) at 3.25, $920.64 (7 percent) at 3.50, and $293.50 (2 percent) at 3.75. At 4.00 acre-feet per water-right acre the net farm returns and cropping patterns are the same for models A and C.

The results obtained from the three linear programming models are graphically summarized in figure 23. This graph indicates the effects of the seven quantities of irrigation water on the net farm return to land and management per water-right acre. In models A and B as irrigation water is increased from 305.50 acre-feet to 336.05 acre-feet (2.50 to 2.75 acre-feet per water-right acre), the net return per water-right acre increases at a constant rate, and from 336.05 acre-feet to 488.80 acre-feet per water-right acre (2.75 to 4.00 acre-feet), the net return per water-right acre also increases at a constant rate but at a lower rate. Beyond 4.00 acre-feet the size of farm (cultivated acres) and cropping enterprises considered in this study become the factors that restrict net farm return from increasing.

In model C as irrigation water is increased from 305.50 acre-feet to 488.80 acre-feet (2.50 to 4.00 acre-feet per water-right acre), the net return per water-right acre increases at almost a constant rate. Beyond 4.00 acre-feet the size of the farm and cropping enterprises considered become the limiting factors as in models A and B.

Optimal Quantity of Irrigation Water

The shadow prices (marginal value products) for an additional acre-foot of irrigation water are presented in table 76. The optimal level of irrigation water diversion for each model can be determined by equating the shadow price with the cost of pumping an acre-foot of irrigation water. The estimated cost of pumping an acre-foot of irrigation water was $7.68. For models A and B the optimal quantity of water was between 305.50 acre-feet and 336.05 acre-feet (2.50 and 2.75 acre-feet per water-right acre), and for model C, 458.25 acre-feet and 488.80 acre-feet (3.75 and 4.00 acre-feet per water-right acre).

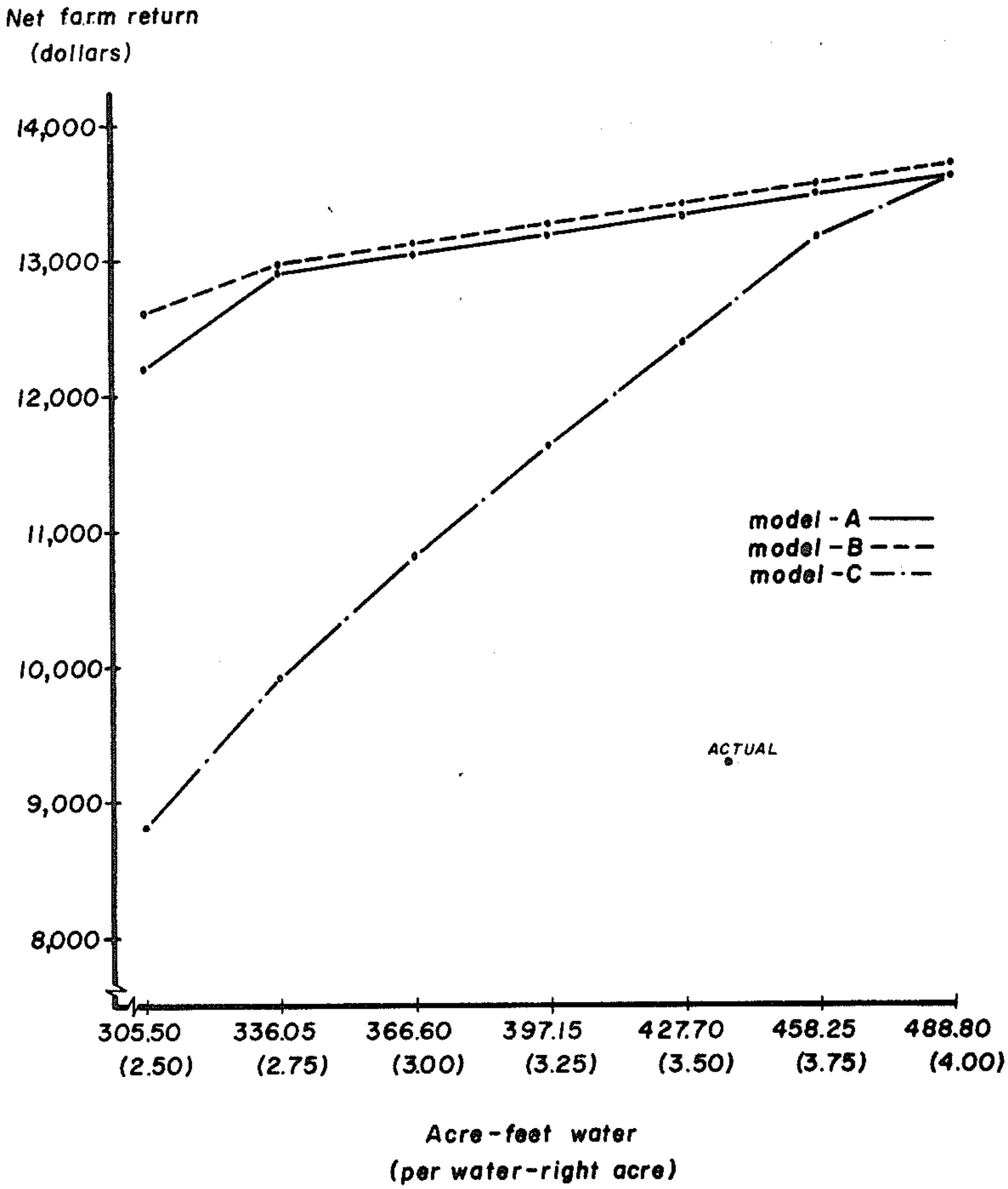


Figure 23. Case Farm I: Net farm return for seven quantities of irrigation water, Roswell Artesian Basin, New Mexico.

It would appear that 3.00 acre-feet per water-right acre would be a sufficient quantity for Case Farm I under the conditions of models A and B. However, in model C, if irrigation water diversion were limited to 3.00 acre-feet per water-right acre instead of the optimal quantity net farm return would be reduced between $2,318.06 to $2,749.74, or approximately 21.4 to 25.4 percent.

Table 76. Case Farm I: Shadow prices for seven quantities of irrigation water diversion, Roswell Artesian Basin, New Mexico.

Quantity of Irrigation Water Diverted (acre-feet)	Shadow Price Model A (dollars)	Shadow Price Model B (dollars)	Shadow Price Model C (dollars)
305.50	25.03	26.29	35.94
336.05	4.50	4.75	33.89
366.60	4.50	4.75	28.13
397.15	4.50	4.75	25.03
427.70	4.50	4.75	25.03
458.25	4.50	4.75	25.03
488.80	4.50	4.75	4.50

CASE FARM J

GENERAL DESCRIPTION

Case Farm J was an owner-operator farm with 151.4 acres of artesian water rights. The farm was located in the Artesia Area of the Roswell Artesian Basin (figure 2).

Soils

The principal soils included on Case Farm J were Reagan Loam, Reagan Silt Loam, and Rustler Silt Loam (figure 24). The Reagan Loam included approximately 29.2 percent of the irrigated cropland, the Reagan Silt Loam about 3.9 percent, and the Rustler Silt Loam about 66.9 percent. The Reagan Loam was SCS Capability Class I and the Reagan Silt Loam and Rustler Silt Loam were Class II. A detailed soils description appears in appendix A.

Irrigation Water

Case Farm J had two artesian wells, 1,195 and 1,205 deep, producing an average of about 1,000 and 1,750 gallons per minute during the period of this study. The water from these wells had an average total soluble salt content of about 1,206 millimhos and the average sodium adsorption ratio was about 0.59 for the period of this study (2). This water was classified as Class 2.

Irrigation System

Case Farm J had one reservoir. One artesian well pumped into the reservoir while the other well pumped directly into an underground pipeline approximately 4,500 feet long. The underground pipeline provided water for about 13,900 feet of earthen primary and secondary ditches (figure 24).

The cropland on Case Farm J had not been leveled and sloped from west to east (figure 24). Borders were used in most of the alfalfa fields. The approximate lengths of irrigation water runs for the different fields are reported in table 77.

Crops Produced

Case Farm J produced primarily cotton and alfalfa with a small acreage of oats. The farm had a cotton allotment of 52.7 acres of which 34.4 acres were planted in 1966, 34.13 acres in 1967, and 50.1 acres in 1968 (table 78). Projected per-acre yields by ASC were

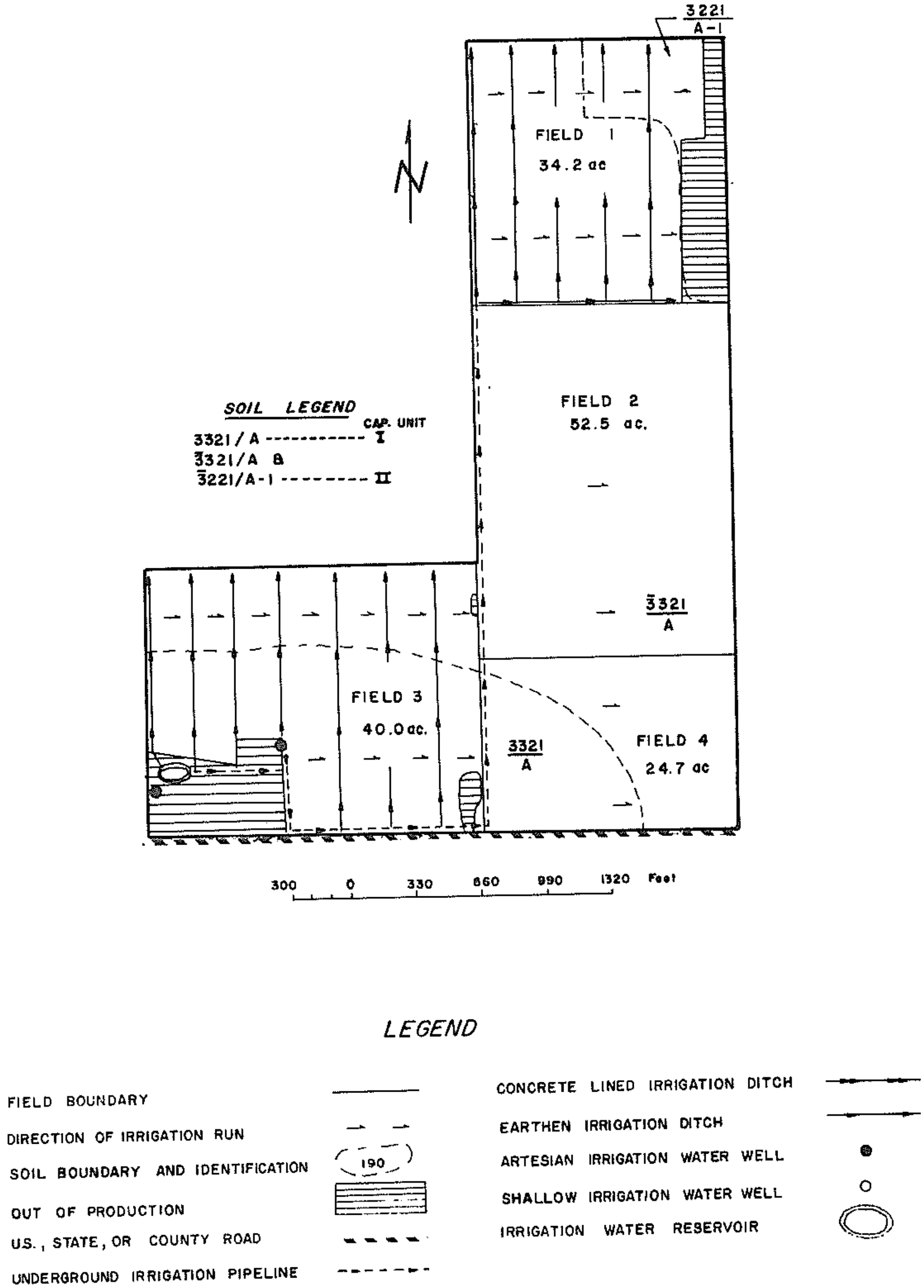


Figure 24. Map of Case Farm J.

Table 77. Case Farm J: Crops planted and approximate length of irrigation water runs by field, Roswell Artesian Basin, New Mexico.

Field Number	Crops Planted 1966	1967	1968	Length of Run (feet)
1	Alfalfa	Alfalfa	Cotton Diverted Fallow	160- 260
2	Cotton Diverted	Cotton Diverted	Oats Fallow	1,270-1,320
3	Alfalfa	Alfalfa	Alfalfa	210- 290
4	Alfalfa	Alfalfa	Cotton Diverted Fallow	1,240-1,290

830 pounds in 1966, 805 pounds in 1967, and 815 pounds in 1968. Actual per-acre yields in pounds were 597.7 in 1966, 598.0 in 1967, and 568 in 1968 (table 79).

Alfalfa was produced on 98.9 acres in 1966 and 1967 and on 40.0 acres in 1968. Yields were adjusted to allow for the lower yield obtained the first year of the assumed five-year production period and are reported in table 79.

Oats were produced on 50.7 acres in 1968. This crop was produced primarily for seed, but was also grazed and harvested for grain.

Irrigation Water Pumped

Irrigation water pumpage was 585.81, 497.92, and 453.41 acre-feet for 1966, 1967, and 1968 respectively (table 78). Diversions per acre were 3.87, 3.29, and 2.99 acre-feet respectively. Diversions by crops are also reported in table 78.

The average per-acre diversion for cotton for the three-year period was 2.60 acre-feet per acre. Alfalfa received an average of 4.57 acre-feet per acre. Oats received an average of 2.79 acre-feet per acre.

Table 78. Case Farm J: Crop acreages and irrigation water pumpage, Roswell Artesian Basin, New Mexico

	Acres				Irrigation Water Pumped							
					Per Crop				Per Acre			
Crop	1966	1967	1968	Average	1966	1967	1968	Average	1966	1967	1968	Average
					(acre-feet)				(acre-feet)			
Cotton	34.4	34.13	50.1	39.54	111.80	80.85	115.60	102.75	3.25	3.27	2.31	2.60
Diverted	18.1	18.37	2.4	12.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alfalfa	98.9	98.90	40.0	79.27	474.01	417.07	196.19	362.42	4.79	4.22	4.90	4.57
Oats	0.0	0.00	50.7	16.90	0.00	0.00	141.62	47.21	0.00	0.00	2.79	2.79
Fallow	0.0	0.00	8.2	2.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	151.4	151.40	151.4	151.40	585.81	497.92	453.41	512.38	3.87	3.29	2.99	3.38

Table 79. Case Farm J: Crops and yield per acre, Roswell Artesian Basin, New Mexico.

Crop	Unit	Yield per Acre 1966	1967	1968	Average
Cotton planted					
Lint	lb.	597.7	598.0	568.0	587.9
Seed	ton	0.47	0.50	0.45	0.47
Alfalfa					
Hay	ton	6.0	6.8	6.0	6.26
Oats					
Seed	lb.	----	----	789.0	789.0
Grain	lb.	----	----	493.0	493.0
Pasture	a.u.m.	----	----	3.55	3.55

In 1967 the average quantity of irrigation water pumped on Case Farm J was higher than the average for all farms in the Artesia area. The average diversion for all farms in the Artesia area was 3.14 acre-feet per water-right acre, 3.33 acre-feet per cultivated acre, and 3.71 acre-feet per cropped acre compared with 3.29 acre-feet per water-right and cultivated acre and 3.74 acre-feet per cropped acre on Case Farm J (9).

In 1968 the average quantity of water diverted on Case Farm J was above the average for the Artesia area. The average diversion on Case Farm J was 2.99 acre-feet per water-right acre while the average for all farms in the Artesia area was 2.80 acre-feet per water-right acre (12).

Irrigation Efficiency

The typical irrigation efficiency by crops is reported in table 80 and yearly estimates in table C10. Irrigation efficiency on cotton ranged from 49.49 percent to 68.15 with an average of 58.72 percent (table C10). Alfalfa irrigation efficiency ranged from 48.76 percent to 71.01 with an average of 57.48 percent. In 1968 irrigation efficiency on oats was estimated to be 48.14 percent.

Table 80. Case Farm J: Typical consumptive irrigation requirement, irrigation water applied, and farm irrigation efficiency.

Crop	Consumptive Irrigation Requirement (acre-inches)	Irrigation Water Applied (acre-inches)	Farm Irrigation Efficiency (percent)
Cotton	20.74	35.32	58.72
Alfalfa	31.98	55.64	57.48
Oats	16.12	33.48	48.14

ECONOMIC ANALYSIS

Financial Summary

The typical per-acre net returns by crops are reported in table 81 and yearly figures are reported in table D10. The net farm return for the three-year period was $11,424.72, $17,071.30, and $10,335.53. for 1966, 1967, and 1968 respectively (table E10). The primary reasons for the large variation in net farm return were the favorable prices and yields for cotton and alfalfa in 1967 and the unfavorable price and yield of cotton in 1968. The 1966 crop year appeared to be fairly typical.

Table 81. Case Farm J: Typical per-acre returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns per Acre (dollars)	Gross Expenses per Acre (dollars)	Net Returns to Land and Management per Acre (dollars)
Cotton planted	293.31	121.38	171.93
Cotton diverted	87.21	15.00	72.21
Alfalfa	156.25	112.88	43.37
Oats	90.46	61.41	29.05
Weighted average	175.97	98.94	77.03

Because of these variations in yields, prices, and net farm returns a typical whole farm budget was computed using typical yields, prices, acreages, and costs (table 82). This typical whole farm budget will be used to compare with the linear programming solutions to determine the effect of different levels of irrigation water diversions on net farm returns. The annual whole farm budgets are presented in appendix E (table E10).

Table 82. Case Farm J: Typical whole farm returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
Cotton planted	39.54	11,597.48	4,799.37	6,798.11
Cotton diverted	12.96	1,130.24	194.40	935.84
Alfalfa	79.27	12,385.94	8,948.00	3,437.94
Oats	16.90	1,528.77	1,037.83	490.94
Fallow	2.73	0.00	0.00	0.00
Total	151.40	26,642.43	14,979.60	11,662.83

Linear Programming Solutions--Model A

The coefficients and constraints for model A are presented below:

$1X_1 + 1X_2 + 1X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 1X_8 + 1X_9 + 1X_{10} \leq 151.4$

acres

$1X_1 + 1X_2 + 1X_3 + 0X_4 + 0X_5 + 0X_6 + 0X_7 + 0X_8 + 0X_9 + 0X_{10} \leq 52.5$

acres of cotton

$1.69X_1 + 2.08X_2 + 2.47X_3 + 4.57X_4 + 0X_5 + 5.33X_6 + 6.00X_7 + 2.30X_8$

$+ 1.96X_9 + 2.79X_{10} \leq 378.50$ acre-feet of irrigation water.

The X variables are identified in table 83.

The parameter changes in irrigation water diversion (Qt), where Q = 378.50 acre-feet of irrigation water and t = 37.85 acre-feet result in the following irrigation water constraints:

2.75 acre-feet per water-right acre = 416.35 acre-feet
3.00 acre-feet per water-right acre = 452.20 acre-feet
3.25 acre-feet per water-right acre = 492.05 acre-feet
3.50 acre-feet per water-right acre = 529.90 acre-feet
3.75 acre-feet per water-right acre = 567.75 acre-feet
4.00 acre-feet per water-right acre = 605.50 acre-feet

Table 83. Case Farm J: Whole farm budget and linear programming solutions, models A, B, and C, Roswell Artesian Basin, New Mexico.

		Whole Farm Budget			Linear Programming Solutions																				
					2.50 acre feet per acre			2.75 acre feet per acre			3.00 acre feet per acre			3.25 acre feet per acre			3.50 acre feet per acre			3.75 acre feet per acre			4.00 acre feet per acre		
Variable	Crop	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars
	MODEL A																								
x_1	Cotton (65)																								
x_2	Cotton (80)	52.50	102.75	7,733.95																					
x_3	Cotton (95)				52.50	129.68	8,764.35	52.50	129.68	8,764.35	52.50	129.68	8,764.35	52.50	129.68	8,764.35	52.50	129.68	8,764.35	52.50	129.68	8,764.35	52.50	129.68	8,764.35
x_4	Alfalfa (A)	79.27	362.42	3,437.94																					
x_5	Alfalfa (B)																								
x_6	Alfalfa (C)																								
x_7	Alfalfa (D)				13.61	81.66	1,116.43	22.98	137.87	1,885.05	32.35	194.09	2,653.67	41.72	250.31	3,422.29	51.08	306.48	4,190.09	60.45	362.71	4,958.71	69.82	418.92	5,727.34
x_8	Grain Sorghum																								
x_9	Castor Beans				85.29	167.16	5,691.40	75.92	148.80	5,066.14	66.55	130.43	4,440.88	57.18	112.06	3,815.62	47.82	93.74	3,191.03	38.45	75.36	2,565.77	29.08	57.00	1,940.51
x_{10}	Oats	16.90	47.21	490.94																					
	Fallow	2.73	0.00	0.00																					
	Total	151.40	512.38	11,662.83	151.40	378.50	15,572.18	151.40	416.35	15,715.54	151.40	454.20	15,858.90	151.40	492.05	16,002.26	151.40	529.90	16,145.47	151.40	567.75	16,288.83	151.40	605.60	16,432.20
	MODEL B																								
x_1	Cotton (65)																								
x_2	Cotton (80)	52.50	102.75	7,733.95																					
x_3	Cotton (95)				52.50	123.38	8,764.35	52.50	123.38	8,764.35	52.50	123.38	8,764.35	52.50	123.38	8,764.35	52.50	123.38	8,764.35	52.50	123.38	8,764.35	52.50	123.38	8,764.35
x_4	Alfalfa (A)	79.27	362.42	3,437.94																					
x_5	Alfalfa (B)																								
x_6	Alfalfa (C)																								
x_7	Alfalfa (D)				18.53	105.62	1,520.02	28.39	161.82	2,328.83	38.25	218.02	3,137.65	48.10	274.18	3,945.64	57.96	330.37	4,754.46	67.82	386.56	5,563.28	77.67	442.73	6,371.27
x_8	Grain Sorghum																								
x_9	Castor Beans				80.37	149.50	5,363.09	70.51	131.15	4,705.13	60.65	112.80	4 047.18	50.80	94.49	3,389.88	40.94	76.15	2,731.93	31.08	57.81	2,073.97	21.23	39.49	1,416.68
x_{10}	Oats	16.90	47.21	490.94																					
	Fallow	2.73	0.00	0.00																					
	Total	151.40	512.38	11,662.83	151.40	378.50	15,647.46	151.40	416.35	15,798.31	151.40	454.20	15,949.18	151.40	492.05	16,099.87	151.40	529.90	16,250.74	151.40	567.75	16,401.60	151.40	605.60	16,552.30
	MODEL C																								
x_1	Cotton (65)																								
x_2	Cotton (80)	52.50	102.75	7,733.95																					
x_3	Cotton (95)				52.50	129.68	8,764.35	52.50	129.68	8,764.35	52.50	129.68	8,764.35	52.50	129.68	8,764.35	52.50	129.68	8,764.35	52.50	129.68	8,764.35	52.50	129.68	8,764.35
x_4	Alfalfa (A)	79.27	362.42	3,437.94	50.00	228.50	2,168.50	50.00	228.50	2,168.50	49.76	227.40	2,158.09												
x_5	Alfalfa (B)																								
x_6	Alfalfa (C)										0.24	1.28	15.48	49.95	266.23	3,220.78									
x_7	Alfalfa (D)													0.05	0.30	4.10	51.08	306.48	4,190.09	60.45	362.71	4,958.71	69.82	418.92	5,727.34
x_8	Grain Sorghum																								
x_9	Castor Beans				10.37	20.32	691.99	29.68	58.17	1,980.55	48.90	95.84	3,263.10	48.90	95.84	3,263.10	47.82	93.74	3,191.03	38.45	75.36	2,565.77	29.08	57.00	1,940.51
x_{10}	Oats	16.90	47.21	490.94																					
	Fallow	2.73	0.00	0.00	38.53	0.00	0.00	19.22	0.00	0.00															
	Total	151.40	512.38	11,662.83	151.40	378.50	11,624.84	151.40	416.35	12,913.40	151.40	454.20	14,210.02	151.40	492.05	15,252.33	151.40	529.90	16,145.47	151.40	567.75	16,288.83	151.40	605.60	16,432.20

In table 83 the whole farm budget for the typical crop year is compared with the results of model A. The linear programming solutions presented in table 83 indicate the optimal net farm returns and the combinations of the nine crops that would be produced if there were no assumed crop rotation program on Case Farm J.

In table 83 the net farm return obtained from the linear programming solutions is also contrasted with $11,662.83, which was obtained from the typical crop year with 511.73 acre-feet of irrigation water (3.38 acre-feet of irrigation water per water-right acre). The net farm return for the typical crop year would have been increased about 34 percent with the combination of crop enterprises that is indicated in model A with 2.50 acre-feet of irrigation water; about 35 percent with 2.75 acre-feet; about 36 percent with 3.00 acre-feet; about 37 percent with 3.25 acre-feet; about 38 percent with 3.50 acre-feet; about 40 percent with 3.75 acre-feet; and 41 percent with 4.00 acre-feet.

The lower net farm return for the typical crop year can be attributed primarily to the production of cotton at the 75.3 percent level of the allotment and to the production of alfalfa (A). Even at low levels (2.50 acre-feet of water per water-right acre) of irrigation water diversions, cotton would be produced on the maximum number of acres allowed under the cotton program (cotton 95), or about 33 percent of the water-right acres. About 9 percent of the water-right acres would be devoted to the production of alfalfa at the "D" level, and the remaining tillable acres (56 percent of the water-right acres) would be devoted to castor beans. The above combination of enterprises would result in a net farm return of approximately $15,572.

As more irrigation water becomes available, alfalfa D substitutes for castor beans at a rate of 9.37 acres per one-fourth acre-foot of irrigation water per water-right acre until 4.78 acre-feet of irrigation water is pumped per water-right acre, where only cotton 95 and alfalfa D are produced on the cropable acres. If more than 4.78 acre-feet were available net farm returns would not increase, but would remain at $16,877.12 which is 44.7 percent above the typical whole farm budget.

Although the above combinations of crop enterprises result in the maximum returns for each quantity of irrigation water, they do not specifically allow for a crop rotation program. Crop yields and therefore returns, would be reduced if these combinations of crop enterprises were produced for extended time periods at the lower levels of irrigation water pumpage.

Linear Programming Solutions--Model B

The coefficients and constraints for model B are the same as for model A except that irrigation water coefficients have been reduced by 5 percent. The irrigation water coefficients and the first irrigation water constraint for model B are listed below:

$$1.61X_1 + 1.98X_2 + 2.35X_3 + 4.34X_4 + 0X_5 + 5.06X_6 + 5.70X_7 + 2.19X_8 + 1.86X_9 + 2.65X_{10} \leq 378.50 \text{ acre-feet of irrigation water}$$

The X variables are identified in table 83.

In table 83 the whole farm budget for the typical crop year is compared with the results of model B. These solutions presented in table 83 indicate the optimal net farm returns and the combinations of crops that would be produced if there were no assumed crop rotation program on Case Farm J.

In table 83 the net farm return obtained from the linear programming solutions is also contrasted with $11,662.83, which was obtained from the typical crop year with 511.73 acre-feet of irrigation water (3.38 acre-feet of irrigation water per water-right acre). The net farm return for the typical crop year would have been increased about 24 percent with the combination of crop enterprises that is indicated in model B with 2.50 acre-feet of irrigation water; about 36 percent with 2.75 acre-feet; about 37 percent with 3.00 acre-feet; about 38 percent with 3.25 acre-feet; about 39 percent with 3.50 acre-feet; about 41 percent with 3.75 acre-feet; and about 42 percent with 4.00 acre-feet.

The solutions for model B reflect a 5 percent increase in irrigation water efficiency on each crop. If 2.50 acre-feet of irrigation water per water-right acre were available, cotton 95 would comprise about 33 percent of the water-right acres, castor beans about 53 percent, alfalfa D about 12 percent, and the remaining 2 percent would be diverted. As more irrigation water becomes available alfalfa D (5.70 acre-feet) substitutes for castor beans at a rate of 9.86 acres per one-fourth acre-foot of irrigation water per water-right acre until 4.54 acre-feet per acre are pumped. If more than 4.54 acre-feet were available net farm returns would not be increased, but would remain at $16,877.12. This is about 45 percent above the typical whole farm budget. A 5 percent increase in irrigation efficiency increased the optimal net farm returns by an average of 1 percent.

Linear Programming Solutions--Model C

The coefficients and constraints for model C are the same as for model A except that an additional constraint was placed on a minimum amount of alfalfa being produced. The coefficients and the added constraint are listed below:

$$0X_1 + 0X_2 + 0X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 0X_8 + 0X_9 + 0X_{10} \geq 50.0$$

acres of alfalfa

The X variables are identified in table 83.

In table 83 the whole farm budget for the typical crop year is compared with the results of model C. These solutions, presented in table 83, indicate the optimal net farm returns and the combinations of crops that would be produced if a minimum of one-third of the water-right acres were devoted to alfalfa production, which is the assumed crop rotation program.

In table 83 the net farm return obtained from the linear programming solutions is also contrasted with $11,662.83, which was obtained from the typical crop year with 511.73 acre-feet of irrigation water (3.38 acre-feet of irrigation water per water-right acre). The net farm return for the typical crop year would have been decreased less than 1 percent with the combination of crop enterprises that is indicated in model C with 2.50 acre-feet of irrigation water; increased about 11 percent with 2.75 acre-feet; increased about 22 percent with 3.00 acre-feet; increased about 31 percent with 3.25 acre-feet; increased about 39 percent with 3.50 acre-feet; increased about 40 percent with 3.75 acre-feet; and increased about 41 percent with 4.00 acre-feet.

The primary reason for the lower return figure at 2.50 acre-feet of irrigation water per water-right acre is the requirement that about one-third of the farm be planted in alfalfa. In order to have enough water for alfalfa approximately one-third of the farm must be left fallow. Alfalfa A would be produced, which requires 4.34 acre-feet of irrigation per acre, and cotton 95 would be produced.

As more irrigation water becomes available more acres would be devoted to castor beans. At the 2.75 level of irrigation water diversion, alfalfa A would remain the same and castor beans would increase from 10.37 to 29.68 acres. At the 3.00 acre-feet irrigation water diversion level, alfalfa A acreage would decrease to 49.76 acres and alfalfa C would be produced on 0.24 acres. Castor beans would be increased to 48.9 acres. With 3.25 acre-feet of irrigation water available per water-right acre, alfalfa A would shift to alfalfa C and D, and castor beans would remain at 48.90 acres. At 3.50 acre-feet of irrigation water available per water-right acre, alfalfa C would shift to alfalfa D with a small decrease in castor bean acreage.

The optimal solutions and cropping patterns for 3.75 and 4.00 acre-feet per water-right acre are the same as model A and are reported in table 83.

The immediate economic effect of forcing in a crop rotation of about one-third of the farm into alfalfa is a reduction in net farm returns at irrigation water diversion less than 3.50 acre-feet per water-right acre. This effect can be estimated by comparing solutions for model A with solutions from model C. Net farm return would be reduced by $3,947.34 (34 percent) at 2.50 acre-feet per water-right acre, by $3,802.14 (21.7 percent) at 2.75 acre-feet per water-right acre, $1,657.88 (11.6 percent) at 3.00 acre-feet per water-right acre, and $749.93 (4.9 percent) at 3.25 acre-feet per water-right acre.

The results obtained from the three linear programming models are graphically summarized in figure 25. This graph indicates the effects of the seven quantities of irrigation water on the net farm return. In models A and B, as irrigation water is increased from 378.50 acre-feet to 723.69 acre-feet (2.50 to 4.78 acre-feet per water-right acre) the net farm return increases at a constant rate. Beyond 723.69 acre-feet the size of farm and cropping enterprises considered in this study become the factors that restrictsnet farm returns.

In model C, as irrigation water is increased from 378.50 acre-feet to 529.90 acre-feet (2.50 to 3.50 acre-feet per water-right acre), the net return per water-right acre increases at almost a constant rate. From 529.90 to 723.69 acre-feet (3.50 to 4.78 acre-feet) the rate of increase is at a lower constant rate, and beyond 723.69 acre-feet (4.78 acre-feet per water-right acre) the size of the farm and cropping enterprises considered become the limiting factors.

Optimal Quantity of Irrigation Water

The shadow prices (marginal value products) for an additional acre-foot of irrigation water are presented in table 84. The optimal level of irrigation water diversion for each model can be determined by equating the shadow price with the cost of pumping an acre-foot of irrigation water. The estimated cost of pumping an acre-foot of irrigation water was $7.68. For models A and B the optimal quantity of water was below 2.50 acre-feet per water-right acre; for models A and B it was between 302.80 and 340.65 acre-feet (2.00 and 2.25 acre-feet per water-right acre), and for model C it was between 492.05 and 529.90 acre-feet (3.25 and 3.50 acre-feet per water-right acre).

It would appear that 3.00 acre-feet per water-right acre would be a sufficient quantity for Case Farm J under conditions of models

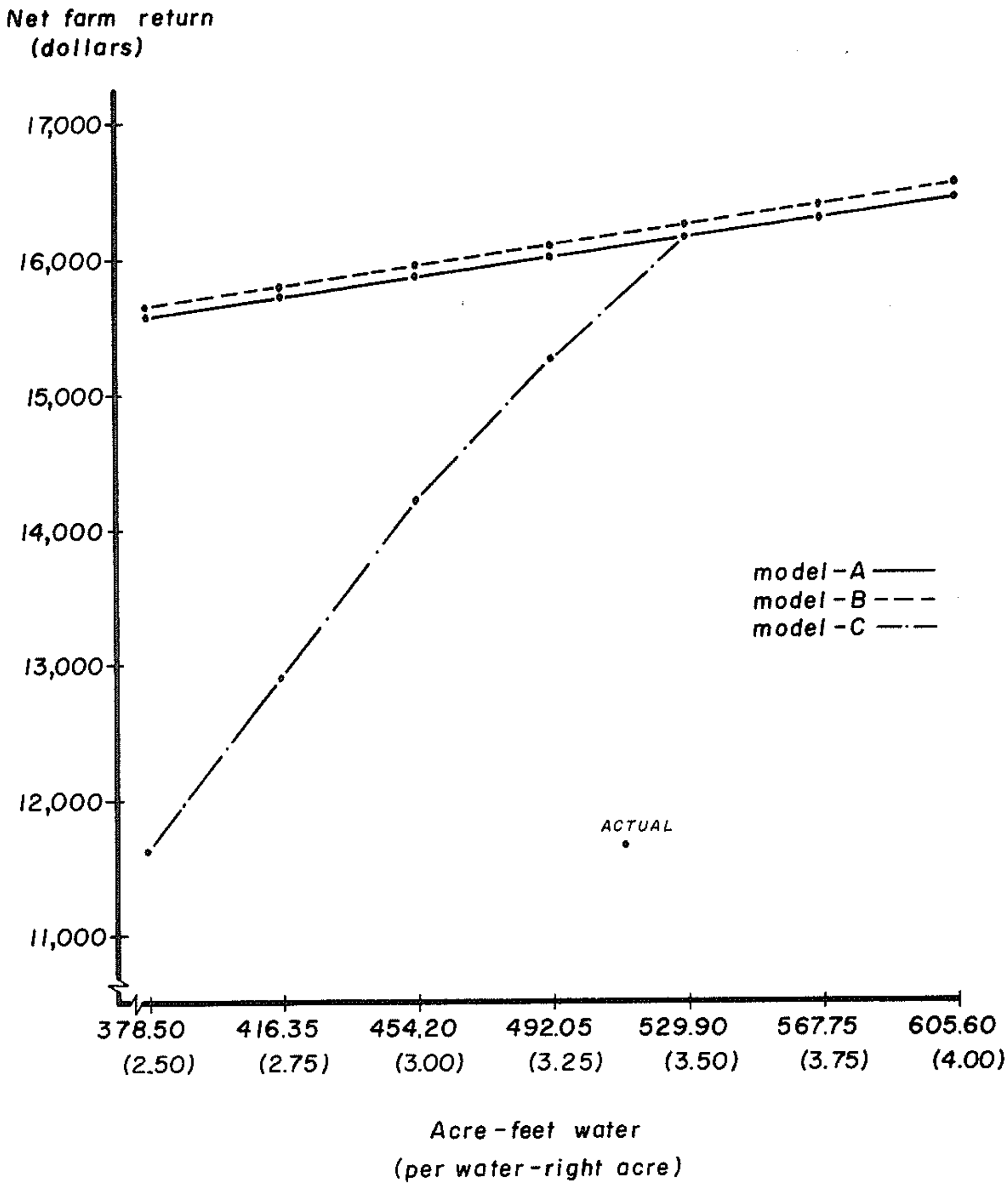


Figure 25. Case Farm J: Net farm return for seven quantities of irrigation water, Roswell Artesian Basin, New Mexico.

A and B. However, in model C if irrigation water diversion were limited to 3.00 acre-feet per water-right acre instead of the optimal quantity, net returns per water-right acre would be reduced from between $6.94 to $12.84. On a whole farm basis net farm returns would have been reduced between $1,051.31 to $1,944.45 or approximately 7.4 to 13.7 percent.

Table 84. Case Farm J: Shadow prices for seven quantities of irrigation water diversion, Roswell Artesian Basin, New Mexico.

Quantity of Irrigation Water Diverted (acre-feet)	Shadow Price Model A (dollars)	Shadow Price Model B (dollars)	Shadow Price Model C (dollars)
378.50	3.79	3.98	34.05
416.35	3.79	3.98	34.05
452.20	3.79	3.98	27.78
492.05	3.79	3.98	26.19
529.90	3.79	3.98	3.79
567.75	3.79	3.98	3.79
605.60	3.79	3.98	3.79

CASE FARM K

GENERAL DESCRIPTION

Case Farm K was a rented farm with 79.0 acres of shallow water rights. This farm was part of a 580-acre farming operation located in the Artesia Area of the Roswell Artesian Basin (figure 2).

Soils

The soils included on Case Farm K were Reagan Loam, Rustler Silt Loam, and Atoka Loam (figure 26). The Reagan Loam comprised approximately 57 percent of the cropland, Rustler Silt Loam approximately 39 percent, and Atoka Loam approximately 4 percent. The Reagan Loam was SCS Capability Class I, the Rustler Silt Loam was Class II, and the Atoka Loam was Class III.

Irrigation Water

Case Farm K had one shallow well which was 260 feet deep. The average production was about 850 gallons per minute for the three-year period. The water from this well had an average total soluble salt content of 1,026 millimhos and the average sodium adsorption ratio was 0.54 for the three-year period (2). The quality classification of this water was Class 2.

Irrigation System

The shallow well on Farm K pumped directly into a reservoir which in turn drained into a concrete-lined ditch that was approximately 3,950 feet in length. This concrete ditch provided water for about 4,342 feet of earthen primary and secondary lateral ditches.

The cropland on Farm K had not been leveled. Fields 1, 2, and 4 were irrigated from west to east, and fields 3 and 5 were irrigated from southwest to northeast. All fields had a two-way slope. A secondary lateral ditch was required to adequately irrigate the northeast corner of field 3 (figure 26).

The crops in fields 1, 2, and 4 were irrigated entirely from the concrete-lined ditch, and the crops in fields 3 and 5 were irrigated from the earthen laterals (figure 26). Borders were not used in alfalfa fields.

The approximate lengths of irrigation water runs for the different fields are reported in table 85.

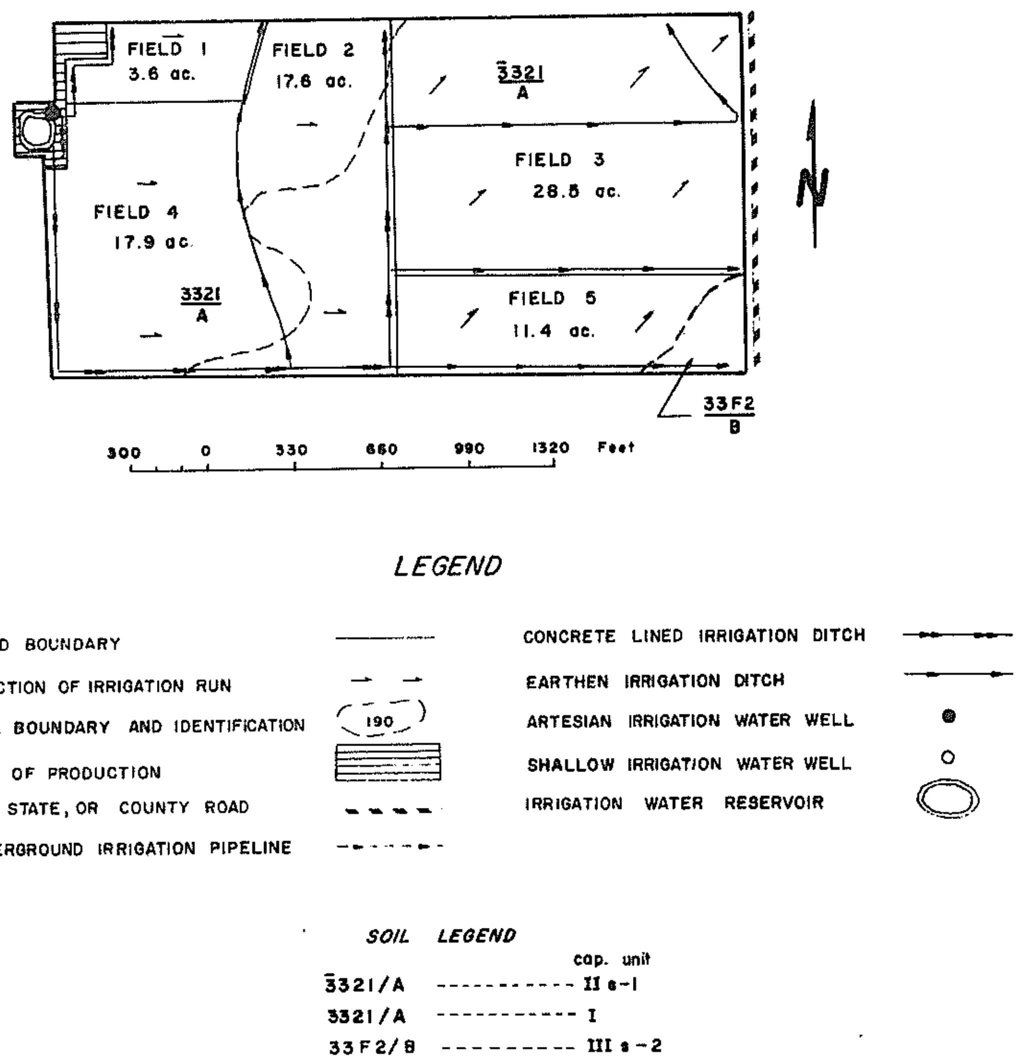


Figure 26. Map of Case Farm K.

Table 85. Case Farm K: Crops planted and approximate length of irrigation water runs by field, Roswell Artesian Basin, New Mexico.

Field Number	Crops Planted 1966	1967	1968	Length of Run (feet)
1	Alfalfa	Alfalfa	Cotton	550-600
2	Cotton Diverted	Grain sorghum	Cotton Grain sorghum	370-580
3	Alfalfa	Alfalfa	Alfalfa	180-660
4	Alfalfa	Cotton	Cotton	630-840
5	Cotton	Diverted Fallow	Alfalfa Diverted Fallow Alfalfa	180-520

Crops Produced

The principal crops produced on Case Farm K were cotton, alfalfa, and grain sorghum. Case Farm K had a cotton allotment of 27.5 acres. During the 1966 and 1968 crop years, cotton was produced on 26.1 acres and 1.4 acres were diverted, while in 1967 cotton was produced on 17.9 acres and 9.6 acres were diverted (table 86). Projected per-acre yields by ASC were 870 pounds in each of the three years. The actual per-acre yields were 870.0 pounds per acre in 1966, 1,145.0 pounds in 1967, and 911.0 pounds in 1968 (table 87).

Alfalfa was produced on 50.0 acres in 1966, 32.1 acres in 1967, and 39.9 acres in 1968 (table 86). In 1968, 3.5 acres were seeded in the spring and 7.9 acres of the 39.9 acres were fall-planted seedling alfalfa. The yields for the three years are reported in table 87. Grain sorghum was produced on 17.6 acres in 1967, and 12.5 acres in 1968. The yields are reported in table 87.

Irrigation Water Pumpage

In 1966 a total of 366.8 acre-feet of irrigation water was pumped on Farm K, 287.09 acre-feet in 1967, and 315.86 acre-feet in 1968 (table 86). The average per-acre diversion for cotton for the three-year period was 3.63 acre-feet per acre. Alfalfa received an

Table 86. Case Farm K: Crop acreages and irrigation water pumpage, Roswell Artesian Basin, New Mexico

	Acres				Irrigation Water Pumped							
					Per Crop				Per Acre			
Crop	1966	1967	1968	Average	1966	1967	1968	Average	1966	1967	1968	Average
					(acre-feet)				(acre-feet)			
Cotton	26.1	17.9	26.1	23.37	91.80	71.88	90.97	84.88	3.52	4.02	3.42	3.63
Diverted	1.4	9.6	1.4	4.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alfalfa	50.0	32.1	32.0[1]	38.03	275.00	164.17	165.69	201.62	5.50	5.11	5.18	5.30
Seedling alfalfa	0.0	0.0	7.9[2]	2.63[3]	0.00	0.00	19.20	6.39	0.00	0.00	2.43	2.43
Grain sorghum	0.0	17.6	12.5	10.03	0.00	51.04	40.10	30.38	0.00	2.90	3.21	3.03
Fallow	1.5	1.8	7.0	3.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	79.0	79.0	79.0	79.0	366.80	287.09	315.86	323.27	4.64	3.63	4.00	4.09

1. Spring planted, 3.5 acres.
2. Not included in total, 1.0 acre was diverted, 6.9 acres were fallow.
3. Not included in total.

Table 87. Case Farm K: Crops and yield per acre, Roswell Artesian Basin, New Mexico.

Crop	Unit	Yield per Acre 1966	1967	1968	Average
Cotton planted					
Lint	lb.	870.00	1,145.0	911.0	975.33
Seed	ton	0.68	0.89	0.73	0.77
Alfalfa					
Hay	ton	6.4	5.5	5.5	5.5
Grain sorghum	lb.	----	6,500.00	6,500.0	6,500.0

average of 5.30 acre-feet per acre for the same period. Grain sorghum received an average of 3.03 acre-feet per acre for the two-year period. The average diversion per water-right acre was 4.64 acre-feet per acre in 1966, 3.63 acre-feet per acre in 1967, and 4.00 acre-feet per acre in 1968 (table 86).

In 1967 the average quantity of irrigation water diverted on Farm K was higher than the average quantity of irrigation water diverted on all farms in the Artesia Area. The average quantity of irrigation water diverted on Farm K was 3.63 acre-feet per water-right acre, 3.63 acre-feet per cultivated acre, and 4.25 acre-feet per cropped acre. The average quantity of irrigation water diverted on farms in the Artesia Area was 3.14 acre-feet per water-right acre, 3.33 acre-feet per cultivated acre, and 3.71 acre-feet per cropped acre (9).

In 1968 the average quantity of irrigation water diverted on Farm K was also higher than the average for the Artesia Area. The average was 4.00 acre-feet per water-right acre for Farm K compared with 2.80 acre-feet per water-right acre for farms in the Artesia Area (12).

Irrigation Efficiency

Typical irrigation efficiency by crops is reported in table 88 and yearly estimates in table C11. Irrigation efficiency on cotton ranged from 45.60 to 48.24 percent with an average of 47.31 percent; on alfalfa from 46.12 to 58.64 with an average of 50.28 percent; and on grain sorghum from 46.31 to 64.86 averaging 55.13 percent (tables 88 and C11).

Table 88. Case Farm K: Typical consumptive irrigation requirement, irrigation water applied, and farm irrigation efficiency.

Crop	Consumptive Irrigation Requirement (acre-inches)	Irrigation Water Applied (acre-inches)	Farm Irrigation Efficiency (percent)
Cotton	20.74	43.84	47.31
Alfalfa	31.98	63.60	50.28
Grain sorghum	20.21	36.66	55.13

ECONOMIC ANALYSIS

Financial Summary

The typical per-acre net returns by crops are reported in table 89 and for each of the three years in table D11. The net farm return for 1966, 1967, and 1968 was $7,097.55, $9,381.69, and $7,000.31 respectively (table E11). The primary reasons for the large variations in net farm return were the favorable prices and yields of cotton and alfalfa in 1967 and the unfavorable price of cotton in 1968.

Table 89. Case Farm K: Typical per-acre returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns per Acre (dollars)	Gross Expenses per Acre (dollars)	Net Returns to Land and Management per Acre (dollars)
Cotton planted	429.31	175.61	253.70
Cotton diverted	92.02	14.40	77.62
Alfalfa	150.50	117.30	33.20
Grain sorghum	120.25	68.00	52.25
Weighted average	217.35	117.82	99.53

Because of the wide variations in yields, prices, and net farm return a typical whole farm budget was computed using typical yields, prices, and costs (table 90). This typical whole farm budget will be used to compare with the linear programming solutions to determine the effect of different levels of irrigation water diversions on net farm returns. The annual whole farm budgets are presented in appendix E (table E11).

Table 90. Case Farm K: Typical whole farm returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
Cotton planted	23.37	10,032.97	4,104.01	5,928.96
Cotton diverted	4.13	380.04	59.47	320.57
Alfalfa	40.66	6,120.84	4,770.59	1,350.25
Grain sorghum	10.03	1,206.11	682.04	524.07
Fallow	3.43	0.00	0.00	0.00
Total	81.62	17,739.96	9,616.11	8,123.85

Linear Programming Solutions--Model A

The coefficients and constraints for model A are presented below:

$1X_1 + 1X_2 + 1X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 1X_8 + 1X_9 \leq$ 79.0 acres

$1X_1 + 1X_2 + 1X_3 + 0X_4 + 0X_5 + 0X_6 + 0X_7 + 0X_8 + 0X_9 \leq$ 27.5 acres of cotton

$2.36X_1 + 2.90X_2 + 3.45X_3 + 5.30X_4 + 0X_5 + 5.33X_6 + 6.00X_7 + 3.03X_8 + 2.60X_9 \leq$ 197.5 acre-feet of irrigation water

The X variables are identified in table 91.

The parameter changes in irrigation water diversion (Qt), where Q = 197.50 acre-feet of irrigation water and t = 19.75 acre-feet result in the following irrigation water constraints:

2.75 acre-feet per water-right acre = 217.25 acre-feet
3.00 acre-feet per water-right acre = 237.00 acre-feet
3.25 acre-feet per water-right acre = 256.75 acre-feet
3.50 acre-feet per water-right acre = 276.50 acre-feet
3.75 acre-feet per water-right acre = 296.25 acre-feet
4.00 acre-feet per water-right acre = 316.00 acre-feet

In table 91 the whole farm budget for the typical crop year is compared with the results of model A. The linear programming solutions presented in table 91 indicate the optimal net farm returns and the combinations of the eight crops that would be produced if there were no assumed crop rotation program on Case Farm K.

In table 91 the net farm return obtained from the linear programming solutions is also contrasted with \$8,123.85, which was obtained from the typical crop year with 323.23 acre-feet of irrigation water (4.09 acre-feet of irrigation water per water-right acre). The net farm return for the typical crop year would have been increased about 15 percent with the combination of crop enterprises that is indicated in model A with 2.50 acre-feet of irrigation water; about 21 percent with 2.75 acre-feet; and about 24 percent with 2.89 acre-feet. Net farm return would not increase beyond 2.89 acre-feet of irrigation water per water-right acre but would remain at \$10,102.85.

The lower net farm return to land and management for the typical crop year can be attributed primarily to the production of cotton at the 85 percent level of the allotment and to the production of alfalfa (A). Even at low levels (2.50 acre-feet of water per water-right acre) of irrigation water diversions, cotton would be produced on the maximum number of acres allowed under the cotton program, or about 33 percent of the water-right acres. About 50 percent of the water-right acres would be devoted to the production of castor beans and the remaining tillable acres (15 percent of the water-right acres) would be fallow. The above combination of enterprises would result in a net farm return of approximately \$9,316.

As more irrigation water becomes available, castor beans acreage would be increased. At 2.89 acre-feet of irrigation water per water-right acre the maximum net farm return is reached with approximately 26.13 acres of planted cotton (cotton 95) and 51.50 acres of castor beans. If more than 2.89 acre-feet were available, net farm returns would not increase, but would remain at \$10,102.85.

Although the above combinations of crop enterprises result in the maximum returns for each quantity of irrigation water, they do not specifically allow for a crop rotation program. Crop yields, and therefore returns, may be reduced if these combinations of crop enterprises were produced for extended time periods.

Linear Programming Solutions--Model B

The coefficients and constraints for model B are the same as for model A except that irrigation water coefficients have been reduced by 5 percent. The irrigation water coefficients and the first irrigation water constraint for model B are listed below:

$$2.24X_1 + 2.76X_2 + 3.28X_3 + 5.04X_4 + 0X_5 + 5.06X_6 + 5.70X_7 + 2.88X_8$$

$$+ 2.47X_9 \leq 19.75 \text{ acre-feet of irrigation water}$$

Table 91. Case Farm K: Whole farm budget and linear programming solutions, models A, B, and C, Roswell Artesian Basin, New Mexico.

Vari-able	Crop	Whole Farm Budget			Linear Programming Solutions: 2.50 acre feet per acre			2.75 acre feet per acre			3.00 acre feet per acre			3.25 acre feet per acre			3.50 acre feet per acre			3.75 acre feet per acre			4.00 acre feet per acre		
		Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars	Acres	Irri-gation Water ac. ft.	Net Returns dollars
	MODEL A																								
X_1	Cotton (65)																								
X_2	Cotton (80)	27.50	84.88	6,249.53																					
X_3	Cotton (95)				27.50	94.88	6,734.75	27.50	94.88	6,734.75	27.50	94.88	6,734.75	27.50	94.88	6,734.75	27.50	94.88	6,734.75	27.50	94.88	6,734.75	27.50	94.88	6,734.75
X_4	Alfalfa (A)	40.66[1]	208.01	1,350.25																					
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)																								
X_8	Grain Sorghum	10.30	30.38	524.07																					
X_9	Castor Beans				39.47	102.62	2,581.34	47.07	122.37	3,078.38	51.50	133.90	3,368.10	51.50	133.90	3,368.10	51.50	133.90	3,368.10	51.50	133.90	3,368.10	51.50	133.90	3,368.10
	Fallow	3.43	0.00	0.00	12.03	0.00	0.00	4.43	0.00	0.00															
	Total	79.00	323.27	8,123.85	79.00	197.50	9,316.09	79.00	217.25	9,813.13	79.00	228.78	10,102.85	79.00	228.78	10,102.85	79.00	228.78	10,102.85	79.00	228.78	10,102.85	79.00	228.78	10,102.85
	MODEL B																								
X_1	Cotton (65)																								
X_2	Cotton (80)	27.50	84.88	6,249.53																					
X_3	Cotton (95)				27.50	90.20	6,734.75	27.50	90.20	6,734.75	27.50	90.20	6,734.75	27.50	90.20	6,734.75	27.50	90.20	6,734.75	27.50	90.20	6,734.75	27.50	90.20	6,734.75
X_4	Alfalfa (A)	40.66[1]	208.01	1,350.25																					
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)																								
X_8	Grain Sorghum	10.30	30.38	524.07																					
X_9	Castor Beans				43.44	107.30	2,840.98	51.44	127.05	3,364.18	51.50	127.21	3,368.10	51.50	127.21	3,368.10	51.50	127.21	3,368.10	51.50	127.21	3,368.10	51.50	127.21	3,368.10
	Fallow	3.43	0.00	0.00	8.06	0.00	0.00	0.06	0.00	0.00															
	Total	79.00	323.27	8,123.85	79.00	197.50	9,575.73	79.00	217.25	10,098.93	79.00	217.41	10,102.85	79.00	217.41	10,102.85	79.00	217.41	10,102.85	79.00	217.41	10,102.85	79.00	217.41	10,102.85
	MODEL C																								
X_1	Cotton (65)				27.50	64.90	5,281.93																		
X_2	Cotton (80)	27.50	84.88	6,249.53				27.50	79.76	6,008.20															
X_3	Cotton (95)										27.50	94.88	6,734.75	27.50	94.88	6,734.75	27.50	94.88	6,734.75	27.50	94.88	6,734.75	27.50	94.88	6,734.75
X_4	Alfalfa (A)	40.66[1]	208.01	1,350.25																					
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)				24.00	127.92	1,197.12	24.00	127.92	1,197.12	24.00	127.92	1,197.12	24.00	127.92	1,197.12	24.00	127.92	1,197.12	21.08	112.35	1,051.47			
X_7	Alfalfa (D)																			2.92	17.52	189.30	24.00	144.00	1,555.92
X_8	Grain Sorghum	10.30	30.38	524.07																					
X_9	Castor Beans				1.80	4.68	117.72	3.68	9.57	240.67	5.46	14.20	357.08	13.06	33.95	854.12	20.66	53.70	1,351.16	27.50	71.50	1,798.50	27.50	71.50	1,798.50
	Fallow	3.43	0.00	0.00	25.70	0.00	0.00	23.82	0.00	0.00	22.04	0.00	0.00	14.44	0.00	0.00	6.84	0.00	0.00						
	Total	79.00	323.27	8,123.85	79.00	197.50	6,596.77	79.00	217.25	7,445.97	79.00	237.00	8,288.95	79.00	256.75	8,785.99	79.00	276.50	9,283.03	79.00	296.25	9,774.02	79.00	310.38	10,089.17

1 Not included in total, 2.63 acres, was fallow

The X variables are identified in table 91.

In table 91 the whole farm budget for the typical crop year is compared with the results of model B. These solutions presented in table 91 indicate the optimal net farm returns and the combinations of crops that would be produced if there were no assumed crop rotation program on Case Farm K.

In table 91 the net farm return obtained from the linear programming solutions is also contrasted with $8,123.85, which was obtained from the typical crop year with 323.23 acre-feet of irrigation water (4.09 acre-feet of irrigation water per water-right acre). The net farm return for the typical crop year would have been increased about 18 percent with the combination of crop enterprises that is indicated in model B with 2.50 acre-feet of irrigation water; about 24 percent with 2.75 acre-feet; and about 24 percent with 2.752 acre-feet of irrigation water per water-right acre. Net farm return would not increase beyond 2.752 acre-feet of irrigation water per water-right acre but would remain at $10,102.85.

The solutions for model B reflect a 5 percent increase in irrigation water efficiency on each crop. If 2.50 acre-feet of irrigation water per water-right acre were available, cotton would comprise about 33 percent (cotton 95) of the water-right acres, castor beans about 55 percent, and the remaining 12 percent would be diverted and fallow. As more irrigation water becomes available castor bean acreage increases to 51.50 acres at 2.752 acre-feet per water-right acre. If more than 2.752 acre-feet were available net farm return would not be increased, but would remain at $10,102.85. This is 24.4 percent above the typical whole farm budget. A 5 percent increase in irrigation efficiency increased the optimal net farm returns by an average of 1 percent.

Linear Programming Solutions--Model C

The coefficients and constraints for model C are the same as for model A except that an additional constraint was placed on a minimum amount of alfalfa being produced. The coefficients and the added constraint are listed below:

$0X_1 + 0X_2 + 0X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 0X_8 + 0X_9 \geq$ 24.0 acres of

alfalfa

The X variables are identified in table 91.

In table 91 the whole farm budget for the typical crop year is compared with the results of model C. These solutions, presented in table 91, indicate the optimal net farm returns and the combinations of crops that would be produced if a minimum of one-third of the water-right acres were devoted to alfalfa production, which is the assumed crop rotation program.

In table 91 the net farm return obtained from the linear programming solutions is also contrasted with $8,123.85 which was obtained from the typical crop year with 323.23 acre-feet of irrigation water (4.09 acre-feet of irrigation water per water-right acre). The net farm return for the typical crop year would have been decreased about 23 percent with the combination of crop enterprises that is indicated in model C with 2.50 acre-feet of irrigation water;decreased about 9 percent with 2.75 acre-feet; increased about 2 percent with 3.00 acre-feet; increased about 8 percent with 3.25 acre-feet; increased about 14 percent with 3.50 acre-feet; increased about 20 percent with 3.75 acre-feet; and increased about 24 percent with 3.93 acre-feet which is the maximum optimal irrigation water diversion.

The primary reason for the lower return figure at 2.50 acre-feet of irrigation water per water-right acre is the level of cotton production. In order to have enough water for alfalfa, even at a low level, cotton would be planted on 65 percent or 17.88 acres of the cotton allotment. Alfalfa C would be produced on 24 acres which requires 5.33 acre-feet of irrigation per acre, 1.8 acres of castor beans, and 25.7 acres would be left fallow.

As more irrigation water becomes available more acres would be devoted to cotton, and castor beans. At the 2.75 level of irrigation water diversion, planted cotton shifts from 17.88 acres to 22.0 acres (cotton 80), alfalfa C acreage would remain the same, castor beans would increase from 1.80 to 3.68 acres, and 23.82 acres fallow. At the 3.00 acre-feet irrigation water diversion level, planted cotton acreage would shift to 26.13 acres (cotton 95), alfalfa would remain the same, and castor beans increase to 5.46 acres. With 3.25 acre-feet of irrigation water available per water-right acre the maximum net farm return is obtained with 26.13 acres of planted cotton, 24.00 acres of alfalfa C, and 13.06 acres of castor beans.

The optimal solutions and cropping patterns for 3.50, 3.75, and 4.00 acre-feet per water-right acre are reported in table 91.

The immediate economic effect of forcing in a crop rotation of about one-third of the farm into alfalfa is a reduction in net farm returns at irrigation water diversion levels of less than 4.00 acre-feet per water-right acre. This effect can be estimated by comparing solutions from model A with solutions from model C. Net farm return would be reduced by $2,719.32 (41 percent) at 2.50 acre-feet per water-right acre, by $2,367.16 (32 percent) at 2.75 acre-feet per water-right acre, by $1,813.90 (22 percent) at 3.00 acre-feet per water-right acre, by $1,316.86 (15 percent) at 3.25 acre-feet per water-right acre, by $819.82 (8 percent) at 3.50 acre-feet per water-right acre, by $328.83 (3 percent) at 3.75 acre-feet per water-right acre, and by $13.68 (less than 1 percent) at 4.00 acre-feet per water-right acre.

The results obtained from the three linear programming models are graphically summarized in figure 27. This graph indicates the effect of the seven quantities of irrigation water on the net farm return. In models A and B, as irrigation water is increased from 197.50 acre-feet to 228.31 acre-feet (2.50 to 2.89 acre-feet per water-right acre), and from 197.50 to 217.41 acre-feet (2.50 to 2.752 acre-feet per water-right acre) the net farm return increases at a constant rate. Beyond 228.31 and 217.41 acre-feet for models A and B respectively, the size of farm and cropping enterprises considered in this study become the factors that restrict the increase in net farm returns.

In model C, as irrigation water is increased from 197.50 acre-feet to 310.38 acre-feet (2.50 to 3.93 acre-feet per water-right acre), the net returns per water-right acre increase at almost a constant rate. Beyond 310.38 acre-feet (3.93 acre-feet per water-right acre) the size of the farm and cropping enterprises considered become the limiting factors to increases in net farm return.

Optimal Quantity of Irrigation Water

The shadow prices (marginal value products) for an additional acre-foot of irrigation water are presented in table 92. The optimal level of irrigation water diversion for each model can be determined by equating the shadow price with the cost of pumping an acre-foot of irrigation water. The estimated cost of pumping an acre-foot of irrigation water was $7.68. For models A and B the optimal quantity of water was between 217.23 and 237.00 acre-feet (2.75 and 3.00 acre-feet per water-right acre), and for model C it was 3.93 acre-feet (3.39 acre-feet per water-right acre).

Table 92. Case Farm K: Shadow prices for seven quantities of irrigation water diversion, Roswell Artesian Basin, New Mexico.

Quantity of Irrigation Water Diverted (acre-feet)	Shadow Price Model A (dollars)	Shadow Price Model B (dollars)	Shadow Price Model C (dollars)
197.50	25.15	26.48	48.91
217.25	25.15	26.48	48.04
237.00	0	0	25.15
256.75	0	0	25.15
276.50	0	0	25.15
296.25	0	0	22.31
316.00	0	0	0

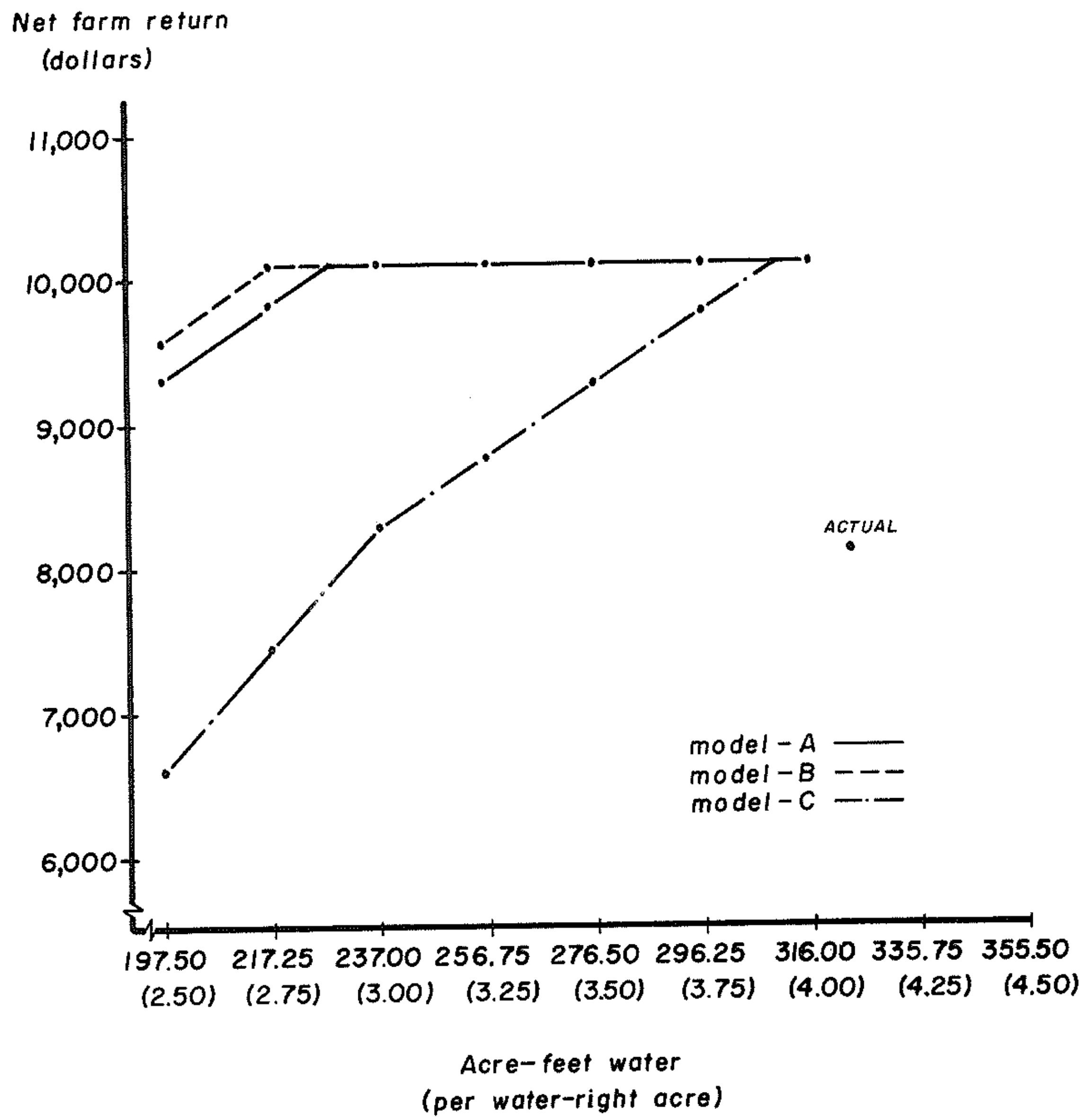


Figure 27. Case Farm K: Net farm return for seven quantities of irrigation water, Roswell Artesian Basin, New Mexico.

It would appear that 3.00 acre-feet per water-right acre would be a sufficient quantity for Case Farm K under conditions of models A and B. However, in model C, if irrigation water diversion were limited to 3.00 acre-feet per water-right acre instead of the optimal quantity, net returns per water-right acre would be reduced between $18.80 and $22.79. On a whole farm basis net returns would be reduced between $1,485.07 to $1,800.22 or approximately 17.9 to 21.7 percent.

CASE FARM L

GENERAL DESCRIPTION

Case Farm L was an owner-operator farm with 151.7 acres of artesian water rights. The farm was located in the Artesian Area of the Roswell Artesian Basin (figure 2).

Soils

The soils included on Farm L were Reagan Loam, Reagan Silt Loam, and Cave Gravelly Loam (figure 28). The Reagan Loam comprised approximately 97 percent, the Reagan Silt Loam about 3 percent, and the Cave Gravelly Loam less than 1 percent. The Reagan Loam was SCS Capability Class I, the Reagan Silt Loam was Class II, and the Cave Gravelly Loam was Class VII.

Irrigation Water

Case Farm L had two artesian wells, 830 and 876 feet deep. The average production was 800 and 1,300 gallons per minute for the three-year period. The water from these wells had an average total soluble salt content of about 1,518 millimhos and the average sodium adsorption ratio was approximately 0.96 for the three-year period (2). The quality classification of the water was Class 2.

Irrigation System

A reservoir was not used on this farm because the quantity of water delivered from the simultaneous pumping of both artesian wells provided a sufficient head of irrigation water. Both wells were pumped directly into a concrete ditch which was approximately 6,870 feet in total length and which provided water for about 8,105 feet of earthen primary and secondary lateral ditches.

Except for field number 7 and the southern half of 4, all of the cropland on Farm L had been leveled (figure 28). The leveled cropland sloped from west to east. Crops in fields 1, 5, 7, and 8 were irrigated from the concrete ditch and fields 2, 3, 4, 6, and 7 were irrigated from earthen laterals. Two 330-foot-long secondary earthen lateral ditches were employed in the irrigation of the unleveled cropland. Borders were not employed in the irrigation of any of the alfalfa fields.

The approximate lengths of irrigation water runs for the different fields are reported in table 93.

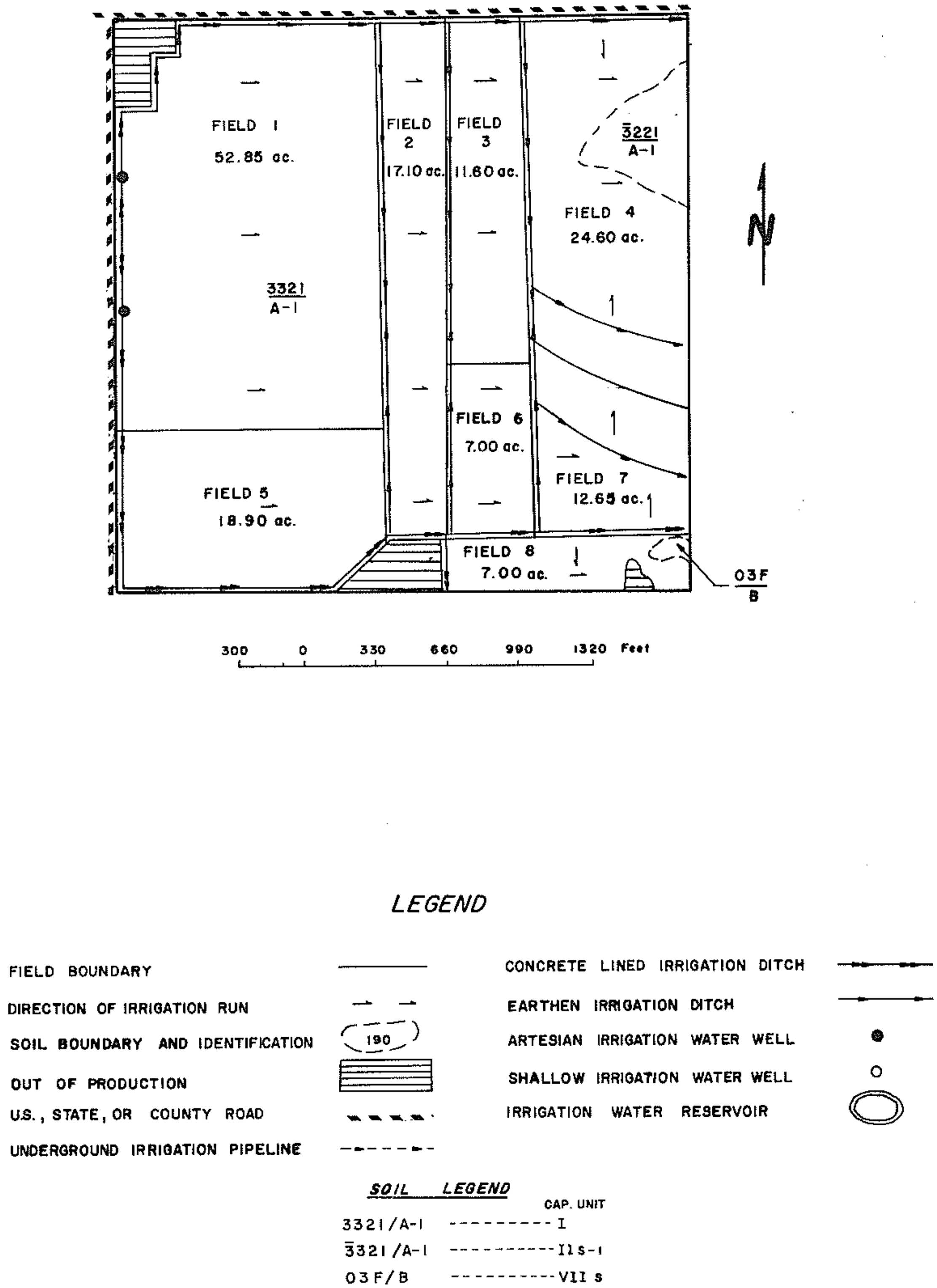


Figure 28. Map of Case Farm L.

Table 93. Case Farm L: Crops planted and approximate length of irrigation water runsby field, Roswell Artesian Basin, New Mexico.

Field Number	Crops Planted 1966	1967	1968	Length of Run (feet)
1	Cotton Diverted	Cotton	Cotton	1,190
2	Alfalfa	Alfalfa	Alfalfa	290
3	Alfalfa	Diverted	Alfalfa	370
4	Alfalfa	Alfalfa	Cotton	250- 740
5	Corn	Diverted Alfalfa	Alfalfa Diverted	990-1,200
6	Alfalfa	Alfalfa	Alfalfa	400
7	Alfalfa	Alfalfa	Alfalfa	260- 350
8	Alfalfa	Alfalfa	Alfalfa	200

Crops Produced

The principal crops produced on Case Farm L were cotton and alfalfa. Case Farm L had a cotton allotment of 52.8 acres in 1966, 81.3 acres in 1967, and 81.5 acres in 1968. In 1966 there were 46.2 acres of cotton, in 1967 there were 52.85 acres, and in 1968 there were 77.45 acres (table 94). The diversion rate under the government cotton program was 6.65 acres in 1966, 28.45 acres in 1967, and 4.1 acres in 1968. Projected per-acre yields in pounds by ASC were 830 in 1966, 800 in 1967, and 735 in 1968. The actual per-acre yields in pounds were 725.1 in 1966, 857.0 in 1967, and 418.0 in 1968 (table 95). Corn silage was produced on 18.9 acres in 1966. The yield is reported in table 95.

Irrigation Water Pumpage

In 1966 a total of 681.78 acre-feet of irrigation water was pumped on Case Farm L. In 1967 the total was 541.93 acre-feet and in 1968, 482.16 acre-feet (table 94). The average diversion per water-right acre was 4.49 acre-feet per acre in 1966, 3.57 acre-feet per acre in 1967, and 3.18 acre-feet per acre in 1968 (table 94). The average per-

Table 94. Case Farm L: Crop acreages and irrigation water pumpage, Roswell Artesian Basin, New Mexico

Crop	Acres				Irrigation Water Pumped							
					Per Crop				Per Acre			
	1966	1967	1968	Average	1966	1967	1968	Average	1966	1967	1968	Average
					(acre-feet)				(acre-feet)			
Cotton	46.20	52.85	77.45	58.83	192.09[1]	202.33[2]	167.95	166.87	4.16[3]	3.83[3]	2.17	3.19
Diverted	6.65	28.45	4.10	13.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Alfalfa	62.85	70.40	58.55	63.93	334.99	331.80	258.70	308.50	5.33	4.71	4.42	4.88
Seedling alfalfa	17.10	14.80[4]	11.60	14.50[5]	115.60	7.80	55.51	59.64	6.76	0.57	4.79	4.11
Corn silage	18.90	0.00	0.00	6.30	39.10	0.00	0.00	13.03	2.07	0.00	0.00	2.07
Total	151.70	151.70	151.70	151.70	681.78	541.93	482.16	568.62	4.49	3.57	3.18	3.75

1. Includes 53.82 acre-feet pumped during January, 1966, as a pre-plow application for the 1966 cotton crop.
2. Includes 61.75 acre-feet pumped during November and December, 1966, as a pre-plow application for the 1967 cotton crop.
3. Includes 1.16 acre-feet of irrigation for pre-plow application.
4. Not included in total, was diverted.
5. Not included in total, 4.93 acres.

Table 95. Case Farm L: Crops and yield per acre, Roswell Artesian Basin, New Mexico.

Crop	Unit	Yield per Acre 1966	1967	1968	Average
Cotton planted	lb.	725.1	857.0	418.0	666.7
Lint	lb.	725.1	857.0	418.0	666.7
Seed	ton	0.56	0.66	0.33	0.52
Alfalfa					
Hay	ton	7.2	6.3	6.3	6.6
Corn silage	ton	15.0	----	----	15.0

acre diversion for cotton for the three-year period was 3.19 acre-feet per acre: an average of 0.77 acre-feet was applied as a pre-plow application partially as a method for pink bollworm control and partially for proper seedbed preparation. Alfalfa received an acreage of 4.88 acre-feet per acre on the established stand. The seedling alfalfa which was planted in the spring received an average of 4.11 acre-feet per acre. The corn silage received 2.07 acre-feet per acre in 1966.

In 1967 the average quantity of irrigation water diverted on Case Farm L was higher than the average quantity of irrigation water diverted on all farms in the Artesia Area. The average irrigation water diversion of Farm L was 3.57 acre-feet per water-right acre, 3.57 acre-feet per cultivated acre, and 4.40 acre-feet per cropped acre. The average diversion for farms in the Artesia Area was 3.14 acre-feet per water-right acre, 3.33 acre-feet per cultivated acre, and 3.71 acre-feet per cropped acre (9).

In 1968 the average quantity of irrigation water diverted per water-right acre on Farm L was also higher than the average for all farms in the Artesia Area. The average was 3.18 acre-feet per water-right acre for Farm L compared with 2.80 acre-feet per water-right acre for the Artesia Area (12).

Irrigation Efficiency

The typical irrigation efficiency by crops is reported in table 96 and yearly estimates in table C12. Irrigation water effciency on cotton ranged from 38.66 to 72.54 with an average of 50.98 percent; on alfalfa from 48.97 to 63.62 with an average of 54.61 percent; and corn silage had 63.12 percent (table 96 and C12).

Table 96. Case Farm L: Typical consumptive irrigation requirement, irrigation water applied, and farm irrigation efficiency.

Crop	Consumptive Irrigation Requirement (acre-inches)	Irrigation Water Applied (acre-inches)	Farm Irrigation Efficiency (percent)
Cotton	20.74	40.68	50.98
Alfalfa	31.98	58.86	54.61
Corn silage	15.68	24.84	63.12

ECONOMIC ANALYSIS

Financial Summary

The typical per-acre net returns by crops are reported in table 97 and for each of the three years in table D12. The net farm returns for 1966, 1967, and 1968 were $10,539.47, $19,757.16, and $7,904.29 respectively (table E12). The primary reasons for the large variations in net farm returns were the favorable yields and prices of cotton and alfalfa in 1968, the unfavorable yields and prices for cotton and alfalfa in 1967, and the production of corn silage and lower cotton base in 1966.

Table 97. Case Farm L: Typical per-acre returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns per Acre (dollars)	Gross Expenses per Acre (dollars)	Net Returns to Land and Management per Acre (dollars)
Cotton planted	326.29	157.06	169.23
Cotton diverted	84.77	12.17	72.60
Alfalfa	165.00	127.05	37.95
Corn silage	67.55	39.23	28.32
Weighted average	214.97	125.20	89.77

Because of the wide variations in yields, prices, and net farm returns a typical whole farm budget was computed using typical yields, prices and costs (table 98). This typical whole farm budget will be compared with the linear programming solutions to determine the effects of different levels of irrigation water diversions on net farm returns. The annual whole farm budgets are presented in appendix E (table E12).

Table 98. Case Farm L: Typical whole farm returns and expenses by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns	Gross Expenses	Net Returns to Land and Management
		(dollars)	(dollars)	(dollars)
Cotton planted	58.83	19,195.64	9,329.84	9,955.80
Cotton diverted	13.07	1,107.94	159.06	948.88
Alfalfa	78.43	12,940.95	9,964.53	2,976.42
Corn silage	6.30	425.57	247.15	178.42
Total	156.63	33,670.10	19,610.58	14,059.52

Linear Programming Solutions--Model A

The coefficients and constraints for model A are presented below:

$$1X_1 + 1X_2 + 1X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 1X_8 + 1X_9 + 1X_{10} \leq 151.7$$

acres

$$1X_1 + 1X_2 + 1X_3 + 0X_4 + 0X_5 + 0X_6 + 0X_7 + 0X_8 + 0X_9 + 0X_{10} \leq 71.9$$

acres of cotton

$$1.95X_1 + 2.40X_2 + 2.85X_3 + 4.71X_4 + 0X_5 + 5.33X_6 + 6.00X_7 + 2.25X_8$$

$$+ 2.07X_9 + 2.25X_{10} \leq 379.25$$ acre-feet of irrigation water

The X variables are identified in table 99.

The parameter changes in irrigation water diversion (Qt), where Q = 379.25 acre-feet of irrigation water and t = 37.925 acre-feet result in the following irrigation water constraints:

2.75 acre-feet per water-right acre = 417.17 acre-feet
3.00 acre-feet per water-right acre = 455.10 acre-feet
3.25 acre-feet per water-right acre = 493.02 acre-feet
3.50 acre-feet per water-right acre = 530.95 acre-feet
3.75 acre-feet per water-right acre = 568.87 acre-feet
4.00 acre-feet per water-right acre = 606.80 acre-feet

In table 99 the whole farm budget for the typical crop year is compared with the results of model A. The linear programming solutions presented in table 99 indicate the optimal net farm returns and the combinations of the nine crops that would be produced if there were no assumed crop rotation program on Case Farm L.

In table 99 the net farm return obtained from the linear programming solutions is also contrasted with $14,059.52, which was obtained from the typical crop year with 568.62 acre-feet of irrigation water (3.75 acre-feet of irrigation water per water-right acre). The net farm return for the typical crop year would have been increased about 22 percent with the combination of crop enterprises that is indicated in model A with 2.50 acre-feet of irrigation water; about 23 percent with 2.75 acre feet; about 24 percent with 3.00 acre-feet; about 24 percent with 3.25 acre-feet; about 25 percent with 3.50 acre-feet; about 26 percent with 3.75 acre-feet; and about 26 percent with 4.00 acre-feet.

The lower net farm return for the typical crop year can be attributed primarily to the production of cotton at the 87 percent level of the allotment and to the production of alfalfa A. and corn silage. Even at low levels (2.50 acre-feet of water per water-right acre) of irrigation water diversions, cotton would be produced on the maximum number of acres allowed under the cotton program (cotton 95), or about 45 percent of the water-right acres. About 51.1 percent of the water-right acres would be devoted to the production of castor beans and the remaining tillable acres (3.32 acres) would be fallow. The above combination of enterprises would result in a net farm return of approximately $17,096.

As more irrigation becomes available, alfalfa D substitutes for castor beans at a rate of 10.12 acres per one-fourth acre-foot of irrigation water per water-right acre until 4.51 acre-feet of irrigation water is pumped per water-right acre, where only cotton and alfalfa D are produced on the water-right acres. If more than 4.51 acre-feet were available net farm returns to land and management would not increase,but would remain at $17,931.44, which is 27.5 percent above the typical whole farm budget.

Although the above combinations of crop enterprises result in the maximum returns for each quantity of irrigation water, they do not specifically allow for a crop rotation program. Crop yields, and therefore returns, may be reduced if these combinations of crop enterprises

Table 99. Case Farm L: Whole farm budget and linear programming solutions, models A, B, and C, Roswell Artesian Basin, New Mexico.

		Whole Farm Budget			Linear Programming Solutions: 2.50 acre feet per acre			2.75 acre feet per acre			3.00 acre feet per acre			3.25 acre feet per acre			3.50 acre feet per acre			3.75 acre feet per acre			4.00 acre feet per acre		
Variable	Crop	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars	Acres	Irrigation Water ac. ft.	Net Returns dollars
	MODEL A																								
X_1	Cotton (65)																								
X_2	Cotton (80)	71.90	187.45	10,904.68																					
X_3	Cotton (95)				71.90	204.92	11,820.36	71.90	204.92	11,820.36	71.90	204.92	11,820.36	71.90	204.92	11,820.36	71.90	204.92	11,820.36	71.90	204.92	11,820.36	71.90	204.92	11,820.36
X_4	Alfalfa (A)	78.43[1]	368.14	2,976.42																					
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)							8.72	52.32	667.78	18.84	113.03	1,442.77	28.95	173.70	2,216.99	39.06	234.36	2,991.21	49.18	295.07	3,766.20	59.29	355.74	4,540.43
X_8	Castor Beans				77.48	174.33	5,275.61	71.08	159.93	4,839.84	60.96	137.15	4,150.77	50.85	114.40	3,462.38	40.74	91.67	2,773.99	30.62	68.88	2,084.92	20.51	46.14	1,396.53
X_9	Corn Silage	6.30	13.03	178.42																					
X_{10}	Grain Sorghum																								
	Fallow				2.32	0.00	0.00																		
	Total	151.70	568.62	14,059.52	151.70	379.25	17,095.97	151.70	417.17	17,327.98	151.70	455.10	17,413.90	151.70	493.02	17,499.73	151.70	530.95	17,585.56	151.70	568.87	17,671.48	151.70	606.80	17,757.32
	MODEL B																								
X_1	Cotton (65)																								
X_2	Cotton (80)	71.90	187.45	10,904.68																					
X_3	Cotton (95)				71.90	194.85	11,820.36	71.90	194.85	11,820.36	71.90	194.85	11,820.36	71.90	194.85	11,820.36	71.90	194.85	11,820.36	71.90	194.85	11,820.36	71.90	194.85	11,820.36
X_4	Alfalfa (A)	78.43[1]	368.14	2,976.42																					
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)																								
X_7	Alfalfa (D)				3.83	21.83	293.30	14.48	82.54	1,108.88	25.13	143.25	1,924.46	35.79	204.00	2,740.80	46.44	264.71	3,556.38	57.09	325.41	4,371.95	67.75	386.17	5,188.30
X_8	Castor Beans				75.97	162.57	5,172.80	65.32	139.78	4,447.64	54.67	117.00	3,722.48	44.01	94.17	2,996.64	33.36	71.39	2,271.48	22.71	48.61	1,546.32	12.05	25.78	820.48
X_9	Corn Silage	6.30	13.03	178.42																					
X_{10}	Grain Sorghum																								
	Fallow																								
	Total	151.70	568.62	14,059.52	151.70	379.25	17,286.46	151.70	417.17	17,376.88	151.70	455.10	17,467.30	151.70	493.02	17,557.80	151.70	530.95	17,648.22	151.70	568.87	17,738.63	151.70	606.80	17,829.14
	MODEL C																								
X_1	Cotton (65)				71.90	140.20	9,735.98																		
X_2	Cotton (80)	71.90	187.45	10,904.68				71.90	172.56	10,778.53															
X_3	Cotton (95)										71.90	204.92	11,820.36	71.90	204.92	11,820.36	71.90	204.92	11,820.36	71.90	204.92	11,820.36	71.90	204.92	11,820.36
X_4	Alfalfa (A)	78.43[1]	368.14	2,976.42	44.28	208.56	1,680.43	35.30	166.26	1,339.64	26.31	123.92	998.46												
X_5	Alfalfa (B)																								
X_6	Alfalfa (C)				5.72	30.49	330.33	14.70	78.35	848.93	23.69	126.26	1,368.10	50.00	266.50	2,887.50	50.00	266.50	2,887.50	4.61	24.57	266.23			
X_7	Alfalfa (D)																			45.39	272.34	3,475.97	59.29	355.74	4,540.43
X_8	Castor Beans													9.60	21.60	653.66	26.46	59.53	1,801.66	29.80	67.04	2,029.08	20.51	46.14	1,396.53
X_9	Corn Silage	6.30	13.03	178.42																					
X_{10}	Grain Sorghum																								
	Fallow				29.80	0.00	0.00	29.80	0.00	0.00	29.80	0.00	0.00	20.20	0.00	0.00	3.34	0.00	0.00						
	Total	151.70	568.62	14,059.52	151.70	379.25	11,746.74	151.70	417.17	12,967.09	151.70	455.10	14,186.92	151.70	493.02	15,361.52	151.70	530.95	16,509.52	151.70	568.87	17,591.64	151.70	606.80	17,757.32

1 Not included in total, 4.93 acres

were produced for extended time periods at the lower levels of irrigation water pumpage.

Linear Programming Solutions--Model B

The coefficients and constraints for model B are the same as for model A except that irrigation water coefficients have been reduced by 5 percent. The irrigation water coefficients and the first irrigation constraint for model B are listed below:

$$1.85X_1 + 2.25X_2 + 2.71X_3 + 4.47X_4 + 0X_5 + 5.06X_6 + 5.70X_7 + 2.14X_8$$

$$+ 1.97X_9 + 2.14X_{10} \leq 379.25 \text{ acre-feet of irrigation water}$$

The X variables are identified in table 99.

In table 99 the whole farm budget for the typical crop year is compared with the results of model B. These solutions presented in table 99 indicate the optimal net farm returns and the combinations of crops that would be produced if there were no assumed crop rotation program on Case Farm L.

In table 99 the net farm return obtained from the linear programming solutions is also contrasted with $14,059.52, which was obtained from the typical crop year with 568.62 acre-feet of irrigation water (3.75 acre-feet of irrigation water per water-right acre). The net farm return for the typical crop year would have been increased about 23 percent with the combination of crop enterprises that is indicated in model B with 2.50 acre-feet of irrigation water; about 24 percent with 2.75 acre-feet; about 24 percent with 3.00 acre-feet; about 25 percent with 3.25 acre-feet; about 26 percent with 3.50 acre-feet; about 26 percent with 3.75 acre-feet; and about 27 percent with 4.00 acre-feet.

The solutions for model B reflect a 5 percent increase in irrigation water efficiency on each crop. If 2.50 acre-feet of irrigation water per water-right acre were available, cotton 95 would comprise about 45 percent of the water-right acres, castor beans about 50 percent, alfalfa about 3 percent, and the remaining 2 percent would be diverted. As more irrigation water becomes available alfalfa D (5.70 acre-feet) substitutes for castor beans at a rate of 10.65 acres per one-fourth acre-foot of irrigation water per water-right acre until 4.28 acre-feet per acre are pumped. If more than 4.28 acre-feet were available net farm return would not be increased, but would remain at $17,931.44. This is about 28 percent above the typical whole farm budget. A 5 percent increase in irrigation efficiency increased the optimal net farm returns by an average of 1 percent.

Linear Programming Solutions--Model C

The coefficients and constraints for model C are the same as for model A except that an additional constraint was placed on a minimum amount of alfalfa being produced. The coefficients and the added constraint are listed below:

$$0X_1 + 0X_2 + 0X_3 + 1X_4 + 0X_5 + 1X_6 + 1X_7 + 0X_8 + 0X_9 + 0X_{10} \geq 50$$

acres of alfalfa

The X variables are identified in table 99.

In table 99 the whole farm budget for the typical crop year is compared with the results of model C. These solutions, presented in table 99, indicate the optimal net farm returns and the combinations of crops that would be produced if a minimum of one-third of the water-right acres were devoted to alfalfa production, which is the assumed crop rotation program.

In table 99 the net farm return obtained from the linear programming solutions is also contrasted with $14,059.52, which was obtained from the typical crop year with 568.62 acre-feet of irrigation water (3.75 acre-feet of irrigation water per water-right acre). The net farm return for the typical crop year would have been decreased about 20 percent with the combination of crop enterprises that is indicated in model C with 2.50 acre-feet of irrigation water; decreased about 8 percent with 2.75 acre-feet; increased about 1 percent with 3.00 acre-feet; increased about 9 percent with 3.25 acre-feet; increased about 17 percent with 3.50 acre-feet; increased about 25 percent with 3.75 acre-feet; and increased about 26 percent with 4.00 acre-feet.

The primary reason for the lower return figure at 2.50 acre-feet of irrigation water per water-right acre is the requirement that about one-third of the farm be planted in alfalfa. In order to have enough water for alfalfa approximately one-third of the farm must be left fallow. Alfalfa A and C should be produced on 44.28 and 5.72 acres respectively, which require 4.71 and 5.33 acre-feet of irrigation per acre respectively. Cotton 65 should be produced on 46.7 acres (table 99).

As more irrigation water becomes available a larger acreage would be devoted to alfalfa C. At the 2.75 level of irrigation water diversion 8.98 acres of alfalfa A shifts to alfalfa C, cotton 65 shifts to cotton 80, and the fallow acreage remains unchanged. At the 3.00 acre-feet irrigation water diversion level, alfalfa A acreage would decrease to 26.31 acres and alfalfa C increases to 23.69 acres, cotton acreage shifts to cotton 95 and fallow remains unchanged. With 3.25 acre-feet of irrigation water available per water-right acre, the maximum net farm return is obtained with 68.31 acres of planted cotton (cotton 95), and 50.0 acres of alfalfa C, 9.6 acres of castor beans, and 20.20 acres of fallow.

The optimal solution and cropping patterns for 3.50 acre-feet per water-right acre would include cotton 95, 50 acres of alfalfa C, 26.46 acres of castor beans, and 3.34 acres fallow.

With 3.75 acre-feet per water-right acre cotton should be produced on 68.31 acres (cotton 95), alfalfa C on 4.61 acres, alfalfa D on 45.39 acres, and castor beans on 29.80 acres. The optimal solution at 4.00 acre-feet per water-right acre is the same as model A.

The immediate economic effect of forcing in a crop rotation of about one-third of the farm into alfalfa is a reduction in net farm returns at irrigation water diversion less than 4.00 acre-feet per water-right acre. This effect can be estimated by comparing solutions from model A with solutions from model C. Net farm returns would be reduced by $5,349.23 (46 percent) at 2.50 acre-feet per water-right acre, by $4,360.89 (34 percent) at 2.75 acre-feet per water-right acre, by $3,226.98 (23 percent) at 3.00 acre-feet per water-right acre, by $2,138.21 (14 percent) at 3.25 acre-feet per water-right acre, by $1,076.04 (6.5 percent) at 3.50 acre-feet per water-right acre, by $79.84 (less than 1 percent) at 3.75 acre-feet per water-right acre; they are the same at 4.00 acre-feet per acre.

The results obtained from the three linear programming models are graphically summarized in figure 29. This graph indicates the effect of the seven quantities of irrigation water on the net farm return. In models A and B, as irrigation water is increased from 379.25 acre-feet to 606.80 acre-feet (2.50 to 4.00 acre-feet per water-right acre), the net farm return increases almost at a constant rate. Beyond 835.87 and 649.28 acre-feet (4.51 and 4.28 acre-feet per water-right acre) for models A and B respectively, the size of farm and cropping enterprises considered in this study become the factors that restrict net farm returns.

In model C, as irrigation water is increased from 379.25 acre-feet to 568.87 acre-feet (2.50 to 3.75 acre-feet per water-right acre), the net return per water-right increases at almost a constant rate. From 568.87 to 606.80 acre-feet (3.75 to 4.00 acre-feet) the rate of increase is at a lower constant rate. At 606.80 acre-feet model C becomes the same as model A. Beyond 835.85 acre-feet (4.51 acre-feet per water-right acre) the size of the farm and cropping enterprises considered become the limiting factors, in the same manner as for model A.

Optimal Quantity of Irrigation Water

The shadow prices (marginal value products) for an additional acre-foot of irrigation water are presented in table 100. The optimal level of irrigation water diversion for each model can be determined by equating the shadow price with the cost of pumping an acre-foot of irrigation water. The estimated cost of pumping

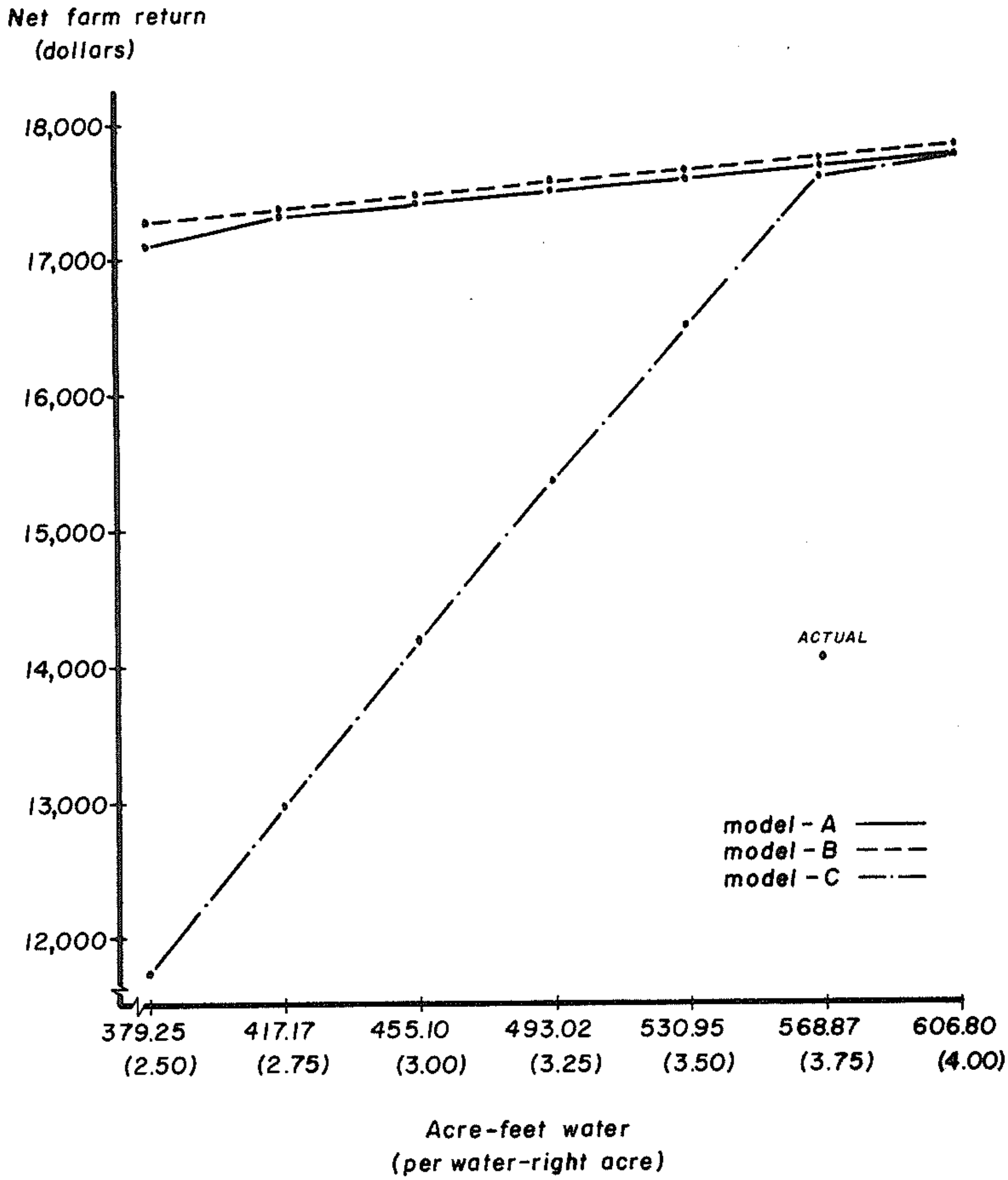


Figure 29. Case Farm L: Net farm return for seven quantities of irrigation water, Roswell Artesian Basin, New Mexico.

an acre-foot of irrigation water was $7.68. For model A the optimal quantity of water was between 379.25 and 417.18 acre-feet (2.50 and 2.75 acre-feet per water-right acre); for model B, between 341.32 and 329.25 acre-feet (2.25 and 2.50 acre-feet per water-right acre); and for model C, between 568.88 and 606.80 acre-feet (3.75 and 4.00 acre-feet per water-right acre).

It appears that 3.00 acre-feet per water-right acre would be a sufficient quantity of irrigation water under conditions of models A and B. However, in model C if irrigation water diversions were limited to 3.00 acre-feet per water-right acre, net farm returns would be reduced between $3,404.72 to $3,570.40, or approximately 24 percent, for Case Farm L.

Table 100. Case Farm L: Shadow prices for seven quantities of irrigation water diversion, Roswell Artesian Basin, New Mexico.

Quantity of Irrigation Water Diverted (acre-feet)	Shadow Price Model A (dollars)	Shadow Price Model B (dollars)	Shadow Price Model C (dollars)
379.25	30.26	2.38	31.94
417.17	2.26	2.38	31.94
455.10	2.26	2.38	31.94
493.02	2.26	2.38	30.26
530.95	2.26	2.38	30.26
569.87	2.26	2.38	28.10
606.80	2.26	2.38	2.26

SUMMARY

The Roswell Artesian Basin in southeastern New México is one of the state's most important irrigated cropland areas. However, increased withdrawals of water, mostly for agricultural use, since the early 1900's have resulted in a reduction of underground reserves. Legal restraints in the form of a 1966 court decree have limited the quantity of ground water that can be used for irrigation to an average annual allotment of 3.0 acre-feet per water-right acre. Historically many farmers have used more irrigation water than 3 acre-feet per water-right acre per annum. Farmers are currently faced with the need to adjust their farming operations to the limited quantities of irrigation water and/or obtain additional irrigation water to maximize net farm returns.

To supply current information as a step toward solving the above mentioned problems a three-year study was initiated in 1966 by the New Mexico Water Resources Research Institute in cooperation with the New Mexico Agricultural Experiment Station. This study was designed to obtain information on crops grown, yields, soil quality, water quality, types of irrigation systems, methods of irrigation, and amounts of water consumed by alfalfa and cotton, and to analyze these factors as they relate to the water requirements for crop production. A team composed of agronomists, agricultural engineers, agricultural economists, and soil specialists was selected to conduct the research.

The specific objectives of this, the agricultural economics phase of the study, were:

1. To determine the present cropping systems, management practices, and income patterns of the farms in the basin.

2. To evaluate the economic effects of alternative cropping systems and management practices under varying amounts of irrigation water with specific emphasis on three acre-feet of irrigation water per acre.

The case study method was used to obtain information about production requirements, costs, and returns for farms in the Roswell Artesian Basin. This method was selected because so few farmers had detailed records on irrigation water use for the different crops grown in the Roswell Artesian Basin. Twelve study farms were selected from Chaves and Eddy Counties, New Mexico. Each of the 12 farms was selected from a different geographic location in the basin. Other criteria used in the selection of study farms included the type of crops grown, the type of irrigation systems, the type of soil, the quality and quantity of irrigation water, and the willingness of the farmer to keep the necessary records. The average cropping program and irrigation water diversion for the 12 case study farms appeared

to be typical of the average for all farms in the Roswell Artesian Basin.

Both enterprise and whole farm budgets were employed in the analysis of each case farm. The enterprise budgets were developed from the supervised study farm records to determine the production requirements, costs, and returns for the different crop enterprises during the 1966, 1967, and 1968 crop years. Enterprise budgets were combined into whole farm budgets and were used in the derivation of coefficients for three linear programming models. Whole farm budgets were computed for individual case study farms to compare the net farm returns and irrigation water diversion during a typical year with the results of the linear programming analysis.

Parametric linear programming models were used to analyze the effects of different quantities of irrigation water on the net farm return of each case study farm. Three linear programming models were developed for each case farm, to ascertain the effect of seven different quantities of irrigation water on the net return of each case farm. The quantities of water considered in the models were 2.50, 2.75, 3.00, 3.25, 3.50, 3.75, and 4.00 acre-feet per acre, times the adjudicated water-rights acreage of the individual case farm. The cotton programs considered are described on page 26, and the alfalfa enterprises considered are discussed on page 27.

Linear programming model A was designed to analyze only the effect of the different levels of irrigation water on the net return of each case farm. Provisions for a crop rotation program were not included in this model. The solutions for model A represent the maximum annual return obtainable from each of the seven quantities of irrigation water based on production requirements, costs, and returns based on the 12 case study farms and other data.

Linear programming model B contained a 5 percent increase in irrigation efficiency over model A. Provisions for a crop rotation program were not included in this model. The solutions for model B represent the maximum annual return obtainable from each of the seven quantities of irrigation water based on production requirements, gain in irrigation efficiency, costs, and returns used in this study.

Linear programming model C contained provisions for a crop rotation program. The rotation plan required the production of alfalfa on approximately 30 percent of the acreage of a farm.

The solutions for the linear programming models provided estimates of the shadow price (marginal value products) for irrigation water. These values are the amount by which net farm return would

Table 101. Physical summary of twelve case study farms, Roswell Artesian Basin, New Mexico.

Item	Unit of Measurement	Case Farm A	B	C	D	E	F	G	H	I	J	K	L	Average
Typical Cropping Program (cropped acres)														
Cotton planted	acres	102.60	74.62	57.00	67.40	75.90	160.77	53.70	70.62	33.50	39.54	23.37	58.83	68.15
Cotton diverted	acres	32.50	17.00	13.30	24.30	16.70	26.93	11.70	7.77	9.45	12.96	4.13	13.07	15.82
Alfalfa	acres	79.10	156.10	64.00	121.80	122.20	80.00	91.10	93.43	74.70	79.27	40.66	78.43	90.07
Forage sorghum	acres		7.20	11.70	28.40				3.25					4.21
Corn silage	acres				46.60		100.00						6.30	12.74
Grain sorghum	acres			17.30	15.60	58.30						10.03		8.44
Small grains	acres	24.00	31.60	42.00	46.90	84.50	40.00	56.00		3.25	16.90			28.76
Fallow	acres	25.40	2.18	7.00	4.80	7.00	18.97	9.20	2.18	1.30	2.73	3.43		7.02
Total cropped acres	acres	263.60	288.70	212.30	355.80	364.60	426.57	221 70	177.25	122.20	151.40	81.62	156.63	235.21
Total water-right acres	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88
(cropped acres)														
Cotton planted	percent	38.92	25.85	26.85	18.94	20.82	37.68	24.22	39.84	27.42	26.12	28.63	37.56	29.40
Cotton diverted	percent	12.33	5.89	6.26	6.83	4.58	6.31	5.28	4.38	7.73	8.56	5.06	8.35	6.80
Alfalfa	percent	30.01	54.07	30.15	34.23	33.51	18.75	41.09	52.72	61.13	52.36	49.82	50.07	42.33
Forage sorghum	percent		2.49	5.51	7.98				1.83					1.48
Corn silage	percent				13.10		23.44						4.02	3.38
Grain sorghum	percent			8.15	4.39	15.99						12.29		3.40
Small grains	percent	9.10	10.95	19.78	13.18	23.18	9.37	25.26		2.66	11.16			10.39
Fallow	percent	9.64	0.75	3.30	1.35	1.92	4.45	4.15	1.23	1.06	1.80	4.20		2.82
Total cropped acres	percent	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total water-right acres	percent[1]	88.01	96.61	74.66	85.36	76.80	93.75	84.44	98.17	100.00	100.00	96.79	96.85	90.95
Net farm return per water-right acre	dollars	115.93	92.60	52.06	84.57	100.74	90.40	71.36	140.06	75.91	77.03	102.83	92.68	91.35
Typical Irrigation Water Diversion (per-acre)														
Cotton planted	ac-ft	2.55	2.51	2.80	2.38	2.03	1.83	2.70	3.74	3.29	2.60	3.63	3.39	2.79
Cotton diverted	ac-ft													
Alfalfa	ac-ft	4.79	4.44	4.01	4.54	3.70	1.30	3.81	5.37	4.36	4.57	5.12	4.69	4.23
Forage sorghum	ac-ft		1.10	2.05	1.84				2.86					1.96
Corn silage	ac-ft				1.97		1.32						2.07	1.79
Grain sorghum	ac-ft			1.32	1.08	1.91						3.03		1.84
Small grains	ac-ft	1.04	2.68	1.40	1.99	1.99	.80	1.19		.43	2.79			1.59
Fallow	ac-ft													
Average		2.89	3.42	3.29	3.19	3.09	1.41	2.68	4.46	3.58	3.38	4.09	3.75	3.27

Table 101. Physical summary of twelve case study farms, Roswell Artesian Basin, New Mexico, continued.

Item	Unit of Measurement	Case Farm A	B	C	D	E	F	G	H	I	J	K	L	Average
Typical Yield (per-acre)														
Cotton														
Lint	lb	706.9	854.4	504.2	632.2	903.5	550.8	617.7	970.4	773.9	587.9	975.3	666.7	728.66
Seed	ton	0.54	0.65	0.38	0.48	0.70	0.38	0.53	0.74	0.63	0.47	0.77	0.52	0.57
Alfalfa														
Hay	ton	4.33	6.00	4.90	6.80	6.60	1.41[2]	4.05	6.85	5.87	6.26	5.80	6.60	5.46
Pasture	a.u.m.	11.22						10.25						10.74
Seed	lb						22.73	113.80	21.60					52.71
Forage sorghum														
Silage	ton		15.00		22.95									18.98
Pasture	a.u.m.			5.00					7.20					5.82
Corn silage	ton				17.70		16.90						15.00	16.53
Grain sorghum	cwt			34.00		67.50						65.00		55.50
Small grains														
Seed and grain	bu		57.50	40.60	61.80	75.00		29.40			37.12			50.24
Hay	ton				3.90		3.35	3.30						3.52
Pasture	a.u.m.	9.33	9.60		5.70			9.00		5.00	3.55			6.74
Typical Farm Irrigation Efficiency														
Cotton planted	percent	59.12	63.21	56.02	63.34	77.53	81.17	59.12	42.09	54.31	58.72	47.31	50.98	59.41
Cotton diverted	percent													
Alfalfa	percent	47.03	57.39	56.89	48.59	54.06		65.54	43.47	62.86	57.48	50.63	54.61	54.41
Forage sorghum	percent		53.39	48.74	51.88				34.94					47.24
Corn silage	percent				64.32		90.75						63.12	72.73
Grain sorghum	percent			112.94	78.56	77.84						55.13		81.12
Small grains	percent	118.97	68.53	91.22	63.01	63.94	81.10	97.51		78.77	48.14			79.02
Weighted average	percent	61.45	60.63	68.06	57.66	65.80	84.35	72.74	42.72	60.75	56.68	50.18	53.50	61.21

1 Percent of total cropped acres
2 Alfalfa for seed

change as a result of changing the quantity of irrigation water by one acre-foot. Maximum profit for a farm is attained when the shadow price is equal to the cost of pumping one acre-foot of irrigation water ($7.68 per acre-foot).

The average size of the 12 case farms was 209.88 water-right acres (table 101). However, 10 of the 12 case farms double-cropped part of the water-right acreage and the average total size in terms of cropped acres was 235.21 acres which is 12.1 percent above the water-right acreage. The average net farm return for the typical farm was $91.35 per water-right acre, obtained from the production of cotton on 29.4 percent of the cropland, diverted acres on 6.8 percent, alfalfa on 42.3 percent, forage crops on 4.9 percent, grain sorghum on 3.4 percent, small grains on 10.4 percent, and fallow or out of production on 2.8 percent of the cropped acres, and on a water-right acre basis cotton accounted for 32.5 percent, diverted 7.5 percent, and alfalfa 42.9 percent.

The three-year average irrigation water diversion (per water-right acre) on the 12 case study farms ranged from 1.41 to 4.46 acre-feet with an average of 3.27 acre-feet for all 12 farms (table 101). Diversions on cotton ranged from 1.83 to 3.74 acre-feet with an average of 2.79 acre-feet per acre for all 12 farms. Diversions for alfalfa ranged from 1.30 to 5.37 acre-feet with an average of 4.23 acre-feet for all 12 farms. The primary reason for the low diversion level on one farm, Case Farm F, was the production of seed alfalfa all three years of the study. The remaining irrigation water diversions for the remaining crops on each of the case farms are presented in table 101.

Yields per acre by crops and case farms are reported in table 101. Cotton yields ranged from 504.2 to 975.3 pounds with an average of 728.7 pounds on the 12 case farms. Alfalfa yields ranged from 1.41 to 6.85 tons with an average yield of 5.46 tons per acre. The reason for the extremely low yield of alfalfa hay on one farm, Case Farm F, was the production of alfalfa seed during all three years of the study.

Farm irrigation efficiency averaged 61.21 percent for the 12 case study farms (table 101), ranging from 42.72 to 84.35 percent. The average irrigation efficiency on cotton was 59.41 percent with a range from 42.09 to 81.17 percent. The irrigation efficiency on alfalfa ranged from 43.47 to 65.54 percent with an average of 54.41 percent on 11 of the 12 case farms. Irrigation efficiency was based on cotton, corn silage, and oats for Case Farm F because of the alfalfa seed production. Case Farms F, G, and H also produced alfalfa seed and Case Farms A and G grazed alfalfa during part of the growing season (table 101). Irrigation efficiencies for the remaining crops produced on the case farms are presented in table 101.

Linear Programming--Model A

The typical cropping program under actual use in the study period for the average of the 12 case farms diverted an average of 3.27 acre-feet of irrigation water per water-right acre with a per-acre net return to land and management of $91.35. However, the solutions for linear programming model A with 2.50 acre-feet of irrigation water available indicated that an average net return of $106.43 per water-right acre would be obtained if crop enterprises were combined optimally (table 102). The average net return per acre would have been increased 16.5 percent or $15.08 per water-right acre above the typical whole farm budget with the crop enterprises in model A at the 2.50 acre-feet diversion level (table 103). Comparing the 2.50 acre-feet diversion level with 3.00 acre-feet, net farm return would be decreased 5.4 percent ($5.70) per water-right acre. Net returns increased primarily from a larger acreage of planted cotton, and by increases in grain sorghum, castor beans, and a reduction in small grains and alfalfa. The optimal combination of crops for the average-sized farm, with 2.50 acre-feet of irrigation water available per water-right acre, required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa D on 8.5 percent, grain sorghum on 30.6 percent, castor beans on 10.7 percent, forage sorghum on 6.7 percent, and fallow acreage on 3.3 percent (table 102). (With respect to income generation, grain and forage sorghums and castor beans, as used in this study, are almost equal and therefore interchangeable.)

At 2.75 acre-feet of irrigation water per water-right acre, the solutions for model A indicated the average net farm return would be increased 20.1 percent, or $18.39 per water-right acre above the typical whole farm budget, decreased 2.2 percent ($2.39) per water-right acre below the 3.00 acre-feet diversion level, and increased 2.9 percent ($3.31) per water-right acre above the optimal solutions with 2.50 acre-feet of irrigation water (table 103). The increased return was achieved by an increased acreage of alfalfa and a slight decrease in grain sorghum, castor beans, forage sorghum, and fallow acreage with cotton acreage unchanged. The optimal cropping program for the average-sized farm with 2.75 acre-feet of irrigation water per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa D on 13.9 percent, grain sorghum on 27.4 percent, castor beans on 10.8 percent, forage sorghum on 5.9 percent, and fallow acreage on 1.8 percent (table 102).

At 3.00 acre-feet of irrigation water per water-right acre, the solutions for model A indicated the average net farm return would be increased 22.7 percent or $20.78 per water-right acre above the typical whole farm budget, and 2.2 percent ($2.39) per water-right acre above the optimal solution with 2.75 acre-feet of irrigation water (table 103). The increased return was achieved by an

Table 102. Model A: Linear programming summary of 12 case study farms, Roswell Artesian Basin, New Mexico.

Item	Unit of Measurement	Case Farm A	B	C	D	E	F	G	H	I	J	K	L	Average (acres)	(percent)
2.50 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres														
Alfalfa (C)	acres														
Alfalfa (D)	acres	20.55	15.42	19.84	44.51	27.05	62.20	11.32			13.61			17.86	8.5
Grain sorghum	acres	46.05	171.86	68.36		160.45	150.10	110.48	62.69					64.17	30.6
Small grains	acres														
Castor beans	acres									68.43	85.29	39.47	77.48	22.56	10.7
Forage sorghum	acres				167.49									13.96	6.6
Corn silage	acres														
Fallow	acres	25.40							32.92	10.82		12.03	2.32	6.96	3.3
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.00
Net farm return per water-right acre	dollars	127.72	115.22	63.09	96.64	105.60	99.74	89.28	146.51	99.69	102.86	117.93	112.70	106.43	
2.75 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres														
Alfalfa (C)	acres														
Alfalfa (D)	acres	37.41	34.01	28.30	63.32	44.16	87.20	23.32		1.00	22.98		8.72	29.20	13.9
Grain sorghum	acres	29.19	153.27	59.90		143.34	125.10	98.48	80.09					57.45	27.4
Small grains															
Castor beans	acres									78.25	75.92	47.07	71.08	22.69	10.8
Forage sorghum	acres				148.68									12.39	5.9
Corn silage	acres														
Fallow	acres	25.40							15.52			4.43		3.78	1.8
Total		232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.2	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	129.74	117.43	65.72	97.62	106.36	108.81	90.68	152.71	105.56	103.80	124.22	114.23	109.74	
3.00 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres														
Alfalfa (C)	acres														
Alfalfa (D)	acres	54.27	52.61	36.77	82.13	61.28	112.20	35.32	1.34	9.73	32.35		18.84	41.40	19.7
Grain sorghum	acres	12.33	134.67	51.43		126.22	100.10	86.48	94.27					50.46	24.0
Small grains	acres														
Castor beans	acres									69.52	66.55	51.50	60.96	20.71	9.9
Forage sorghum	acres				129.87									10.82	5.2
Corn silage	acres														
Fallow	acres	25.40												2.12	1.0
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	131.76	119.64	68.36	98.61	107.12	115.53	92.09	158.37	106.69	104.75	127.88	114.79	112.13	
3.25 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres														
Alfalfa (C)	acres														
Alfalfa (D)	acres	66.60	71.20	45.24	100.94	78.39	137.20	47.32	13.77	18.45	41.72		28.95	54.15	25.8
Grain sorghum	acres		116.08	42.96		109.11	75.10	74.48	81.84					41.63	19.8
Small grain	acres														
Castor beans	acres									60.80	57.18	51.50	50.85	18.36	8.8
Forage sorghum	acres				111.06									9.25	4.4
Corn silage	acres														
Fallow	acres	25.40												2.12	1.0
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	133.23	121.85	71.00	99.59	107.87	118.61	93.49	159.52	107.81	105.70	127.88	115.36	113.49	
3.50 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres														
Alfalfa (C)	acres														
Alfalfa (D)	acres	66.60	89.80	53.71	119.75	95.51	162.20	59.32	26.20	27.18	51.08		39.06	65.86	31.4
Grain sorghum	acres		97.48	34.49		91.99	50.10	62.48	69.41					33.83	16.1
Small grains	acres														
Castor beans	acres									52.07	47.82	51.50	40.74	16.01	7.6
Forage sorghum	acres				92.25									7.69	3.7
Fallow	acres	25.40												2.12	1.0
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	133.23	124.07	73.63	100.58	108.63	119.26	94.89	160.67	108.94	106.64	127.88	115.92	114.53	
3.75 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres														
Alfalfa (C)	acres														
Alfalfa (D)	acres	66.60	108.39	62.17	138.56	112.62	187.20	71.32	38.63	35.91	60.45		49.18	77.58	37.0
Grain sorghum	acres		78.89	26.03		74.88	25.10	50.48	56.98					26.03	12.4
Small grains	acres														
Castor beans	acres									43.34	38.45	51.50	30.62	13.66	6.5
Forage sorghum	acres				73.44									6.12	2.9
Fallow	acres	25.40												2.12	1.0
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	133.23	126.28	76.27	101.56	109.38	119.90	96.30	161.81	110.06	107.59	127.88	116.49	115.56	
4.00 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres														
Alfalfa (C)	acres														
Alfalfa (D)	acres	66.60	126.99	70.64	157.37	129.74	212.20	83.32	51.05	44.64	69.82		59.29	89.50	42.5
Grain sorghum	acres		60.29	17.56		57.76	0.10	38.48	44.56					18.23	8.7
Small grains	acres														
Castor beans	acres									34.61	29.08	51.50	20.51	11.31	5.4
Forage sorghum	acres				54.63									4.55	2.2
Corn silage	acres														
Fallow	acres	25.40												2.12	1.0
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	133.23	128.49	78.91	102.55	110.14	120.55	97.70	162.92	111.19	108.54	127.88	117.06	116.60	

Table 103. Model A: Linear programming comparison, average of 12 case study farms, Roswell Artesian Basin, New Mexico.

Acre-Feet per Water-Right Acres	Net Return per Water-Right Acre	Linear Programming Solution Minus Whole Farm Budget		Change in Net Return per Water-Right Acre		Difference Between 3.00 Acre-Feet	
	(dollars)	(dollars)	(percent)	(dollars)	(percent)	(dollars)	(percent)
Average Typical Whole Farm Budget							
3.27	91.35					-20.78[1]	-18.5
Linear Programming Solution							
2.50	106.43	15.08	16.5			-5.70	-5.4
				3.31	2.9		
2.75	109.74	18.39	20.1			-2.39	-2.2
				2.39	2.2		
3.00	112.13	20.78	22.7			0.00	0.0
				1.36	1.2		
3.25	113.49	22.14	24.2			1.36	1.2
				1.04	0.9		
3.50	114.53	23.18	24.5			2.40	2.1
				1.03	0.9		
3.75	115.56	24.21	26.5			3.43	3.0
				1.04	0.9		
4.00	116.60	25.25	27.6			4.47	4.0

1. Example: \$91.35 - \$112.13 = -\$20.78.

increased acreage of alfalfa and a slight decrease in grain sorghum, castor beans, forage sorghum, and fallow acreage with cotton acreage unchanged. The optimal cropping program for the average-sized farm with 3.00 acre-feet of irrigation water per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa D on 19.7 percent, grain sorghum on 24.0 percent, castor beans on 9.9 percent, forage sorghum on 5.2 percent, and fallow acreage on 1.0 percent (table 102).

At 3.25 acre-feet of irrigation water per water-right acre, the solutions for model A indicated the average net farm return would be increased 24.2 percent or $22.14 per water-right acre above the typical whole farm budget, and increased 1.2 percent ($1.36) per water-right acre above the optimal solution with 3.00 acre-feet of irrigation water (table 103). The increased return was achieved by an increased acreage of alfalfa and a slight decrease in forage crops, grain sorghum, and castor beans acreage with cotton acreage unchanged. The optimal cropping program for the average-sized farm with 3.25 acre-feet of irrigation water per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa D on 25.8 percent, grain sorghum on 19.8 percent, castor beans on 8.8 percent, forage sorghum on 4.4 percent, and fallow acreage on 1.0 percent (table 102).

At 3.50 acre-feet of irrigation water per water-right acre, the solutions for model A indicated the average net farm return would be increased 25.4 percent or $23.18 per water-right acre above the typical whole farm budget, increased 2.1 percent ($2.40) per water-right acre above the 3.00 acre-feet level, and increased 0.9 percent ($1.04) per water-right acre above the optimal solution with 3.25 acre-feet of irrigation water (table 103). The increased return was achieved by an increased acreage of alfalfa and a slight decrease in the acreage of grain sorghum, castor beans, and forage sorghum with cotton acreage unchanged. The optimal cropping program for the average-sized farm with 3.50 acre-feet of irrigation water per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa D on 31.4 percent, grain sorghum on 16.1 percent, castor beans on 7.6 percent, forage sorghum on 3.7 percent, and fallow acreage on 1.0 percent (table 102).

At 3.75 acre-feet of irrigation water per water-right acre, the solutions for model A indicated the average net farm return would be increased 26.5 percent or $24.21 per water-right acre above the typical whole farm budget, increased 3.0 percent ($3.34) per water-right acre above the 3.00 acre-feet level, and increased 0.9 percent ($1.03) per water-right acre above the optimal solution with 3.75 acre-feet of irrigation water (table 103). The increased return was achieved by an increased acreage of alfalfa and a slight decrease of grain sorghum, castor beans, and forage sorghum with cotton acreage unchanged. The optimal cropping program for the average-sized farm with 3.75 acre-feet of irrigation water per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa D on 37.0 percent, grain sorghum on 12.4 percent, castor beans on 6.5 percent, forage sorghum on 2.9 percent, and fallow acreage on 1.0 percent (table 102).

At 4.00 acre-feet of irrigation water per water-right acre, the solutions for model A indicated the average net farm return would be increased 27.6 percent or $25.25 per water-right acre above the typical whole farm budget, increased 4.00 percent ($4.47) per water-right acre, and 0.9 percent ($1.04) per water-right acre above the optimal solution with 3.75 acre-feet of irrigation water (table 103). The increased return was achieved by an increased acreage of alfalfa and a slight decrease in acreage of the other crops except cotton which remained unchanged. The optimal cropping program for the average-sized farm with 4.00 acre-feet of irrigation water per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa D on 42.5 percent, forage sorghum on 2.2 percent, grain sorghum on 8.7 percent, castor beans on 5.4 percent, and fallow acreage on 1.0 percent (table 102).

The solutions for linear programming model A represented the maximum net farm return that would be expected with different levels of irrigation water under conditions of this study. Model A contained no provisions for a crop rotation program. Although the solutions for this model may be valid for one or more years, crop yields and thus net farm return might be reduced if the optimal cropping program were followed for extended time periods.

Linear Programming--Model B

Linear programming model B did not contain provisions for a crop rotation program but did represent a 5 percent increase in irrigation efficiency above model A on each crop. Solutions for linear programming model B with 2.50 acre-feet of irrigation water per water-right acre indicated the average net return of $109.27 per water-right acre would be obtained if crop enterprises were combined optimally (table 104). The average net return per acre would have been increased 19.6 percent or $17.92 per water-right acre above the typical whole farm budget with the crop enterprises in model B at the 2.50 acre-feet level (table 105). Comparing the 2.50 acre-feet diversion level with 3.00 acre-feet, net farm return would be decreased 3.5 percent ($3.82) per water-right acre.

Table 104. Model B: Linear programming summary of 12 case study farms, Roswell Artesian Basin, New Mexico.

Item	Unit of Measurement	Case Farm A	B	C	D	E	F	G	H	I	J	K	L	Average (acres)	(percent)
2.50 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres														
Alfalfa (C)	acres														
Alfalfa (D)	acres	29.41	25.12	24.30	54.26	36.11	75.51	17.52			18.53		3.83	23.72	11.3
Grain sorghum	acres	37.19	162.16	63.90		151.39	136.79	104.28	71.78					60.61	28.9
Small grains	acres														
Castor beans	acres									74.76	80.37	43.44	75.97	22.88	10.9
Forage sorghum	acres				157.74									13.15	6.3
Corn silage	acres														
Fallow	acres	25.40							23.83	4.49		8.06		5.15	2.4
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	128.78	116.38	64.48	97.15	106.00	117.01	90.01	149.75	103.13	103.35	121.21	113.95	109.27	
2.75 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres														
Alfalfa (C)	acres														
Alfalfa (D)	acres	47.14	44.70	33.21	74.07	54.11	101.82	30.17		5.99	28.39		14.48	36.17	17.2
Grain sorghum	acres	19.46	142.58	54.99		133.39	110.48	91.63	90.05					53.55	25.5
Small grains	acres														
Castor beans	acres									73.26	70.51	51.44	63.32	21.71	10.4
Forage sorghum	acres				137.93									11.49	5.5
Corn silage	acres														
Fallow	acres	25.40							5.56			.06		2.59	1.2
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	130.90	118.70	67.25	98.19	106.80	117.69	91.49	156.26	106.20	104.35	127.83	114.55	111.68	
3.00 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres														
Alfalfa (C)	acres														
Alfalfa (D)	acres	64.88	64.29	42.11	93.88	72.10	128.14	42.82	9.12	15.19	38.25		25.13	49.66	23.7
Grain sorghum	acres	1.72	122.99	46.09		115.40	84.16	78.98	86.49					44.65	21.2
Small grains	acres														
Castor beans	acres									64.06	60.65	51.50	54.67	19.24	9.2
Forage sorghum	acres				118.12									9.84	4.7
Corn silage	acres														
Fallow	acres	25.40												2.12	1.0
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	133.03	121.03	70.03	99.23	107.59	118.37	92.97	159.09	107.39	105.34	127.88	115.14	113.09	
3.25 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres														
Alfalfa (C)	acres														
Alfalfa (D)	acres	66.60	83.87	51.02	113.70	90.10	137.20	55.47	22.22	24.39	48.10		35.79	60.71	28.9
Grain sorghum	acres		103.41	37.18		97.40	75.10	66.33	73.39					37.73	18.0
Small grains	acres														
Castor beans	acres									54.86	50.80	51.50	44.01	16.76	8.0
Forage sorghum	acres				98.30									8.19	3.9
Corn silage	acres														
Fallow	acres	25.40												2.12	1.0
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	133.23	123.36	72.80	100.21	108.39	119.05	94.45	160.30	108.58	106.34	127.88	115.74	114.19	
3.50 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres														
Alfalfa (C)	acres														
Alfalfa (D)	acres	66.60	103.46	59.92	133.51	108.09	180.77	68.11	35.32	33.59	57.96		46.44	74.48	35.5
Grain sorghum	acres		83.82	28.28		79.41	31.53	53.69	60.29					28.08	13.4
Small grains	acres														
Castor beans	acres									45.66	40.94	51.50	33.36	14.29	6.8
Forage sorghum	acres				78.49									6.54	3.1
Corn silage	acres														
Fallow	acres	25.40												2.12	1.0
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	133.23	125.69	75.57	101.30	109.18	119.74	95.93	161.51	109.76	107.34	127.88	116.34	115.29	
3.75 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres														
Alfalfa (C)	acres														
Alfalfa (D)	acres	66.60	123.04	68.83	153.32	126.09	207.09	80.76	48.43	42.79	67.82		57.09	86.82	41.4
Grain sorghum	acres		64.24	19.37		61.41	5.21	41.04	47.18					19.87	9.5
Small grains	acres														
Castor beans	acres									36.46	31.08	51.50	22.71	11.81	5.6
Forage sorghum	acres				58.68									4.89	2.3
Corn silage	acres														
Fallow	acres	25.40												2.12	1.0
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	133.23	128.02	78.35	102.34	109.98	120.42	97.41	162.73	110.95	108.33	127.88	116.93	116.38	
4.00 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres														
Alfalfa (C)	acres														
Alfalfa (D)	acres	66.60	142.63	77.74	173.13	144.08	212.30	93.41	61.53	52.00	77.67		67.75	97.40	46.4
Grain sorghum	acres		44.65	10.46		43.42		28.39	34.08					13.41	6.4
Small grains	acres														
Castor beans	acres									27.25	21.23	51.50	12.05	9.34	4.5
Forage sorghum	acres				38.87									3.24	1.5
Corn silage	acres														
Fallow	acres	25.40												2.12	1.0
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	133.23	130.34	81.12	103.38	110.77	120.56	98.89	163.94	112.14	109.33	127.88	117.53	117.43	

Net returns increased in model B primarily from a larger acreage of planted cotton, and increases in grain sorghum, and castor beans, and a reduction in small grains and alfalfa with cotton acreage unchanged. The optimal combination of crops for the average-sized farm with 2.50 acre-feet of irrigation water available per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa D on 11.3 percent, grain sorghum on 28.9 percent, castor beans on 10.9 percent, forage sorghum on 6.3 percent, and fallow acreage on 2.4 percent (table 104). The economic effect of a 5 percent increase in irrigation efficiency can be determined by comparing solutions from model A with solutions from model B. A 5 percent increase in irrigation efficiency increased the optimal net returns by an average of 2.7 percent ($2.84) per water-right acre at the 2.50 acre-feet level over model A.

At 2.75 acre-feet of irrigation water per water-right acre, the solutions for model B indicated the average net farm return would be increased 22.2 percent or $20.33 per water-right acre above the typical whole farm budget, decreased 1.3 percent ($1.41) per water-right acre below the 3.00 acre-feet level, and increased 2.2 percent ($2.41) per water-right acre above the optimal solution with 2.50 acre-feet of irrigation water (table 105). The increased return was achieved by an increased acreage of alfalfa and a slight decrease in grain sorghum, castor beans, forage sorghum, and fallow acreage with cotton acreage unchanged. The optimal cropping program for the average-sized farm with 2.75 acre-feet of irrigation water per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa D on 17.2 percent, grain sorghum on 25.5 percent, castor beans on 10.4 percent, forage sorghum on 5.5 percent, and fallow acreage on 1.2 percent (table 104). A 5 percent increase in irrigation efficiency increased the optimal net returns by an average of 1.8 percent ($1.94) per water-right acre above model A.

At 3.00 acre-feet of irrigation water per water-right acre, the solutions for model B indicated the average net farm return would be increased 23.8 percent or $21.74 per water-right acre above the typical whole farm budget, and 1.3 percent ($1.41) per water-right acre above the optimal solutions with 2.75 acre-feet of irrigation water (table 105). The increased return was achieved by an increased acreage of alfalfa D and a slight decrease of grain sorghum, castor beans, forage sorghum, and fallow acreage with cotton acreage unchanged. The optimal cropping program for the average-sized farm with 3.00 acre-feet of irrigation water per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa D on 23.7 percent, grain sorghum on 21.2 percent, forage sorghum on 4.7 percent, castor beans on 9.2 percent, and fallow acreage on 1.0 percent (table 104). A 5 percent increase in irrigation efficiency increased the optimal net returns by an average of 0.8 percent ($0.96) per water-

Table 105. Model B: Linear programming comparison, average of 12 case study farms, Roswell Artesian Basin, New Mexico.

Acre-Feet per Water-Right Acres	Net Return per Water-Right Acre	Linear Programming Solution Minus Whole Farm Budget		Change in Net Return per Water-Right Acre		Difference Between 3.00 Acre-Feet	
	(dollars)	(dollars)	(percent)	(dollars)	(percent)	(dollars)	(percent)
Average Typical Whole Farm Budget							
3.27	91.35					-21.74[1]	-19.2
Linear Programming Solution							
2.50	109.27	17.92	19.6			-3.82	-3.5
				2.41	2.2		
2.75	111.68	20.33	22.2			-1.41	-1.3
				1.41	1.3		
3.00	113.09	21.74	23.8			0.00	0.0
				1.10	1.0		
3.25	114.19	22.84	25.0			1.10	1.0
				1.10	1.0		
3.50	115.29	23.94	26.2			2.20	1.9
				1.09	1.0		
3.75	116.38	25.03	27.4			3.29	2.9
				1.05	0.9		
4.00	117.43	26.08	28.5			4.34	3.8

1. Example: $91.35 - $113.09 = -$21.74.

right acre above model A.

At 3.25 acre-feet of irrigation water per water-right acre, the solutions for model B indicated the average net farm return would be increased 25.0 percent or $22.84 per water-right acre above the typical whole farm budget, and 1.0 percent ($1.10) per water-right acre above the optimal solution with 3.00 acre-feet of irrigation water (table 105). The increased return was achieved by an increased acreage of alfalfa D and a slight decrease in the acreages of grain sorghum, castor beans, and forage sorghum with cotton acreage unchanged. The optimal cropping program for the average-sized farm with 3.25 acre-feet of irrigation water per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa D on 28.9 percent, grain sorghum on 18.0 percent, castor beans on 8.0 percent, forage sorghum on 3.9 percent, and fallow acreage on 1.0 percent (table 104). A 5 percent increase in irrigation efficiency increased the optimal net returns by an average of 0.6 percent ($0.70) per water-right acre above model A.

At 3.50 acre-feet of irrigation water per water-right acre, the solutions for model B indicated the average net farm return would be increased 26.2 percent or $23.94 per water-right acre above the typical whole farm budget, increased 1.9 percent ($2.20) per water-right acre above 3.00 acre-feet level, and increased 1.0 percent ($1.10) per water-right acre above the optimal solution with 3.25 acre-feet of irrigation water (table 105). The increased return was achieved by an increased acreage of alfalfa D and a slight decrease of grain sorghum, castor beans, and forage sorghum acreage with cotton acreage unchanged. The optimal cropping program for the average-sized farm with 3.50 acre-feet of irrigation water per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa D on 35.5 percent, grain sorghum on 13.4 percent, castor beans on 6.8 percent, forage sorghum on 3.1 percent, and fallow acreage on 1.0 percent (table 104). A 5 percent increase in irrigation efficiency increased the optimal net returns by an average of 0.7 percent ($0.76) per water-right acre above model A.

At 3.75 acre-feet of irrigation water per water-right acre, the solutions for model B indicated the average net farm return would be increased 27.4 percent or $25.03 per water-right acre above the typical whole farm budget, increased 2.9 percent ($3.29) per water-right acre above the 3.00 acre-feet level, and 1.0 percent ($1.09) per water-right acre above the optimal solution with 3.50 acre-feet of irrigation water (table 105). The increased return was achieved by an increased acreage of alfalfa D and a slight decrease in the acreage of grain sorghum, castor beans, and forage sorghum with cotton acreage unchanged. The optimal cropping program for the average-sized farm with 3.75 acre-feet of irrigation water per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa D on 41.4 percent, grain sorghum on 9.5 percent, castor beans on 5.6 percent, forage sorghum on 2.3 percent, and fallow acreage on 1.0 percent (table 104). A 5 percent increase in irrigation efficiency increased the optimal net returns by an average of 0.7 ($0.82) per water-right acre above model A.

At 4.00 acre-feet of irrigation water per water-right acre, the solutions for model B indicated the average net farm return would be increased 28.5 percent or $26.08 per water-right acre above the typical whole farm budget, increased 3.8 percent ($4.34) per water-right acre above the 3.00 acre-feet level, and 0.9 percent ($1.05) per water-right acre above the optimal solutions with 3.75 acre-feet of irrigation water (table 105). The increased return was achieved by an increased acreage of alfalfa D and a slight decrease in the acreage of grain sorghum, castor beans, and forage sorghum with cotton acreage unchanged. The optimal cropping program for the average-sized farm with 4.00 acre-feet of irrigation water per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa D on 46.4 percent, grain sorghum on 6.4 percent, castor beans on 4.5 percent, forage sorghum on 1.5 percent, and fallow acreage on 1.0 percent (table 104). A 5 percent increase in irrigation efficiency increased the optimal net returns by an average of 0.7 percent ($0.83) per water-right acre above model A.

The solutions for linear programming model B represented the maximum net farm return that would be expected with different levels of irrigation water with a 5 percent increase in irrigation efficiency. Model B contained no provisions for a crop rotation program. Although the solutions for this model may be valid for one or more years, crop yields and thus net farm return may be reduced if the optimal cropping program were followed for extended time periods.

Linear Programming--Model C

Linear programming model C did contain provisions for a crop rotation program, with a minimum of about 30 percent of each farm producing alfalfa. The solutions for linear programming model C with 2.50 acre-feet of irrigation water per water-right acre indicated the average net return of $85.49 per water-right acre would be obtained if crop enterprises were combined optimally (table 106). The average net return per acre would have been decreased 6.4 percent or $5.86 per water-right acre below the typical whole farm budget with the crop enterprises in model C at the 2.50 acre-feet level. Comparing the 2.50 acre-feet diversion level with 3.00 acre-feet, net farm return would be decreased 16.4 percent ($16.81) per water-right acre (table 107). Net returns decreased primarily because a larger percent of the average typical farm was left fallow (21.7

percent) due to the provisions that 32.2 percent of the water-right acres be in alfalfa. The optimal combination of crops for the average-sized farm with 2.50 acre-feet of irrigation water available per water-right acre required the production of cotton on 32.2 percent of the water-right acres, diverted acres on 8.0 percent, alfalfa on 32.2 percent, grain sorghum on 3.7 percent, castor beans on 0.5 percent, forage sorghum on 1.7 percent, and fallow on 21.7 percent (table 106).

The economic effect of forcing in a crop rotation of about 30 percent of the average-sized farm into alfalfa can be estimated by comparing solutions from model A with solutions from model C. Net returns would be reduced by 24.5 percent ($20.94) per water-right acre at the 2.50 acre-feet level.

At 2.75 acre-feet of irrigation water per water-right acre, the solutions for model C indicated the average net farm return would be increased 3.2 percent or $2.96 per water-right acre above the typical whole farm budget, decreased 7.8 percent ($7.99) per water-right acre below the 3.00 acre-feet level,and 10.3 percent ($8.82) per water-right acre above the optimal solution with 2.50 acre-feet of irrigation water. The increased return was achieved primarily by an increased acreage of planted cotton and a decrease in fallow acreage. The optimal cropping program for the average-sized farm with 2.75 acre-feet of irrigation water per water-right acre required the production of cotton on 34.9 percent of the water-right acres, diverted acres on 5.3 percent, alfalfa on 32.1 percent, grain sorghum on 5.3 percent, castor beans on 1.4 percent, forage sorghum on 5.5 percent, corn silage on 2.1 percent, and fallow acreage on 13.4 percent (table 106). The economic effect of forcing in a crop rotation would be a reduction in net returns by 16.4 percent ($15.43) per water-right acre.

At 3.00 acre-feet of irrigation water per water-right acre, the solutions for model C indicated that the average net farm return would be increased 12.0 percent or $10.95 per water-right acre above the typical whole farm budget and 8.5 percent ($7.99) per water-right acre above the optimal solutions with 2.75 acre-feet of irrigation water (table 107). The increased return was achieved primarily by an increased acreage of cotton 95 and a decrease in the fallow acreage. The optimal cropping program for the average-sized farm with 3.00 acre-feet of irrigation water per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa D on 32.2 percent, grain sorghum on 8.2 percent, castor beans on 2.2 percent, forage sorghum on 9.4 percent, and fallow acreage on 7.8 percent (table 106). The economic effect of forcing in a crop rotation would be a reduction in net return by 9.6 percent ($9.83) per water-right acre.

Table 106. Model C: Linear programming summary of 12 case study farms, Roswell Artesian Basin, New Mexico.

Item	Unit of Measurement	Case Farm A	B	C	D	E	F	G	H	I	J	K	L	Average (acres)	(percent)
2.50 Acre-feet per Water-right Acre															
Cotton (65)	acres	140.00		70.30		92.50			78.39			27.50	71.90	40.05	19.1
Cotton (80)	acres									42.95				3.58	1.7
Cotton (95)	acres		91.62		91.70		187.70	65.40			52.50			40.74	19.4
Alfalfa (A)	acres	2.61	12.55	25.55	100.00	92.00	48.64		44.06	23.75	50.00		44.28	36.96	17.6
Alfalfa (B)	acres	63.99						62.00						10.50	5.0
Alfalfa (C)	acres		79.45				83.36		6.94	16.25		24.00	5.72	17.98	8.6
Alfalfa (D)	acres			26.45										2.20	1.0
Grain sorghum	acres					69.33		23.54						7.74	3.7
Small grains	acres														
Castor beans	acres										10.37	1.80		1.01	0.5
Forage sorghum	acres				42.53									3.54	1.7
Corn silage	acres														
Fallow	acres	25.40	95.28	36.20	69.47	26.17	80.30	36.26	44.61	39.25	38.53	25.70	29.80	45.58	21.7
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	109.05	98.35	56.56	79.42	87.77	99.74	75.02	109.97	72.27	76.78	83.50	77.43	85.49	
2.75 Acre-feet per Water-right Acre															
Cotton (65)	acres			70.30										5.86	2.8
Cotton (80)	acres	140.00				92.50			78.39			27.50	71.90	34.19	16.3
Cotton (95)	acres		91.62		91.70		187.70	65.40		42.95	52.50			44.32	21.1
Alfalfa (A)	acres			2.38	100.00	92.00			44.71	13.31	50.00		35.30	28.14	13.4
Alfalfa (B)	acres	62.11						62.00						10.34	4.9
Alfalfa (C)	acres		92.00				132.00		6.29	26.69		24.00	14.70	24.64	11.7
Alfalfa (D)	acres	4.49		49.62										4.51	2.1
Grain sorghum	acres					87.12		45.83						11.08	5.3
Small grains	acres														
Castor beans	acres										29.68	3.68		2.78	1.4
Forage sorghum	acres		53.24		85.06									11.53	5.5
Corn silage	acres						52.91							4.41	2.1
Fallow	acres	25.40	42.04	36.20	26.94	8.38	27.39	13.97	44.61	39.25	19.22	23.82	29.80	28.08	13.4
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	119.24	106.48	62.33	87.96	96.57	108.81	81.04	123.14	81.11	85.29	94.25	85.48	94.31	
3.00 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres			13.74	20.34	72.74			45.35		49.76		26.31	19.02	9.1
Alfalfa (B)	acres	55.79						48.46						8.69	4.1
Alfalfa (C)	acres		56.96		79.66	19.26	118.21	13.54	5.65	11.69	0.24	24.00	23.69	29.41	14.0
Alfalfa (D)	acres	10.81	35.04	38.26			13.79			28.31				10.52	5.0
Grain sorghum	acres					95.50	80.30	59.80						19.63	9.4
Small grains	acres														
Castor beans	acres										48.90	5.46		4.53	2.2
Forage sorghum	acres		95.28		112.00									17.27	8.2
Corn silage	acres														
Fallow	acres	25.40		36.20					44.61	39.25		22.04	29.80	16.44	7.8
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	128.75	114.07	66.14	95.70	103.76	115.53	86.35	136.32	88.69	93.86	104.92	93.52	102.30	
3.25 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres							12.18						1.01	0.5
Alfalfa (C)	acres					83.07		49.82	51.00		49.95	24.00	50.00	25.65	12.2
Alfalfa (D)	acres	66.60	92.00	52.00	100.94	8.93	137.20			40.00	0.05			41.48	19.8
Grain sorghum	acres		27.44	12.22		95.50	75.10	59.80	6.15					23.02	11.0
Small grains	acres														
Castor beans	acres									9.09	48.90	13.06	9.60	6.72	3.2
Forage sorghum	acres		67.84		111.06									14.91	7.1
Corn silage	acres														
Fallow	acres	25.40		23.98					38.46	30.16		14.44	20.20	12.72	6.0
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.40	209.88	100.0
Net farm return per water-right acre	dollars	133.23	119.70	70.76	99.60	106.74	118.56	90.50	144.85	95.15	100.74	111.22	101.26	107.69	
3.50 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres														
Alfalfa (C)	acres							15.61	51.00			24.00	50.00	11.72	5.6
Alfalfa (D)	acres	66.60	92.00	53.70	119.75	95.51	162.20	46.39		40.00	51.08			60.60	28.9
Grain sorghum	acres		88.08	34.50		91.99	50.10	59.80	23.55					29.00	13.8
Small grains	acres														
Castor beans	acres									21.31	47.82	20.66	26.46	9.69	4.6
Forage sorghum	acres		7.20		92.25									8.29	3.9
Corn silage	acres														
Fallow	acres	25.40							21.06	17.94		6.84	3.34	6.21	3.0
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	133.23	123.84	73.63	100.58	108.63	119.26	94.38	151.05	101.40	106.64	117.51	108.83	111.58	
3.75 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres														
Alfalfa (C)	acres								51.00			21.08	4.61	6.39	3.0
Alfalfa (D)	acres	66.60	108.38	62.17	138.56	112.62	187.20	71.32		40.00	60.45	2.92	45.39	74.63	35.6
Grain sorghum	acres		78.90	26.03		74.88	25.10	50.48	40.95					24.70	11.8
Small grains	acres														
Castor beans	acres									33.53	38.45	27.50	29.80	10.77	5.1
Forage sorghum	acres				73.44									6.12	2.9
Corn silage	acres														
Fallow	acres	25.40							3.66	5.72				2.90	1.4
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	133.23	126.28	76.27	101.56	109.38	119.90	96.30	157.25	107.66	107.59	123.72	115.96	114.59	
4.00 Acre-feet per Water-right Acre															
Cotton (65)	acres														
Cotton (80)	acres														
Cotton (95)	acres	140.00	91.62	70.30	91.70	92.50	187.70	65.40	78.39	42.95	52.50	27.50	71.90	84.37	40.2
Alfalfa (A)	acres														
Alfalfa (B)	acres														
Alfalfa (C)	acres														
Alfalfa (D)	acres	66.60	126.99	70.64	157.37	129.74	212.20	83.32	51.05	44.64	69.82	24.00	59.29	91.30	43.5
Grain sorghum	acres		60.29	17.56		57.76	0.10	38.48	44.56					18.23	8.7
Small grains	acres														
Castor beans	acres									34.61	29.08	27.50	20.51	9.31	4.4
Forage sorghum	acres				54.63									4.55	2.2
Corn silage	acres														
Fallow	acres	25.40												2.12	1.0
Total	acres	232.00	278.90	158.50	303.70	280.00	400.00	187.20	174.00	122.20	151.40	79.00	151.70	209.88	100.0
Net farm return per water-right acre	dollars	133.23	128.49	78.91	102.55	110.14	120.55	97.70	162.97	111.19	108.54	127.71	117.06	116.59	

Table 107. Model C: Linear programming comparison, average of 12 case study farms, Roswell Artesian Basin, New Mexico.

Acre-Feet per Water-Right Acres	Net Return per Water-Right Acre	Linear Programming Solution Minus Whole Farm Budget		Change in Net Return per Water-Right Acre		Difference Between 3.00 Acre-Feet	
	(dollars)	(dollars)	(percent)	(dollars)	(percent)	(dollars)	(percent)
Average Typical Whole Farm Budget							
3.27	91.35					-10.95[1]	-10.7
Linear Programming Solution							
2.50	85.49	- 5.86	- 6.4			-16.81	-16.4
				8.82	10.3		
2.75	94.31	2.96	3.2			- 7.99	- 7.8
				7.99	8.5		
3.00	102.30	10.95	12.0			0.00	0.0
				5.39	5.3		
3.25	107.69	16.34	17.9			5.39	5.3
				3.89	3.6		
3.50	111.58	20.23	22.1			9.82	9.1
				3.01	2.7		
3.75	114.59	23.25	25.4			12.29	12.0
				2.00	1.7		
4.00	116.59	25.24	27.6			14.29	14.0

1. Example: \$91.35 - \$102.30 = -\$10.95.

At 3.25 acre-feet of irrigation water per water-right acre, the solutions for model C indicated the average net farm return would be increased 17.9 percent or $16.34 per water-right acre above the typical whole farm budget, and 5.3 percent ($5.39) per water-right acre above the optimal solutions with 3.00 acre-feet of irrigation water (table 107). The increased return was achieved by an increased acreage of grain sorghum and castor beans and a decrease in fallow and forage sorghum acreage with cotton acreage unchanged. The optimal cropping program for the average-sized farm with 3.25 acre-feet of irrigation water per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa on 32.5 percent, grain sorghum on 11.0 percent, castor beans on 3.2 percent, forage sorghum on 7.1 percent, and fallow acreage on 6.0 percent (table 106). The economic effect of forcing in a crop rotation would be a reduction in net returns by 5.4 percent ($5.80) per water-right acre.

At 3.50 acre-feet of irrigation water per water-right acre, the solutions for model C indicated the average net farm return would be increased 22.1 percent or $20.23 per water-right acre above the typical whole farm budget, increased 9.1 percent ($9.82) per water-right acre above the 3.00 acre-feet level, and 3.6 percent ($3.89) per water-right acre above the optimal solutions with 3.25 acre-feet of irrigation water (table 107). The increased return was achieved by an increased acreage of alfalfa D, grain sorghum, and fallow with cotton acreage unchanged. The optimal cropping program for the average-sized farm with 3.50 acre-feet of irrigation water per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa on 34.5 percent, grain sorghum on 13.8 percent, castor beans on 4.6 percent, forage sorghum on 3.9 percent, and fallow acreage on 3.0 percent (table 106). The economic effect of forcing in a crop rotation would be a reduction in net returns by 2.6 percent ($2.95) per water-right acre.

At 3.75 acre-feet of irrigation water per water-right acre, the solutions for model C indicated the average net farm return would be increased 25.4 percent or $23.25 per water-right acre above the typical whole farm budget, increased 12.0 percent ($12.29) per water-right acre above the 3.00 acre-feet level, and increased 2.7 percent ($3.01) per water-right acre above the optimal solution with 3.50 acre-feet of irrigation water (table 107). The increased return was achieved by an increased acreage of alfalfa D and castor beans and a decreased acreage of alfalfa C and grain and forage sorghums with cotton acreage unchanged. The optimal cropping program for the average-sized farm with 3.75 acre-feet of irrigation water per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa on 38.6 percent, grain sorghum on 11.8 percent, castor beans on 5.1 percent, forage sorghum on 2.9 percent, and fallow acreage on 1.4 percent. The economic effect of forcing in a crop rotation would be a reduction in net returns by 0.8 percent ($0.97) per water-right acre.

At 4.00 acre-feet of irrigation water per water-right acre, the solutions for model C indicated the average net farm return would be increased 27.6 percent or $25.24 per water-right acre above the typical whole farm budget, increased 14.0 percent ($14.29) per water-right acre above the 3.00 acre-feet level, and increased 1.7 percent ($2.00) per water-right acre above the optimal solution with 3.75 acre-feet of irrigation water (table 107). The increased return was achieved by an increased acreage of alfalfa D and a slight decrease in acreage of grain sorghum, castor beans, forage sorghum, and fallow with cotton acreage unchanged. The optimal cropping program for the average-sized farm with 4.00 acre-feet of irrigation water per water-right acre required the production of cotton on 38.2 percent of the water-right acres, diverted acres on 2.0 percent, alfalfa D on 43.5 percent, grain sorghum on 8.7 percent, castor beans on 4.4 percent, forage sorghum on 2.2 percent, and fallow acreage on 1.0 percent (table 106). There would be virtually no economic effect of forcing in a crop roation at 4.00 acre-feet per water-right acre.

The results obtained from the three linear programming models are graphically summarized in figure 30. This graph indicates the effects of seven quantities of irrigation water on net farm returns. In models A and B, as irrigation water is increased from 524.70 acre-feet to 629.64 acre-feet (2.50 to 3.00 acre-feet per water-right acre) net farm return increases at almost a constant rate. From 629.64 to 839.52 acre-feet (3.00 to 4.00 acre-feet per water-right acre) the rate of increase is at a lower constant rate for models A and B.

In model C, as irrigation water is increased from 524.70 acre-feet to 629.64 acre-feet (2.50 to 3.00 acre-feet per water-right acre), the net farm return increases at almost a constant rate. From 629.64 to 734.58 acre-feet (3.00 to 3.50 acre-feet per water-right acre) the net farm return increases at a lower rate, and from 734.58 to 839.52 acre-feet (3.50 to 4.00 acre-feet) the net farm return increases at a lower rate.

Optimal Quantity of Irrigation Water

The shadow prices (marginal value products) for an additional acre-foot of irrigation water are presented in table 108. The optimal level of irrigation water diversion for each model can be determined by equating the shadow price with the cost of pumping an acre-foot of irrigation water, which was $7.68. An economically rational farmer would continue to pump irrigation water until the

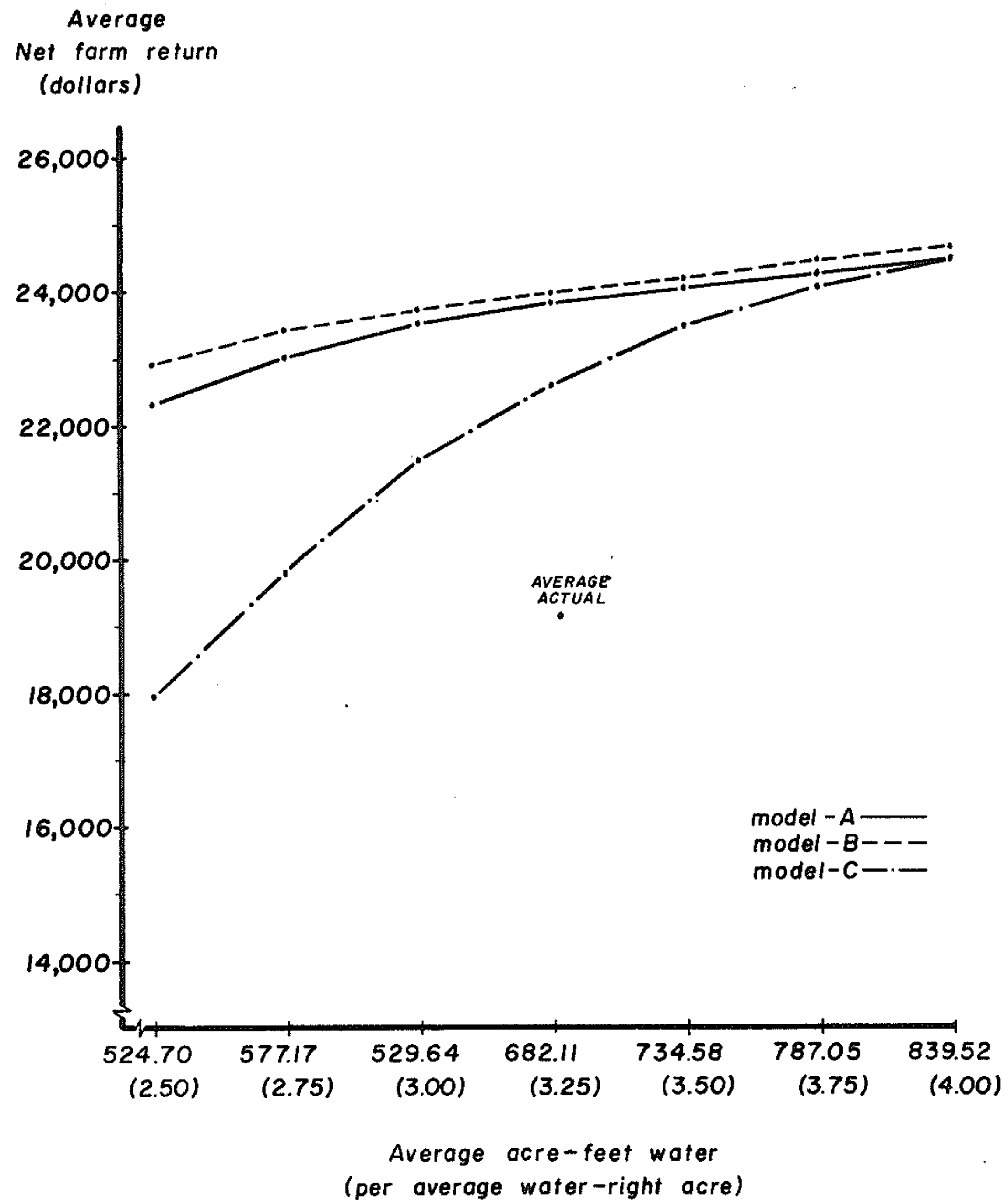


Figure 30. Average net farm return for seven quantities of irrigation water of 12 case study farms, Roswell Artesian Basin, New Mexico.

last acre-foot pumped generates enough additional net return to just pay for the cost of pumping that acre-foot of water. This is the point of maximum profit with respect to irrigation water. The average optimal quantity of irrigation water that would maximize net farm return on the 12 case study farms was between 577.17 and 629.64 acre-feet (2.75 acre-feet and 3.00 acre-feet per water-right acre) in models A and B (table 108). The average shadow prices for model A at the 577.17 and 629.64 acre-feet diversion level (2.75 acre-feet and 3.00 acre-feet per water-right acre) were $8.58 and $4.80 respectively (table 108). Somewhere between the 577.17 and 629.64 acre-feet diversion level the shadow price for an additional acre-foot of irrigation water for the whole farm is equal to $7.68, (the cost of an acre-foot of irrigation water) which is the profit maximizing point with respect to irrigation water. The average shadow prices for model B at the 577.17 and 629.64 acre-feet diversion level (2.75 acre-feet and 3.00 acre-feet per water-right acre) were $9.03 and $5.06 respectively (table 108). Somewhere between the 577.17 and 629.64 acre-feet diversion level the shadow price for an additional acre-foot of irrigation water for the whole farm is equal to $7.68, which is the profit maximizing point with respect to irrigation water. In model C the average optimal quantity of irrigation water was between 787.05 and 839.52 acre-feet (3.75 and 4.00 acre-feet per water-right acre) (table 108). The average shadow prices for model C at the 787.05 and 839.52 acre-feet diversion level (3.75 acre-feet and 4.00 acre-feet per water-right acre) were $11.54 and $4.13 respectively (table 108). Somewhere between the 787.05 and 839.52 acre-feet diversion level the shadow price for an additional acre-foot of irrigation water for the whole farm is equal to $7.68, which is the profit maximizing point with respect to irrigation water. The primary reason for the higher optimal irrigation water diversion level for model C was the requirement that about 30 percent of the water-right acres be in alfalfa. This forced cropland to be left fallow at the lower levels of diversion. Fallow acreage accounted for about 22 percent of the water-right acres at the 2.50 acre-feet diversion level, 13 percent at the 2.75 acre-feet level, 8 percent at the 3.00 acre-feet level, 6 percent at the 3.25 acre-feet level, and 3 percent at the 3.50 acre-feet level.

At the irrigation water diversion of 3.00 acre-feet per water-right acre, net return per water-right acre is not affected in models A and B because the optimal quantity was between 2.75 and 3.00 acre-feet per water-right acre. In model C at the irrigation water diversion of 629.64 acre-feet (3.00 acre-feet per water-right acre) instead of the average optimal quantity of 787.05 and 839.52 acre-feet (3.75 and 4.00 acre-feet per water-right acre) the net return is reduced between 12 and 14 percent ($12.29 and $14.29) per water-right acre. For the average-sized farm in this study (209.88 acres) net farm returns are reduced between $2,600 and $3,000.

Table 108: Shadow price summary for seven quantities of irrigation water diversions of 12 case study farms, Roswell Artesian Basin, New Mexico.

Quantity of Irrigation Water Diverted		Shadow Price (Marginal value product for one additional acre-foot of irrigation water)												
		Case Farm												
		A	B	C	D	E	F	G	H	I	J	K	L	Average[1]
(ac-ft)	(ac-ft per ac)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)	(dollars)
Model A														
524.70	2.50	8.06	8.84	10.55	3.82	3.02	2.66	5.62	24.80	25.03	3.79	25.15	30.26	12.63
577.17	2.75	8.06	8.84	10.55	3.82	3.02	2.60	5.62	24.80	4.50	3.79	25.15	2.26	8.58[2]
629.64	3.00	8.06	8.84	10.55	3.82	3.02	2.60	5.62	4.60	4.50	3.79	0.00	2.26	4.80
682.11	3.25	0.00	8.84	10.55	3.82	3.02	2.60	5.62	4.60	4.50	3.79	0.00	2.26	4.13
734.58	3.50	0.00	8.84	10.55	3.82	3.02	2.60	5.62	4.60	4.50	3.79	0.00	2.26	4.13
787.05	3.75	0.00	8.84	10.55	3.82	3.02	2.60	5.62	4.60	4.50	3.79	0.00	2.26	4.13
839.52	4.00	0.00	8.84	10.55	3.82	3.02	2.60	5.62	4.60	4.50	3.79	0.00	2.26	4.13
Model B														
524.70	2.50	8.48	9.31	11.09	4.03	3.18	2.73	5.92	26.05	26.29	3.98	26.48	2.38	10.83
577.17	2.75	8.48	9.31	11.09	4.03	3.18	2.73	5.92	26.05	4.75	3.98	26.48	2.38	9.03[2]
629.64	3.00	8.48	9.31	11.09	4.03	3.18	2.73	5.92	4.84	4.75	3.98	0.00	2.38	5.06
682.11	3.25	0.00	9.31	11.09	4.03	3.18	2.73	5.92	4.84	4.75	3.98	0.00	2.38	4.35
734.58	3.50	0.00	9.31	11.09	4.03	3.18	2.73	5.92	4.84	4.75	3.98	0.00	2.38	4.35
787.05	3.75	0.00	9.31	11.09	4.03	3.18	2.73	5.92	4.84	4.75	3.98	0.00	2.38	4.35
839.52	4.00	0.00	9.31	11.09	4.03	3.18	0.00	5.92	4.84	4.75	3.98	0.00	2.38	4.12
Model C														
524.70	2.50	41.92	35.87	23.06	33.11	36.56	39.39	26.06	52.58	35.94	34.05	48.91	31.94	36.54
577.17	2.75	39.26	31.88	23.06	33.11	33.85	34.92	24.06	52.58	33.89	34.05	48.04	31.94	35.05
629.64	3.00	24.53	27.40	17.82	24.78	12.20	14.88	16.58	39.21	28.13	27.78	25.15	31.94	24.20
682.11	3.25	0.00	16.56	11.77	3.82	8.73	2.60	16.58	24.80	25.03	26.19	25.15	30.26	15.96
734.58	3.50	0.00	16.56	10.55	3.82	3.02	2.60	14.97	24.80	25.03	3.79	25.15	30.26	13.38
787.05	3.75	0.00	8.84	10.55	3.82	3.02	2.60	5.62	24.80	25.03	3.79	22.31	28.10	11.54[2]
839.52	4.00	0.00	8.84	10.55	3.82	3.02	2.60	5.62	4.60	4.50	3.79	0.00	2.26	4.13

1. When values are greater than \$7.68 (cost of one acre-foot of irrigation water) it is profitable to increase irrigation water diversion, when values are less than \$7.68 it is profitable to decrease irrigation water diversion until shadow price is equal to \$7.68.
2. Optimal quantity of irrigation water.

Table 109. Comparison of average typical cropping program with models A, B, and C at 3.25 acre-feet of irrigation water diversion per water-right acre, Roswell Artesian Basin, New Mexico.

		Cropping Program				
Item	Unit of Measurement	Average of Roswell Artesian Basin, 1967	Average of 12 Case Study Farms	Model A	Model B	Model C
Crops						
Cotton planted	percent	23.1	32.5	38.2	38.2	38.2
Cotton diverted	percent		7.5	2.0	2.0	2.0
Alfalfa (A and B)	percent	39.6	42.9	0.0	0.0	0.5
Alfalfa (C)	percent	0.0	0.0	0.0	0.0	12.2
Alfalfa (D)	percent	0.0	0.0	25.8	28.9	19.8
Forage sorghum	percent	4.9[1]	2.0	4.4	3.9	7.1
Corn silage	percent		6.1	0.0	0.0	0.0
Grain sorghum	percent	3.5	4.0	19.8	18.0	11.0
Small grains	percent	6.4	13.7	0.0	0.0	0.0
Castor beans	percent	0.0[2]	0.0	8.8	8.0	3.2
Miscellaneous[3]	percent	2.5	0.0	0.0	0.0	0.0
Fallow	percent	20.0[4]	3.3	1.0	1.0	6.0
Total	percent	100.0	112.0[5]	100.0	100.0	100.0
Net return per water-right acre	dollars		91.35	113.40	114.19	107.69

1. Corn silage included with forage sorghum.
2. Less than 0.1 percent.
3. Includes irrigated pasture, pecans, soybeans, fruits, and vegetables.
4. Includes diverted acres and out of production.
5. Does not add up to 100.0 percent because of double cropping.

Since the 12 case study farms appeared to be typical of the farms in the Roswell Artesian Basin, the net returns in the basin would not appear to be maximized under existing cropping programs and irrigation water use. In general, net farm returns would be increased with the implementation of different cropping programs. A comparison of the typical whole farm budget (3.27 acre-feet per water-right acre) to the optimal cropping programs at the 3.25 acre-feet levels in each of the models A, B, and C reflect increased net returns per water-right acre under the optimal cropping programs as follows: model A, 24.2 percent ($22.14); model B, 25.0 percent ($22.84); and model C, 17.9 percent ($16.34). These increased net returns were generated with larger percentages of the water-right acres planted to cotton, increased acreages of such crops as grain sorghum, castor beans, or forage sorghum and decreased acreages of alfalfa, small grains, and fallow (table 109, figure 30). However, the smaller acreage of alfalfa would be produced on a more intensive basis.

A comparison of the whole farm budget (3.27 acre-feet per water-right acre) to the optimal cropping programs at the 3.00 acre-feet levels in each of the models, A, B, and C reflects increased net returns per water-right acre under the optimal cropping programs as follows: model A, 22.7 percent ($20.78); model B, 23.8 percent ($21.74); and model C, 12.0 percent ($10.95). These increased net returns were generated with larger percentages of the water-right acres planted to cotton, increased acreages of such crops as grain sorghum, castor beans, or forage sorghum and decreased acreages of alfalfa, corn silage, and small grains (table 110).

Table 110. Comparison of average typical cropping program with models A, B, and C at 3.00 acre-feet of irrigation water diversion per water-right acre.

Item	Cropping Program: Average of 12 Case Study Farms	Model A	Model B	Model C
Crops	Percent			
Cotton planted	32.5	38.2	38.2	38.2
Cotton diverted	7.5	2.0	2.0	2.0
Alfalfa (A and B)	42.9	0.0	0.0	13.2
Alfalfa (C)	0.0	0.0	0.0	14.0
Alfalfa (D)	0.0	19.7	23.7	5.0
Forage sorghum	2.0	5.2	4.7	8.2
Corn silage	6.1	0.0	0.0	0.0
Grain sorghum	4.0	24.0	21.2	9.4
Small grains	13.7	0.0	0.0	0.0
Castor beans	0.0	9.9	9.2	2.2
Fallow	3.3	1.0	1.0	7.8
Total	112.0[1]	100.0	100.0	100.0
Net return per water-right acre	Dollars			
	91.35	112.13	113.09	102.30

1. Does not add up to 100.0 percent because of double cropping.

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APPENDIX A - SOILS

Table A1. Soils on case study farms by capability classes, Roswell Artesian Basin, New Mexico.

SCS Map Symbol	Soil Name	Capability Class	Description
140 190 3321/A-1 3321/A	Harkey Loam Reagan Loam	I I	Loamy soils for 36 inches or more. Good water intake rate; high water-holding capacity of about 6 inches. Suitable for growing all crops adapted to the climate. Need only good management practices to maintain productivity. Slopes less than 1 foot per 100 feet.
3331/A-0 3321/A-0 A	Reagan Loam Reagan Silty Loam	I Ib	Moderately deep sand soils with medium-textured, moderately permeable subsoils. Moderate readily available moisture capacity. Susceptible to wind erosion.
3321/A-0	Reagan Loam	Ib	Deep, highly calcareous, loamy soils with medium-textured, moderately permeable subsoils; 0-1% slopes.
3321/2B-1	Reagan Loam 1-3%	IIe-1	Deep, highly calcareous, loamy soils with medium-textured, moderately permeable subsoils; 1-3% slopes.
4331/A-0	Vinton Loamy Fine Sand	IIe-4	Deep, loamy soils with fine-textured, very slowly permeable subsoils. High readily available moisture capacity. Fine-textured subsoil restricts air and water movement.
160 3321/A 3221/A-1 3321/A-1 3321/A	Balmorrhea Silty Clay Loam Reagan Silt Loam Rustler Silt Loam	IIs-1 IIs-1 IIs-1	Deep soils, over 36 inches, with clay loam and silty surface soils and silty or clayey subsoils. Water intake rates slow; may be decreased by puddling if worked or grazed wet. Slopes less than 1 foot per 100 feet. Hold 5 to 6 inches of water. High productivity under good management.
2221/A-0	Reagan Silty Clay Loam	IIs-2	Deep, loamy soils with medium-textured, moderately permeable subsoils. High readily available moisture capacity.
2221/A	Unnamed Silt Loam	IIs-5	Deep, loamy surface soils, with fine-textured, slowly permeable subsoils. High water-holding capacity of about 6 inches. Suitable for growing all crops adapted to the climate. Good management practices maintain productivity. Nearly level.
200 250	Reeves Loam Atoka Loam	IIs-14 IIs-14	Moderately deep, loamy soils with medium-textured, moderately or slowly permeable subsoils. Underlain by caliche, gypsum, or silica hardpan between 20-36". Moderate, readily available moisture capacity. Salt problems with gypsum soils.
33F2/B	Atoka Loam	IIIe-2	Moderately deep, loamy soils with medium-textured, moderately or slowly permeable subsoils. Underlain by caliche, gypsum, or silica hardpan between 20-36". Moderate, readily available moisture capacity. Salt problems with gypsum soils. Slopes from 1 to 3 feet per 100 feet.
204	Reeves Loam	IVs-3	Shallow, loamy soils with medium-textured, moderately permeable subsoils underlain by caliche or gypsum at 10-20". Low, readily available moisture capacity. When gypsum is present, salty conditions may occur.
33F3/A-0 03F/B 112 120	Cave Gravelly Loam Cave Gravelly Loam Cave Gravelly Loam Cottonwood Loam	IVs-3 VIIs VIIs VIIs	Soils that have very severe continuing limitations that make them unsuitable for cultivation. Limiting factors may be one or more of the following: stones, shallow, salts, low water-holding capacity, and insufficient moisture.

APPENDIX B - CROP ENTERPRISES

Table B1. Alternative crop enterprises included in linear programming models

Case Farm	Crop	Acre Feet Per Acre		Net Return Per Acre
		Models A and C	Model B	
A	Cotton (65)	1.66	1.58	$153.85
	Cotton (80)	2.04	1.94	169.78
	Cotton (95)	2.42	2.30	184.70
	Alfalfa (A)	4.71	4.47	38.05
	Alfalfa (B)	5.24	4.98	57.21
	Alfalfa (C)	5.33	5.06	58.83
	Alfalfa (D)	6.00	5.70	75.85
	Grain Sorghum	2.56	2.43	48.11
	Barley	1.04	0.99	0.68
B	Cotton (65)	1.63	1.55	$186.30
	Cotton (80)	2.01	1.91	210.43
	Cotton (95)	2.38	2.26	234.57
	Alfalfa (A)	4.44	4.22	36.98
	Alfalfa (B)	0.00	0.00	0.00
	Alfalfa (C)	5.33	5.06	68.90
	Alfalfa (D)	6.00	5.70	87.26
	Grain Sorghum	2.25	2.14	54.11
	Forage Sorghum	1.10	1.05	35.07
	Barley	2.14	2.03	9.76
C	Cotton (65)	1.82	1.73	$ 93.86
	Cotton (80)	2.24	2.13	101.34
	Cotton (95)	2.66	2.53	108.83
	Alfalfa (A)	4.29	4.08	25.46
	Alfalfa (B)	0.00	0.00	0.00
	Alfalfa (C)	5.33	5.06	41.57
	Alfalfa (D)	6.00	5.70	64.89
	Grain Sorghum	1.32	1.25	15.53
	Forage Sorghum	2.05	1.95	-23.10
	Barley	1.40	1.33	-12.83
D	Cotton (65)	1.55	1.47	$142.67
	Cotton (80)	1.90	1.81	157.07
	Cotton (95)	2.26	2.15	171.48
	Alfalfa (A)	4.97	4.72	58.05
	Alfalfa (B)	0.00	0.00	0.00
	Alfalfa (C)	5.33	5.06	66.97
	Alfalfa (D)	6.00	5.70	76.84
	Corn Silage	1.97	1.87	45.46
	Sudex	1.84	1.75	60.93
	Grain Sorghum	2.30	2.19	58.57
	Barley	1.99	1.89	12.40
	Hegari	1.08	1.02	22.63

Table B1. Alternative crop enterprises included in linear programming models, continued

Case Farm	Crop	Acre Feet Per Acre		Net Return Per Acre
		Models A and C	Model B	
E	Cotton (65)	1.71	1.62	$148.10
	Cotton (80)	2.10	2.00	161.30
	Cotton (95)	2.50	2.38	174.50
	Alfalfa (A)	4.45	4.23	65.61
	Alfalfa (B)	0.00	0.00	0.00
	Alfalfa (C)	5.33	5.06	76.35
	Alfalfa (D)	6.00	5.70	82.20
	Grain sorghum	1.91	1.81	69.83
	Barley	1.99	1.89	12.11
F	Cotton (65)	1.19	1.13	$127.63
	Cotton (80)	1.46	1.39	140.24
	Cotton (95)	1.74	1.65	152.86
	Alfalfa (A)	4.71	4.47	38.10
	Alfalfa (B)	1.30	1.24	6.02
	Alfalfa (C)	5.33	5.06	62.52
	Alfalfa (D)	6.00	5.70	72.49
	Corn silage	1.32	1.25	46.10
	Grain sorghum	2.00	1.90	62.11
	Barley	0.30	0.29	2.28
	Oats	1.79	1.70	7.79
G	Cotton (65)	1.76	1.67	$130.28
	Cotton (80)	2.16	2.05	143.97
	Cotton (95)	2.57	2.44	157.66
	Alfalfa (A)	4.71	4.47	37.99
	Alfalfa (B)	4.04	3.84	38.03
	Alfalfa (C)	5.33	5.06	62.41
	Alfalfa (D)	6.00	5.70	72.44
	Grain sorghum	2.10	2.00	50.53
	Barley	1.61	1.53	6.72
	Oats	1.51	1.43	36.40
	Rye	0.45	0.43	-8.08
H	Cotton (65)	2.43	2.31	$216.74
	Cotton (80)	2.99	2.84	246.18
	Cotton (95)	3.55	3.37	275.63
	Alfalfa (A)	4.71	4.47	38.74
	Alfalfa (B)	0.00	0.00	0.00
	Alfalfa (C)	5.33	5.06	63.05
	Alfalfa (D)	6.00	5.70	78.10
	Grain sorghum	2.50	2.38	62.00

Table B1. Alternative crop enterprises included in linear programming models, continued

Case Farm	Crop	Acre Feet Per Acre Models A and C	Acre Feet Per Acre Model B	Net Return Per Acre
I	Cotton (65)	2.14	2.03	$148.56
	Cotton (80)	2.63	2.50	166.53
	Cotton (95)	3.13	2.97	184.50
	Alfalfa (A)	4.46	4.24	30.01
	Alfalfa (B)	0.00	0.00	0.00
	Alfalfa (C)	5.33	5.06	59.49
	Alfalfa (D)	6.00	5.70	78.34
	Grain sorghum	2.50	2.38	56.24
	Castor beans	2.50	2.38	62.58
	Oats	0.43	0.41	-1.72
J	Cotton (65)	1.69	1.61	$137.03
	Cotton (80)	2.08	1.98	151.99
	Cotton (95)	2.47	2.35	166.94
	Alfalfa (A)	4.57	4.34	43.37
	Alfalfa (B)	0.00	0.00	0.00
	Alfalfa (C)	5.33	5.06	64.48
	Alfalfa (D)	6.00	5.70	82.03
	Grain sorghum	2.30	2.19	57.43
	Castor beans	1.96	1.86	66.73
	Oats	2.79	2.65	29.05
K	Cotton (65)	2.36	2.24	$192.07
	Cotton (80)	2.90	2.76	218.48
	Cotton (95)	3.45	3.28	244.90
	Alfalfa (A)	5.30	5.04	33.20
	Alfalfa (B)	0.00	0.00	0.00
	Alfalfa (C)	5.33	5.06	49.88
	Alfalfa (D)	6.00	5.70	64.83
	Grain sorghum	3.03	2.88	52.25
	Castor beans	2.60	2.47	65.40
L	Cotton (65)	1.95	1.85	$135.41
	Cotton (80)	2.40	2.25	149.91
	Cotton (95)	2.85	2.71	164.40
	Alfalfa (A)	4.71	4.47	37.95
	Alfalfa (B)	0.00	0.00	0.00
	Alfalfa (C)	5.33	5.06	57.75
	Alfalfa (D)	6.00	5.70	76.58
	Castor beans	2.25	2.14	68.09
	Corn silage	2.07	1.97	28.32
	Grain sorghum	2.25	2.14	62.11

APPENDIX C - IRRIGATION EFFICIENCY

Table C1. Case Farm A: Consumptive Irrigation Requirement (CIR), acre inches of irrigation water applied, and farm irrigation efficiency by crops, Roswell Artesian Basin, New Mexico.

Crop	1966			1967			1968			Typical		
	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)
Cotton	18.72	28.56	65.54	19.35	43.68	44.30	18.32	23.16	79.10	18.80	31.80	59.12
Alfalfa	30.21	66.48	45.44	31.00	51.12	60.64	26.73	69.36	38.54	29.31	62.32	47.03
Barley	13.89	18.12	76.66	13.08	12.00	109.00	17.42	7.20	241.94	14.80	12.44	118.97

Table C2. Case Farm B: Consumptive Irrigation Requirements (CIR), acre inches of irrigation water applied, and farm irrigation efficiency by crops, Roswell Artesian Basin, New Mexico.

Crop	1966 CIR	1966 Irrigation Water Applied	1966 Farm Irrigation Efficiency	1967 CIR	1967 Irrigation Water Applied	1967 Farm Irrigation Efficiency	Typical CIR	Typical Irrigation Water Applied	Typical Farm Irrigation Efficiency
	(ac in)	(ac in)	(%)	(ac in)	(ac in)	(%)	(ac in)	(ac in)	(%)
Cotton	18.72	27.24	68.72	19.35	33.00	58.64	19.04	30.12	63.21
Alfalfa	30.21	63.00	47.95	31.00	43.68	70.97	30.61	53.34	57.39
Barley	13.89	22.56	61.57	13.08	28.80	45.42	13.49	25.68	52.53
Barley Pasture	13.89	16.92	82.09	13.08	15.00	87.20	13.49	15.96	84.52
Forage Sorghum	14.03	26.28	53.39				14.03	26.28	53.39

Table C3. Case Farm C: Consumptive Irrigation Requirements (CIR), acre inches of irrigation water applied, and farm irrigation efficiency by crops, Roswell Artesian Basin, New Mexico.

Crop	1966			1967			1968			Typical		
	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)
Cotton	18.72	33.60	55.71	19.35	32.76	59.07	18.32	34.32	53.38	18.80	33.56	56.02
Alfalfa	30.21	64.68	46.71	31.00	45.48	68.16	26.73	44.40	60.20	29.31	51.52	56.89
Barley	13.97	12.00	116.42	11.97	12.72	94.10	17.42	22.80	76.40	14.45	15.84	91.22
Grain Sorghum				17.89	15.84	112.94				17.89	15.84	112.94
Forage Sorghum							11.99	24.60	48.74	11.99	24.60	48.74

Table C4. Case Farm D: Consumptive Irrigation Requirements (CIR), acre inches of irrigation water applied, and farm irrigation efficiency by crops, Roswell Artesian Basin, New Mexico.

Crop	1966			1967			1968			Typical		
	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)
Cotton	18.72	33.72	55.52	19.35	36.24	53.39	18.32	19.08	96.02	18.80	29.68	63.34
Alfalfa	30.21	58.32	51.80	31.00	63.84	48.56	26.73	58.80	45.46	29.31	60.32	48.59
Corn	15.32	24.36	62.89	13.32	24.00	55.50	13.28	16.80	79.05	13.97	21.72	64.32
Sudex	14.03	30.00	46.77	12.03	24.24	49.63	11.99	19.08	62.84	12.68	24.44	51.88
Barley	13.97	21.36	65.40	13.08	26.04	50.23	17.42	23.16	75.22	14.82	23.52	63.01
Hegari	14.03	24.24	57.88				11.99	8.88	135.03	13.01	16.56	78.56

Table C5. Case Farm E: Consumptive Irrigation Requirements (CIR), acre inches of irrigation water applied, and farm irrigation efficiency by crops, Roswell Artesian Basin, New Mexico.

Crop	1967			1968			Typical		
	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)
Cotton	19.35	34.20	56.58	18.32	14.40	127.22	18.84	24.30	77.53
Alfalfa	31.00	57.36	54.04	26.73	49.44	54.07	28.87	53.40	54.06
Grain Forghum	17.89	30.60	58.46	17.79	15.24	116.73	17.84	22.92	77.84
Barley	13.08	25.32	79.27	17.42	22.44	77.63	15.27	23.88	63.94

Table C6. Case Farm F: Consumptive Irrigation Requirements (CIR), acre inches of irrigation water applied, and farm irrigation efficiency by crops, Roswell Artesian Basin, New Mexico.

Crop	1966			1967			1968			Typical		
	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)
Cotton	18.72	30.12	62.15	19.35	21.60	89.58	18.32	19.76	103.15	18.80	23.16	81.17
Alfalfa		4.08			27.00			15.48			15.52	
Barley		3.60										
Corn	15.32	16.56	92.51	13.32	15.00	88.80				14.32	15.78	90.75
Oats							17.42	21.48	81.10	17.42	21.48	81.10

Table C7. Case Farm G: Consumptive Irrigation Requirements (CIR), acre inches of irrigation water applied, and farm irrigation efficiency by crops, Roswell Artesian Basin, New Mexico.

Crop	1966			1967			1968			Typical		
	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)
Cotton	18.72	34.80	53.79	19.35	27.12	71.35	18.32	33.48	54.72	18.80	31.80	59.12
Alfalfa	30.21	45.60	66.25	31.00	45.84	67.63	26.73	42.72	62.57	29.31	44.72	65.54
Barley				19.77	26.40	74.89	17.42	13.20	131.97	18.60	19.80	93.94
Oats	18.20	18.12	100.44							18.20	18.12	100.44
Rye							5.30	5.40	98.15	5.30	5.40	98.15

Table C8. Case Farm H: Consumptive Irrigation Requirements (CIR), acre inches of irrigation water applied, and farm irrigation efficiency by crops, Roswell Artesian Basin, New Mexico.

Crop	1967			1968			Typical		
	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)
Cotton	19.35	38.16	50.71	18.32	51.36	35.67	18.84	44.76	42.09
Alfalfa	31.00	54.72	56.65	26.73	78.12	34.22	28.87	66.42	43.47
Forage Sorghum				11.99	34.32	34.94	11.99	34.32	34.94

Table C9. Case Farm I: Consumptive Irrigation Requirements (CIR), acre inches of irrigation water applied, and farm irrigation efficiency by crops, Roswell Artesian Basin, New Mexico.

	1966			1967			Typical		
Crop	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)
Cotton	19.30	38.40	50.26	24.03	41.40	58.04	21.67	39.90	54.31
Alfalfa	31.32	49.20	63.66	35.96	57.84	62.17	33.64	53.52	62.86
Oats				4.06	5.16	78.77	4.06	5.16	78.77

Table C10. Case Farm J: Consumptive Irrigation Requirements (CIR), acre inches of irrigation water applied, and farm irrigation efficiency by crops, Roswell Artesian Basin, New Mexico.

Crop	1966			1967			1968			Typical		
	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)
Cotton	19.30	39.00	49.49	24.03	39.24	61.24	18.89	27.72	68.15	20.74	35.32	58.72
Alfalfa	31.32	57.48	54.49	35.96	50.64	71.01	28.67	58.80	48.76	31.98	55.64	57.48
Oats							16.12	33.48	48.14	16.12	33.48	48.14

Table C11. Case Farm K: Consumptive Irrigation Requirements (CIR), acre inches of irrigation water applied, and farm irrigation efficiency by crops, Roswell Artesian Basin, New Mexico.

Crop	1966			1967			1968			Typical		
	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)	CIR (ac in)	Irrigation Water Applied (ac in)	Farm Irrigation Efficiency (%)
Cotton	19.30	42.24	45.60	24.03	48.24	49.81	18.89	41.04	46.03	20.74	43.84	47.31
Alfalfa	31.32	66.00	47.45	35.96	61.32	58.64	28.67	62.16	46.12	31.98	63.16	50.63
Grain Sorghum				22.57	34.80	64.86	17.84	38.52	46.31	20.21	36.66	55.13

Table C12. Case Farm L: Consumptive Irrigation Requirement (CIR), acre inches of irrigation water applied, and farm irrigation efficiency by crops, Roswell Artesian Basin, New Mexico.

Crop	1966			1967			1968			Typical		
	CIR	Irrigation Water Applied	Farm Irrigation Efficiency	CIR	Irrigation Water Applied	Farm Irrigation Efficiency	CIR	Irrigation Water Applied	Farm Irrigation Efficiency	CIR	Irrigation Water Applied	Farm Irrigation Efficiency
	(ac in)	(ac in)	(%)	(ac in)	(ac in)	(%)	(ac in)	(ac in)	(%)	(ac in)	(ac in)	(%)
Cotton	19.30	49.92	38.66	24.03	45.96	52.28	18.89	26.04	72.54	20.74	40.68	50.98
Alfalfa	31.32	63.96	48.97	35.96	56.52	63.62	28.67	53.04	54.05	31.98	58.86	54.61
Corn Silage	15.68	24.84	63.12							15.68	24.84	63.12

APPENDIX D - ENTERPRISE BUDGETS

Table D1. Case Farm A: Per acre expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns Per Acre (dollars)	Gross Expenses Per Acre (dollars)	Net Returns to Land and Management Per Acre (dollars)
		1966	
Cotton planted	358.27	154.10	204.17
Cotton diverted	95.55	15.28	80.27
Alfalfa (Hay and pasture)	138.00	77.76	60.24
Barley	32.40	28.90	3.50
Weighted average	194.00	85.88	108.12
		1967	
Cotton planted	440.49	197.30	243.19
Cotton diverted	100.79	8.62	92.17
Alfalfa (Hay and pasture)	131.81	81.16	50.65
Barley	32.40	24.98	7.42
Weighted average	238.02	108.67	129.35
		1968	
Cotton planted	244.81	119.14	125.67
Cotton diverted	97.38	15.28	82.10
Alfalfa (Hay and pasture)	155.40	94.68	60.72
Barley	10.80	19.67	- 8.87
Weighted average	199.20	104.32	94.88
		Typical	
Cotton planted	347.86	156.85	191.01
Cotton diverted	97.91	13.06	84.85
Alfalfa (Hay and pasture)	141.74	84.53	57.21
Barley	25.20	24.52	0.68
Weighted average	212.80	99.88	112.92

Table D2. Case Farm B: Per acre expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns Per Acre (dollars)	Gross Expenses Per Acre (dollars)	Net Returns to Land and Management Per Acre (dollars)
		1966	
Cotton planted	473.23	156.01	317.22
Cotton diverted	87.15	6.57	80.58
Alfalfa	142.60	107.69	34.91
Barley	65.63	38.46	27.17
Barley pasture	25.92	24.93	0.99
Forage sorghum	67.50	32.43	35.07
Weighted average	208.73	101.58	107.15
		1967	
Cotton planted	439.49	141.38	298.11
Cotton diverted	92.71	6.57	86.14
Alfalfa	144.90	105.85	39.05
Barley	42.00	39.67	2.33
Barley pasture	25.92	23.70	2.22
Weighted average	209.17	102.01	107.16
		Typical	
Cotton planted	391.31	148.70	242.61
Cotton diverted	88.29	6.57	81.72
Alfalfa	143.75	106.77	36.98
Forage sorghum	67.50	32.43	35.07
Barley	53.82	39.07	14.75
Barley pasture	25.92	24.32	1.61
Weighted average	191.93	101.79	90.14

Table D3. Case Farm C: Per acre expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns Per Acre (dollars)	Gross Expenses Per Acre (dollars)	Net Returns to Land and Management Per Acre (dollars)
		1966	
Cotton planted	192.91	129.45	63.46
Cotton diverted	74.03	14.52	59.51
Alfalfa	125.00	105.38	19.62
Barley	13.50	26.71	-13.21
Weighted average	120.92	90.29	30.63
		1967	
Cotton planted	237.50	146.89	90.61
Cotton diverted	78.16	14.71	63.45
Alfalfa	145.60	95.50	50.10
Barley	13.50	27.17	-13.67
Grain sorghum	60.35	44.82	15.33
Weighted average	121.25	77.34	43.91
		1968	
Cotton planted	331.15	151.25	179.90
Cotton diverted	75.86	14.52	61.34
Alfalfa	112.50	105.83	6.67
Barley	36.57	48.19	-11.62
Forage sorghum	15.19	38.29	-23.10
Weighted average	145.11	92.96	52.15
		Typical	
Cotton planted	253.85	142.53	111.32
Cotton diverted	76.02	14.58	61.44
Alfalfa	127.70	102.24	25.46
Barley	21.19	34.02	-12.83
Grain sorghum	60.35	44.82	15.53
Forage sorghum	15.19	38.29	-23.10
Weighted average	125.50	85.31	40.19

Table D4. Case Farm D: Per acre expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns Per Acre (dollars)	Gross Expenses Per Acre (dollars)	Net Returns to Land and Management Per Acre (dollars)
	1966		
Cotton planted	331.13	157.31	173.82
Cotton diverted	94.68	9.93	84.75
Alfalfa	176.00	126.00	50.00
Corn silage	129.60	74.73	54.87
Sudex	160.00	54.36	105.64
Barley	55.63	44.65	10.98
Hegari	114.59	80.72	33.87
Weighted average	172.71	100.31	72.40
	1967		
Cotton planted	341.30	148.42	192.88
Cotton diverted	98.64	9.75	88.89
Alfalfa	159.60	96.38	63.22
Corn silage	108.00	97.92	10.08
Sudex	80.00	64.18	15.82
Barley	89.70	73.33	16.37
Weighted average	154.55	90.32	64.37
	1968		
Cotton planted	277.81	115.68	162.13
Cotton diverted	76.80	9.71	67.09
Alfalfa	167.50	106.56	60.94
Corn silage	107.15	35.73	71.42
Sudex	101.60	40.28	61.32
Barley	55.63	45.80	9.83
Hegari	34.79	23.40	11.39
Weighted average	150.11	79.90	70.21
	Typical		
Cotton planted	316.75	140.47	176.28
Cotton diverted	90.04	9.80	80.24
Alfalfa	167.70	109.65	58.05
Corn silage	114.92	69.46	45.46
Sudex	113.87	52.94	60.93
Barley	66.99	54.59	12.40
Hegari	74.69	52.06	22.63
Weighted Average	160.39	87.94	72.45

Table D5. Case Farm E: Per acre expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns Per Acre (dollars)	Gross Expenses Per Acre (dollars)	Net Returns to Land and Management Per Acre (dollars)
	1967		
Cotton planted	415.87	190.39	225.48
Cotton diverted	103.49	10.32	93.17
Alfalfa	212.80	120.79	92.01
Grain sorghum	126.00	65.43	60.57
Barley	75.00	58.16	16.84
Weighted average	210.99	108.85	102.14
	1968		
Cotton planted	315.36[1]	70.43	244.93
Cotton diverted	99.53	8.01	91.52
Alfalfa	140.00	100.79	39.21
Grain sorghum	123.50	44.40	79.10
Barley	37.41	30.04	7.37
Weighted average	145.84	60.99	84.85
	Typical		
Cotton planted	367.79	188.89	178.90
Cotton diverted	100.05	9.17	90.88
Alfalfa	176.40	110.79	65.61
Grain sorghum	124.75	54.92	69.83
Barley	56.21	44.10	12.11
Weighted average	176.64	97.75	78.88

1 Includes insurance payment for hail damage (no cotton harvested).

Table D6. Case Farm F: Per acre expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns Per Acre (dollars)	Gross Expenses Per Acre (dollars)	Net Returns to Land and Management Per Acre (dollars)
	1966		
Cotton planted	201.16	88.63	112.53
Cotton diverted	81.90	9.93	71.97
Alfalfa (Hay and seed)	6.60	20.27	- 13.67
Corn silage	135.00	84.36	50.64
Barley	12.50	10.22	2.28
Weighted average	110.27	59.47	50.80
	1967		
Cotton planted	327.55	130.29	197.26
Cotton diverted	87.32	14.63	72.69
Alfalfa (Hay and seed)	72.25	53.62	18.63
Corn silage	113.76	72.19	41.56
Weighted average	150.62	74.19	76.43
	1968		
Cotton planted	275.65	114.25	161.40
Cotton diverted	83.93	9.71	74.22
Alfalfa (Hay and seed)	57.80	44.70	13.10
Oats	67.00	59.21	7.79
Weighted average	202.73	90.21	112.52
	Typical		
Cotton planted	291.06	111.06	180.00
Cotton diverted	84.38	11.42	72.96
Alfalfa (Hay and seed)	45.55	39.53	6.02
Corn silage	124.38	78.28	46.10
Barley	12.50	10.22	2.28
Oats	67.00	59.21	7.79
Weighted average	155.56	70.82	84.74

Table D7. Case Farm G: Per acre expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns Per Acre (dollars)	Gross Expenses Per Acre (dollars)	Net Returns to Land and Management Per Acre (dollars)
		1966	
Cotton planted	266.61	136.84	129.77
Cotton diverted	78.75	10.41	68.34
Alfalfa	146.51	72.72	73.79
Oats	71.72	35.32	36.40
Weighted average	166.57	82.32	84.25
		1967	
Cotton planted	373.64	134.81	238.83
Cotton diverted	84.08	9.91	74.17
Alfalfa	83.68	67.59	16.09
Barley	51.30	49.23	2.07
Weighted average	136.53	69.29	67.24
		1968	
Cotton planted	265.96	147.91	118.05
Cotton diverted	81.24	10.87	70.37
Alfalfa	102.50	78.29	24.21
Barley	46.30	34.93	11.37
Rye	10.80	18.88	- 8.08
Weighted average	101.80	69.13	32.67
		Typical	
Cotton planted	302.07	139.85	162.22
Cotton diverted	81.36	10.40	70.96
Alfalfa	110.90	72.87	38.03
Barley	48.80	42.08	6.72
Oats	71.72	35.32	36.40
Rye	10.80	18.88	- 8.08
Weighted average	132.95	72.69	60.26

Table D8. Case Farm H: Per acre expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns Per Acre (dollars)	Gross Expenses Per Acre (dollars)	Net Returns to Land and Management Per Acre (dollars)
		1967	
Cotton planted	430.24	163.91	266.33
Cotton diverted	99.18	8.78	90.30
Alfalfa	198.40	112.22	86.18
Weighted average	285.53	127.00	158.53
		1968	
Cotton planted	386.52	121.52	265.00
Cotton diverted	102.76	9.12	93.64
Alfalfa	154.00	120.30	33.70
Forage sorghum	19.39	49.82	- 30.43
Weighted average	236.09	111.90	124.19
		Typical	
Cotton planted	428.16	142.72	285.44
Cotton diverted	98.11	8.95	89.16
Alfalfa	155.00	116.26	38.74
Forage sorghum	19.39	49.82	- 30.43
Weighted average	256.95	119.45	137.50

Table D9. Case Farm I: Per acre expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns Per Acre (dollars)	Gross Expenses Per Acre (dollars)	Net Returns to Land and Management Per Acre (dollars)
		1966	
Cotton planted	338.95	166.47	172.48
Cotton diverted	84.00	19.74	64.26
Alfalfa	155.00	121.53	33.47
Weighted average	217.46	132.30	85.16
		1967	
Cotton planted	384.64	146.13	238.51
Cotton diverted	89.47	15.49	73.98
Alfalfa	165.20	111.95	53.25
Oats	13.50	15.22	- 1.72
Weighted average	187.23	101.07	86.16
		Typical	
Cotton planted	346.79	156.30	190.49
Cotton diverted	88.31	17.62	70.69
Alfalfa	146.75	116.74	30.01
Oats	13.50	15.22	- 1.72
Weighted average	191.60	115.69	75.91

Table D10. Case Farm J: Per acre expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns Per Acre (dollars)	Gross Expenses Per Acre (dollars)	Net Returns to Land and Management Per Acre (dollars)
	1966		
Cotton planted	285.83	111.24	174.59
Cotton diverted	87.15	15.62	71.53
Alfalfa	150.00	108.30	41.70
Weighted average	173.35	97.89	75.46
	1967		
Cotton planted	328.20	138.32	189.88
Cotton diverted	86.78	13.75	73.03
Alfalfa	201.60	108.08	93.52
Weighted average	216.21	103.45	112.76
	1968		
Cotton planted	265.89	114.59	151.30
Cotton diverted	87.69	15.62	72.07
Alfalfa	150.00	122.26	27.74
Oats	90.46	61.41	29.05
Weighted average	159.30	91.03	68.27
	Typical		
Cotton planted	293.31	121.38	171.93
Cotton diverted	87.21	15.00	72.21
Alfalfa	156.25	112.88	43.37
Oats	90.46	61.41	29.05
Weighted average	175.97	98.94	77.03

Table D11. Case Farm K: Per acre expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns Per Acre (dollars)	Gross Expenses Per Acre (dollars)	Net Returns to Land and Management Per Acre (dollars)
		1966	
Cotton planted	358.96	161.56	197.40
Cotton diverted	91.35	13.56	77.79
Alfalfa	160.00	123.27	36.73
Weighted average	221.48	131.64	89.84
		1967	
Cotton planted	540.37	185.10	355.27
Cotton diverted	91.09	16.06	75.03
Alfalfa	154.00	111.25	42.75
Grain sorghum	117.00	64.17	52.83
Weighted average	222.15	103.39	118.76
		1968	
Cotton planted	388.59	180.18	208.41
Cotton diverted	93.61	13.59	80.02
Alfalfa	137.50	117.38	20.12
Grain sorghum	123.50	71.82	51.68
Weighted average	151.25	90.06	90.06
		Typical	
Cotton planted	429.31	175.61	253.70
Cotton diverted	92.02	14.40	77.62
Alfalfa	150.50	117.30	33.20
Grain sorghum	120.25	68.00	52.25
Weighted average	217.35	117.82	99.53

Table D12. Case Farm L: Per acre expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Gross Returns Per Acre (dollars)	Gross Expenses Per Acre (dollars)	Net Returns to Land and Management Per Acre (dollars)
		1966	
Cotton planted	309.11	162.05	147.06
Cotton diverted	87.15	11.52	75.63
Alfalfa	179.00	145.14	33.86
Corn silage	67.55	39.23	28.32
Weighted average	200.71	131.24	69.47
		1967	
Cotton planted	423.74	163.22	260.52
Cotton diverted	86.78	12.11	74.67
Alfalfa	176.40	119.87	56.53
Weighted average	232.95	114.29	118.66
		1968	
Cotton planted	207.01	145.92	61.09
Cotton diverted	79.09	12.88	66.21
Alfalfa	157.50	116.14	41.36
Weighted average	180.66	128.55	52.11
		Typical	
Cotton planted	326.29	157.06	169.23
Cotton diverted	84.77	12.17	72.60
Alfalfa	165.00	127.05	37.95
Corn silage	67.55	39.23	28.32
Weighted average	214.97	125.20	89.77

APPENDIX E - WHOLE FARM BUDGETS

Table E1. Case Farm A: Expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
		1966		
Cotton planted	94.7	33,928.17	14,593.27	19,344.90
Cotton diverted	47.9	4,576.84	731.91	3,844.93
Alfalfa (hay and pasture)	64.0	8,832.00	4,976.64	3,855.36
Barley	44.9	1,454.76	1,297.61	157.15
Total	251.5	48,791.77	21,599.43	27,192.34
		1967		
Cotton planted	98.0	43,168.02	19,355.40	23,832.62
Cotton diverted	44.6	4,495.23	384.45	4,110.78
Alfalfa (hay and pasture)	86.6	11,414.75	7,028.46	4,386.29
Barley	22.0	712.80	549.56	163.24
Total	251.2	59,790.80	27,297.87	32,492.93
		1968		
Cotton planted	115.0	28,153.15	13,701.10	14,452.05
Cotton diverted	5.0	486.90	76.40	410.50
Alfalfa (hay and pasture	86.6	13,457.64	8,199.29	5,258.35
Barley	5.0	54.00	98.35	-44.35
Total	211.6	42,151.69	22,075.14	20,076.55
		Typical		
Cotton planted	102.6	35,690.44	16,092.81	19,597.63
Cotton diverted	32.5	3,182.08	424.45	2,757.63
Alfalfa (hay and pasture)	79.1	11,211.63	6,686.32	4,525.31
Barley	24.0	604.80	588.48	16.32
Total	238.2	50,688.95	23,792.06	26,896.89

Table E2. Case Farm B: Expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
		1966		
Cotton planted	74.62	35,312.42	11,641.47	23,670.95
Cotton diverted	19.60	1,708.14	128.77	1,579.37
Alfalfa	156.10	22,259.86	16,810.41	5,449.45
Barley	19.60	1,286.35	753.82	532.53
Barley pasture	12.00	311.04	299.16	11.88
Forage sorghum	14.40	972.00	466.99	505.01
Fallow	2.18	0.00	0.00	0.00
Total	298.50	61,849.81	30,100.62	31,749.19
		1967		
Cotton planted	74.62	32,794.74	10,549.78	22,244.96
Cotton diverted	14.40	1,335.02	94.61	1,240.41
Alfalfa	156.10	22,618.89	16,523.19	6,095.71
Barley	19.60	823.20	777.53	45.67
Barley pasture	12.00	311.04	284.40	26.64
Fallow	2.18	0.00	0.00	0.00
Total	278.90	57,882.89	28,229.51	29,653.39
		Typical		
Cotton planted	74.62	29,199.55	11,095.99	18,103.56
Cotton diverted	17.00	1,500.93	111.69	1,389.24
Alfalfa	156.10	22,439.38	16,666.80	5,772.58
Barley	19.60	1,054.87	765.77	289.10
Barley pasture	12.00	311.04	291.84	19.20
Forage sorghum	7.20	486.00	233.50	252.50
Fallow	2.18	0.00	0.00	0.00
Total	288.70	54,991.77	29,165.59	25,826.18

Table E3. Case Farm C: Expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
		1966		
Cotton planted	41.8	8,063.64	5,411.01	2,652.63
Cotton diverted	22.0	1,628.66	319.44	1,309.22
Alfalfa	94.7	11,837.50	9,978.79	1,858.01
Barley	22.0	297.00	587.62	- 290.62
Total	180.5	21,826.80	16,297.56	5,529.24
		1967		
Cotton planted	63.40	15,057.50	9,312.83	5,744.67
Cotton diverted	14.26	1,114.56	209.76	904.80
Alfalfa	43.10	6,275.86	4,116.05	2,159.31
Barley	52.00	702.00	1,412.84	- 710.84
Grain sorghum	52.00	3,138.20	2,330.64	807.56
Total	224.76	26,287.62	17,382.12	8,905.50
		1968		
Cotton planted	65.7	21,756.56	9,937.13	11,819.43
Cotton diverted	3.5	265.51	50.82	214.69
Alfalfa	54.1	6,086.25	5,725.40	360.85
Barley	52.0	1,901.64	2,505.88	- 604.24
Forage sorghum	35.2	534.69	1,347.81	- 831.12
Total	210.5	30,544.65	14,567.04	10,977.61
		Typical		
Cotton planted	57.0	14,469.45	8,124.21	6,345.24
Cotton diverted	13.3	1,011.07	193.91	817.16
Alfalfa	64.0	8,172.80	6,543.36	1,629.44
Barley	42.0	889.98	1,428.84	- 538.86
Grain sorghum	17.3	1,044.06	755.39	268.67
Forage sorghum	11.7	177.72	447.99	- 270.27
Total	205.3	25,765.08	17,513.70	8,251.38

Table E4. Case Farm D: Expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
		1966		
Cotton planted	60.6	20,066.48	9,532.99	10,533.49
Cotton diverted	32.5	3,077.10	322.72	2,754.38
Alfalfa	133.7	23,531.20	16,846.20	6,685.00
Corn silage	59.2	7,672.32	4,424.02	3,248.30
Sudex	4.0	640.00	217.44	422.56
Barley	33.8	1,880.29	1,509.17	371.12
Hegari	12.4	1,420.92	1,000.93	419.99
Fallow	1.3	0.00	0.00	0.00
Total	337.5	58,288.31	33,853.47	24,434.84
		1967		
Cotton planted	60.5	20,648.65	8,979.41	11,669.24
Cotton diverted	32.5	3,205.80	316.88	2,888.92
Alfalfa	100.4	16,023.84	9,676.55	6,347.29
Corn silage	69.7	7,527.60	6,825.02	702.58
Sudex	40.6	3,248.00	2,605.71	642.29
Barley	57.3	5,139.81	4,201.81	938.00
Fallow	0.0	0.00	0.00	0.00
Total	401.6	55,793.70	32,605.38	23,188.32
		1968		
Cotton planted	81.0	22,502.61	9,506.97	12,995.64
Cotton diverted	8.0	614.40	77.68	536.72
Alfalfa	131.1	21,959.25	13,970.02	7,989.23
Corn silage	11.0	1,616.45	886.93	729.52
Sudex	40.6	4,124.96	1,635.37	2,489.59
Barley	49.6	2,759.25	2,271.68	487.57
Hegari	34.5	1,200.26	807.30	392.96
Fallow	9.1	0.00	0.00	0.00
Total	364.9	54,776.78	29,155.95	25,621.23
		Typical		
Cotton planted	67.4	21,348.95	9,467.68	11,881.27
Cotton diverted	24.3	2,187.97	238.14	1,949.83
Alfalfa	121.8	20,425.86	13,355.37	7,070.49
Corn silage	46.6	5,355.27	3,236.84	2,118.43
Sudex	28.4	3,233.91	1,503.50	1,730.41
Barley	46.9	3,141.83	2,560.27	581.56
Hegari	15.6	1,165.18	812.14	353.04
Fallow	3.5	0.00	0.00	0.00
Total	354.5	56,858.97	31,173.94	25,685.03

Table E5. Case Farm E: Expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
		1967		
Cotton planted	75.3	31,315.01	14,336.37	16,978.64
Cotton diverted	29.3	3,032.26	302.38	2,729.88
Alfalfa	147.0	31,281.60	17,756.13	13,525.47
Grain sorghum	28.4	3,578.40	1,858.21	1,720.19
Barley	74.5	5,587.50	4,332.92	1,254.58
Total	354.5	74,794.77	38,586.01	36,208.76
		1968		
Cotton planted	76.5	24,125.04	5,387.90	18,737.14
Cotton diverted	4.0	398.12	32.04	366.08
Alfalfa	97.4	13,636.00	9,816.95	3,819.05
Grain sorghum	88.1	10,880.35	3,911.64	6,968.71
Barley	94.5	3,535.25	2,838.78	696.47
Total	360.5	52,574.76	21,987.31	30,587.45
		Typical		
Cotton planted	75.9	27,915.26	14,336.37	13,578.89
Cotton diverted	16.7	1,670.84	153.14	1,517.70
Alfalfa	122.2	21,556.08	13,538.54	8,017.54
Grain sorghum	58.3	7,272.93	3,201.84	4,071.09
Barley	84.5	4,749.75	3,726.45	1,023.30
Fallow	7.0	0.00	0.00	0.00
Total	364.6	63,164.86	34,956.34	28,208.52

Table E6. Case Farm F: Expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Return (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
		1966		
Cotton planted	140.0	28,162.40	12,408.20	15,754.20
Cotton diverted	20.0	1,638.00	198.60	1,439.40
Alfalfa (hay and seed)	80.0	528.00	1,621.60	- 1,093.60
Corn silage	160.0	21,600.00	13,497.60	8,102.40
Barley	80.0	1,000.00	817.60	182.40
Total	480.0	52,928.40	28,543.60	24,384.80
		1967		
Cotton planted	80.02	26,210.55	10,425.81	15,784.74
Cotton diverted	43.08	3,761.75	630.26	3,131.49
Alfalfa (hay and seed)	80.00	5,780.00	4,289.60	1,490.40
Corn silage	140.00	15,926.40	10,108.00	5,818.40
Fallow	56.90	0.00	0.00	0.00
Total	400.00	51,678.70	25,453.67	26,225.03
		1968		
Cotton planted	262.3	72,303.00	29,967.78	42,335.22
Cotton diverted	17.7	1,485.56	171.87	1,313.69
Alfalfa	80.0	4,624.00	3,576.00	1,048.00
Oats	40.0	2,680.00	2,368.40	311.60
Total	400.0	81,092.56	36,084.05	45,008.51
		Typical		
Cotton planted	160.77	46,793.72	17,855.12	28,938.60
Cotton diverted	26.93	2,272.35	307.54	1,964.81
Alfalfa (hay and seed)	80.00	3,644.00	3,162.40	481.60
Corn silage	100.00	12,438.00	7,828.00	4,610.00
Barley	26.67	333.38	272.57	60.81
Oats	13.33	893.11	789.27	103.84
Fallow	18.97	0.00	0.00	0.00
Total	426.67	66,374.56	30,214.90	36,159.66

Table E7. Case Farm G: Expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
		1966		
Cotton planted	68.0	18,129.48	9,305.12	8,824.36
Cotton diverted	12.9	1,015.88	134.29	881.59
Alfalfa	79.5	11,647.55	5,781.24	5,866.31
Oats	26.8	1,922.10	946.58	975.52
Fallow	9.2	0.00	0.00	0.00
Total	196.4	32,715.01	16,167.23	16,547.78
		1967		
Cotton planted	41.0	15,319.24	5,527.21	9,792.03
Cotton diverted	19.4	1,631.15	192.25	1,438.90
Alfalfa	79.5	6,652.56	5,375.41	1,277.15
Barley (seed and pasture)	38.1	1,954.53	1,875.66	78.87
Fallow	9.2	0.00	0.00	0.00
Total	187.2	25,557.48	12,970.53	12,586.95
		1968		
Cotton planted	52.1	13,856.52	7,706.11	6,150.41
Cotton diverted	2.9	235.60	31.52	204.08
Alfalfa	114.3	11,859.25	9,058.15	2,801.10
Barley (seed and pasture)	44.9	2,078.87	1,568.36	510.51
Rye	58.1	627.48	1,096.93	- 469.45
Fallow	9.2	0.00	0.00	0.00
Total	281.5	28,657.72	19,461.07	9,196.65
		Typical		
Cotton planted	53.7	16,221.16	7,509.95	8,711.21
Cotton diverted	11.7	951.91	121.68	830.23
Alfalfa	91.1	10,102.99	6,638.46	3,464.53
Barley (seed and pasture)	27.7	1,351.76	1,165.62	186.14
Oats	8.9	638.31	314.35	323.96
Rye	19.4	209.52	366.27	- 156.75
Fallow	9.2	0.00	0.00	0.00
Total	221.7	29,475.65	16,116.33	13,359.32

Table E8. Case Farm H: Expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
		1967		
Cotton planted	69.65	29,966.22	11,416.33	18,549.89
Cotton diverted	9.95	986.84	87.36	899.48
Alfalfa	94.40	18,728.96	10,593.57	8,135.39
Total	174.00	49,682.02	22,097.26	27,584.76
		1968		
Cotton planted	71.60	27,674.83	8,700.83	18,974.00
Cotton diverted	5.60	575.46	51.07	524.39
Alfalfa	92.45	14,237.30	11,121.74	3,115.56
Forage sorghum	6.50	126.04	323.83	- 197.79
Fallow	4.35	0.00	0.00	0.00
Total	180.50	42,613.63	20,197.47	22,416.16
		Typical		
Cotton planted	70.62	30,236.66	10,078.89	20,157.77
Cotton diverted	7.77	762.31	69.54	692.77
Alfalfa	93.43	14,481.65	10,862.17	3,619.48
Forage sorghum	3.25	63.02	161.92	- 98.90
Fallow	2.18	0.00	0.00	0.00
Total	177.25	45,543.64	21,172.52	24,371.12

Table E9. Case Farm I: Expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
		1966		
Cotton planted	44.0	14,913.80	7,324.68	7,589.12
Cotton diverted	6.5	546.00	128.31	417.69
Alfalfa	71.7	11,113.50	8,713.70	2,399.80
Total	122.2	26,573.30	16,166.69	10,406.61
		1967		
Cotton planted	23.0	8,846.72	3,360.99	5,485.73
Cotton diverted	12.4	1,109.43	192.08	917.35
Alfalfa	77.7	12,836.04	8,698.52	4,137.52
Oats	6.5	87.75	98.93	- 11.18
Fallow	2.6	0.00	0.00	0.00
Total	122.2	22,879.94	12,350.52	10,529.42
		Typical		
Cotton planted	33.50	11,617.47	5,236.05	6,381.42
Cotton diverted	9.45	834.53	166.51	668.02
Alfalfa	74.70	10,918.20	8,685.46	2,232.74
Oats	3.25	43.88	49.47	- 5.59
Fallow	1.30	0.00	0.00	0.00
Total	122.20	23,414.08	14,137.49	9,276.59

Table E10. Case Farm J: Expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
		1966		
Cotton planted	34.4	9,832.55	3,826.66	6,005.89
Cotton diverted	18.1	1,577.42	282.72	1,294.70
Alfalfa	98.9	14,835.00	10,710.87	4,124.13
Total	151.4	26,244.97	14,820.25	11,424.72
		1967		
Cotton planted	34.13	11,201.47	4,720.86	6,480.61
Cotton diverted	18.37	1,594.15	252.59	1,341.56
Alfalfa	98.9	19,938.24	10,689.11	9,249.13
Total	151.4	32,733.86	15,662.56	17,071.30
		1968		
Cotton planted	50.1	13,321.09	5,740.96	7,580.13
Cotton diverted	2.4	210.46	37.49	172.97
Alfalfa	40.0	6,000.00	4,890.40	1,109.60
Oats	50.7	4,586.32	3,113.49	1,472.83
Fallow	8.2	0.00	0.00	0.00
Total	151.4	24,117.87	13,782.34	10,335.53
		Typical		
Cotton planted	39.54	11,597.48	4,799.37	6,798.11
Cotton diverted	12.96	1,130.24	194.40	935.84
Alfalfa	79.27	12,385.94	8,948.00	3,437.94
Oats	16.90	1,528.77	1,037.83	490.94
Fallow	2.73	0.00	0.00	0.00
Total	151.4	26,642.43	14,979.60	11,662.83

Table E11. Case Farm K: Expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
		1966		
Cotton planted	26.1	9,368.86	4,216.72	5,152.14
Cotton diverted	1.4	127.89	18.98	108.91
Alfalfa	50.0	8,000.00	6,163.50	1,836.50
Fallow	1.5	0.00	0.00	0.00
Total	79.0	17,496.75	10,399.20	7,097.55
		1967		
Cotton planted	17.9	9,672.62	3,313.29	6,359.33
Cotton diverted	9.6	874.46	154.18	720.28
Alfalfa	32.1	4,943.40	3,571.13	1,372.27
Grain sorghum	17.6	2,059.20	1,129.39	929.81
Fallow	1.8	0.00	0.00	0.00
Total	79.0	17,549.68	8,167.99	9,381.69
		1968		
Cotton planted	26.1	10,142.20	4,702.70	5,429.50
Cotton diverted	1.4	131.05	19.03	112.02
Alfalfa	67.40	5,486.25	4,683.46	802.79
Grain sorghum	12.5	1,543.75	987.75	646.00
Fallow	7.0	0.00	0.00	0.00
Total	114.40	17,303.25	10,302.94	7,000.31
		Typical		
Cotton planted	23.37	10,032.97	4,104.01	5,928.96
Cotton diverted	4.13	380.04	59.47	320.57
Alfalfa	40.66	6,120.84	4,770.59	1,350.25
Grain sorghum	10.03	1,206.11	682.04	524.07
Fallow	3.43	0.00	0.00	0.00
Total	81.62	17,739.96	9,616.11	8,123.85

Table E12. Case Farm L: Expenses and returns by crop, Roswell Artesian Basin, New Mexico.

Crop	Acres	Gross Returns (dollars)	Gross Expenses (dollars)	Net Returns to Land and Management (dollars)
		1966		
Cotton planted	46.20	14,280.88	7,486.71	6,794.17
Cotton diverted	6.65	579.55	76.61	502.17
Alfalfa	79.95	14,311.05	11,603.94	2,707.11
Corn silage	18.90	1,276.70	741.45	535.25
Total	151.70	30,448.18	19,908.71	10,539.47
		1967		
Cotton planted	52.85	22,394.66	8,626.18	13,768.48
Cotton diverted	28.45	1,362.45	190.13	1,172.32
Alfalfa	85.20	15,029.28	10,212.92	4,816.36
Total	166.50	38,786.39	19,029.23	19,757.16
		1968		
Cotton planted	77.45	16,032.92	11,301.50	4,731.42
Cotton diverted	4.10	324.27	52.81	271.46
Alfalfa	70.15	11,048.63	8,147.22	2,901.41
Total	151.70	27,405.82	19,501.53	7,904.29
		Typical		
Cotton planted	58.83	19,195.64	9,239.84	9,955.80
Cotton diverted	13.07	1,107.94	159.06	948.88
Alfalfa	78.43	12,940.95	9,964.53	2,976.42
Corn silage	6.30	425.57	247.15	178.42
Total	156.63	33,670.10	19,610.58	14,059.52