# Projections of farmer response to a falling groundwater table : a marriage of economic and hydrological models.

# PROJECTIONS OF FARMER RESPONSE TO A FALLING GROUNDWATER TABLE: A MARRIAGE OF ECONOMIC AND HYDROLOGIC MODELS

by

Thomas George Burdak

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## APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

William E. Martin
WILLIAM E. MARTIN
Professor of Agricultural Economics

1 July 1970
Date

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# ABSTRACT

The groundwater problems of central Arizona are illustrative of most of the important groundwater management problems encountered in other arid regions. Large-scale pumpage of underground water for crop irrigation was followed by a rapid decline in the underground water level. Public concern was expressed as to the future of agriculture and other water-using industries in the fact of the falling water table and thus the increasing water costs. Various short- and long-run remedies have been proposed for resolving these problems, including large-scale interbasin water transfers, pumpage limitations, pumpage taxes, and continuation of the present policies without new regulation or augmentation.

In order to provide objective criteria for selecting between alternative public policies, it is necessary to project the consequences of each. To do so requires that the interactions through time between the water using sectors of the economy and the physical state of the aquifer be estimated. For this purpose a procedure incorporating dynamic properties into both formal economic and hydrologic models was devised. Previous empirical projections of either hydrologic or economic activity have taken the other activity as largely given.

The integrated model is described, the empirical results of 50 year projections for a case study of Pinal County are presented, the results are compared to an earlier study of the same area which used a less sophisticated procedure, and tentative policy implications are drawn.

CHAPTER I

# INTRODUCTION

## The Problem

The State of Arizona covers approximately 72 million acres. Although most of its valley desert soil is adaptable to cultivation, only about one million acres, or 1.4% of the state's total, are irrigated and used for growing crops because of the limited water available in the state.

Despite this fact, Arizona has some of the largest farms and farm incomes in the nation. Average farm size is much larger than the national average, and Arizona farm incomes have tended to be the highest in the nation.

The character of irrigated agriculture differs widely throughout the state due to the broad range of climatic and geographic conditions encountered. Some areas rely entirely on groundwater supplies for irrigation purposes. Others obtain water for irrigation by diverting surface water. In many areas, water is obtained from both sources. Such is the case in Pinal County, the area with which this study is concerned.

Pinal County has a population of about 62,000 people (19) and is located about midway between Tucson and Phoenix, the two main population centers of the state. This county contains some of the largest farms within Arizona. It contained about 18 percent of the 1.2 million acres of cropland irrigated in Arizona in 1967 (6). The main crops grown in this county are cotton, alfalfa, grain sorghum, barley, and wheat. Of these, cotton is by far the most important crop in terms of net income to the farmer.

The most talked about "problem" facing Arizonans is a rising cost for water brought about by a continuing decline in the groundwater table of the state. With the water table presently declining at the rate of several feet per year in central Arizona (including Pinal County), water costs are increasing both because of the fixed cost of extending present wells to greater depths and the variable cost of pumping the water a greater distance to the surface. While the increasing cost to people living in cities is nominal since they use such small amounts yearly, this is not so for farmers who together use over 90 percent of the water consumed in Arizona annually. Water costs are a significant part of the Arizona farmer's budget.

The question arises as to what adjustments Pinal County farmers will make in the future as their water costs continue to increase. Specifically, how will factor use, cropping patterns, yields, and net income change as farmers react to increasing water costs? If these reactions could be projected, one could then further project the indirect effects of farmer adjustments on the nonfarm community, and finally, estimate the value of water to the entire farm and nonfarm economy.

It is to this end that a larger program of research on water resources is directed.[1] This larger study has been formulated in the following manner: Farmer adjustments are to be projected for each of seven irrigated farming areas containing the vast majority of Arizona's cropland. The results of these individual studies are to be aggregated, and then used in conjunction with an interindustry model of the state (18) to estimate indirect nonfarm effects. Five of these seven farming area studies have been completed (4, 8, 9, 10, 15). The study by Stults (15) focused on farming adjustments in Pinal County.

However, a detailed model of the hydrology of the groundwater basin was not available to Stults, thus it was necessary that he assume "that water withdrawals would have the same impact on the declining water table as had been recorded in the past" (15). Some suspicion of his results was expressed because of this simplifying assumption. This thesis repeats his analysis utilizing an electric analog model of the groundwater system recently completed by the

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1. This overall project is titled "Water in Relation to Social and Economic Growth in an Arid Environment" and is financed by a grant from the Rockefeller Foundation. It is under the general direction of Professor M. M. Kelso of the Department of Agricultural Economics, The University of Arizona.

U. S. Geological Survey, and introducing several other improvements into the economic portion of the model.

## Objectives

The major objective of this study is exactly the same as that of Stults'; that is, "to estimate probable changes in resource use, enterprise combinations, and net income to Pinal County farmers as their water table declines. Estimates will be made over a 50-year time period under given assumptions regarding prices, government programs and technology" (15).

Other objectives are:

1. To improve the accuracy of the Stults projections by refining the economic model with respect to the basic assumptions about resource availabilities.
2. To improve the accuracy of the Stults projections by using an electric analog model of the groundwater system rather than merely assuming impacts based on less reliable data.
3. To demonstrate a procedure whereby an economic optimizing model (linear programming) may be combined with a simulation model of a hydrologic system (electric analog) in order to achieve a dynamic system of projections over time.

## Procedure and Organization of This Thesis

Pinal County is divided into six subareas. These subareas are chosen mainly on the basis of depth to water; thus, the average pumping lift depth varies considerably between subareas, as well as within subareas. Pumping costs (and hence cost of water) differ with each pumping depth.

Division of the county into six subareas for individual consideration is one way in which this study differs from the earlier Stults study. As in his analysis, economic projections are made using linear programming. In this case, however, analyses of changes occurring within each of the subareas of Pinal County are conducted and then the results are added to provide an estimate of changes occurring in the county as a whole.

The linear programming models are for representative farms existing in each subarea. Resource restrictions are the physical quantities of resources available to typical farms within a given subarea. These restrictions are discussed in Chapter III. The objective functions are net returns over variable costs for each of four different size representative farms within each subarea.

The programming models are first solved for the base year, 1966. The cost of water is based on pumping costs by subarea, stratified by the amount of water available at three pumping depths (shallow, medium, and deep).

The results in terms of total pumpage by area are introduced into the electric analog model. The analog model estimates the change in water level at each of many points within each subarea. New pumping depth restrictions are estimated along with their respective pumping costs. These restrictions and costs are placed in a new economic model, and the procedure is repeated.

While the models could be run for each future year, they are actually run only once for each ten-year period. This is an approximation procedure in order to save time and money. The calculations necessary in setting up each successive model are extremely laborious.

Chapter II introduces the crop budgets used to develop the technical coefficients and objective functions of the economic models. This chapter also discusses water production functions and pumping depths in the six subareas of Pinal County. Chapter III presents the manner in which aggregate resource restrictions for Pinal County were allocated among and within the six subareas. The linear programming model is the topic of Chapter IV. The analog model is presented in Chapter V, while Chapter VI contains the results and conclusions.

## Source of Data and Definition of Subareas

The basis of the economic model is a detailed description of the organizations, costs, and returns of the farms in Pinal County, Arizona, developed by Stults (16) from a 17-page personal interview questionnaire for 30 percent of all farms over 25 acres in size and, because a larger proportion of large sized farms was sampled, 38 percent of the field crop acreage.

Several corrections in the Stults budgets were necessary. The questionnaires themselves were used to allocate resources among subareas of the county.

The hydrologic model is the relevant portion of the electric-analog of the Central Arizona groundwater system developed by Anderson. The data used and their construction and testing are described in Anderson (1).

The subareas are named as follows: Casa Grande, Eloy, Coolidge, Queen Creek, Maricopa, and Stanfield. Five of these subareas are illustrated and defined in Figure 1. The Queen Creek subarea, lying in the northeast corner of the county, is not shown since it is outside of groundwater basin illustrated by this map. Queen Creek is included in the economic models, but since it is outside of the basin covered by the hydrologic system, groundwater decline estimates are handled separately.

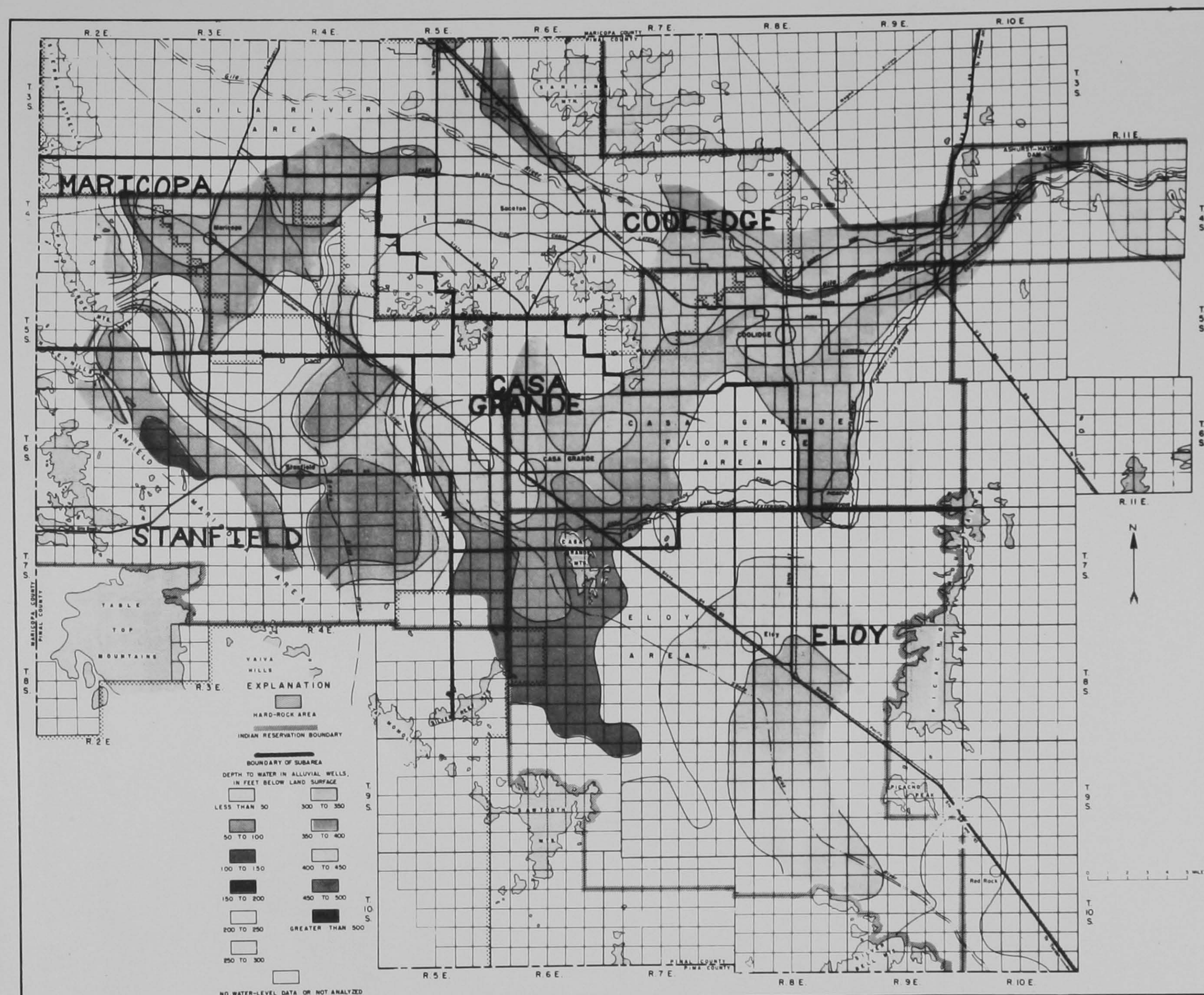

Figure 1. Map Depicting Five of Six Subareas of this Analysis

# CHAPTER II

# REPRESENTATIVE COSTS AND RETURNS

The linear programming model requires that net revenue per acre be calculated for each process (technique) by which each crop is grown. This chapter discusses the derivation of costs and returns for those crops typically grown in Pinal County. Budgets are developed for each of the main crops--short staple (upland) cotton, long staple (American-Egyptian) cotton, barley, grain sorghum, alfalfa, and wheat--stratified in the detail necessary for the model.

## Farm Sizes

Costs and returns per acre typically vary by farm size because of economies due to size. Stults divided the farms in Pinal County into four size groups for cost and return analysis. His definitions of Farm Sizes I, II, III, and IV are given in Table 1.

## Pumping Lifts

The variable factor around which this study revolves is the cost of water. Since nearly all farmers in Pinal County pump their water, the water cost to most farmers is the cost of pumping the water used. Since the cost of pumping water varies with pumping lift, Stults divided

Table 1. Breakdown of Pinal County Farms Into Four Size Groups

| Size Group | Range of Cropped Acres | Average Cropped Acres |
|---|---|---|
| Farm Size I | 0-220 | 106 |
| Farm Size II | 221-520 | 341 |
| Farm Size III | 521-960 | 675 |
| Farm Size IV | 961 and above | 1,705 |

Source: (15).

pumping lifts into three categories: "shallow," "middle," and "deep." These three pumping lifts are defined in Table 2.

Table 2. Pumping Lifts Defined

| Pumping Depth | Range of Pumping Depth | Weighted Average Depth; 1966 |
|---|---|---|
| | Feet | |
| Shallow | 0-349 | 315 |
| Middle | 350-499 | 460 |
| Deep | 500 and greater | 540 |

Source: (15).

Thus, a "shallow" lift is one from which water is pumped from a depth ranging from less than one foot up to a depth of 349 feet. Using the information on his schedules, Stults calculated the average depth of all wells pumping from the "shallow" range, weighted by pump capacity, to be 315 feet. The same was done for wells having "middle" and "deep" lifts. Water cost is then determined by multiplying the cost per acre-foot per foot of lift times the weighted average depth of that pumping lift. Some surface water is available from an irrigation district in two of the areas within the county.

Production Functions for Water

Theoretically, given the cost of water and the water-yield response relationship, the farmer should be able to determine the optimal amount of water use per acre for any crop in order to maximize profits. The higher the price of water (the deeper the lift), the less water should be used per acre.

In analyzing the schedules of his farm survey, Stults found that such a relationship does in fact exist. Stults estimated the rates of water use, as reported by farmers, according to the depth from which water was being pumped. He assumed the pumping rates reported to be optimum. Arraying the amount of water farmers reported using for solid-planted short-staple cotton according to pumping depth, he found that half the water used to grow cotton is within one-half acre-foot of the mean rate of water use of five acre-feet. The other half of the water is divided about equally among farmers using more than 5.5 acre-feet and those using less than 4.5 acre-feet. Farmers using more than 5.5 acre-feet use an average of about six acre-feet, and those using less than 4.5 acre-feet average about four acre-feet. These relationships are portrayed below for short-staple cotton.

| | Rate of Water Use (acre-feet) | Pumping Cost (dollars) | Product Price (cents) |
|---|---|---|---|
| "Shallow" (315 ft.) | 6 | 6.78 | 31 |
| "Middle" (460 ft.) | 5 | 9.90 | 31 |
| "Deep" (540 ft.) | 4 | 11.62 | 31 |

The yield response which just offsets the cost saved by moving from six to five acre-feet when pumping lifts drop from "shallow" to "middle" lifts was calculated by Stults to be 32 pounds. Similarly, the yield response that offsets the cost of moving from five to four acre-feet as pumping lifts drop from "middle" to "deep" is 37 pounds. Stults used this method to estimate the water response functions for all crops considered in this study, except alfalfa. Alfalfa was considered to have a linear yield-water use relationship over the range of yields used. Table 3 depicts

Table 3. Yield-Water Use Relationships, Field Crops, Pinal County, 1966

| Crop | "Shallow" Pumping Lift | | "Middle" Pumping Lift | | "Deep" Pumping Lift | |
|---|---|---|---|---|---|---|
| | Water Use | Yield | Water Use | Yield | Water Use | Yield |
| | (acre-feet) | | (acre-feet) | | (acre-feet) | |
| American-Egyptian cotton, solid-planted | 6.0 | 610 lbs. | 5.0 | 587 lbs. | 4.0 | 557 lbs. |
| American-Egyptian cotton, skip-row | 7.0 | 766 lbs. | 6.0 | 743 lbs. | 5.0 | 713 lbs. |
| Upland cotton, solid-planted | 6.0 | 1,065 lbs. | 6.0 | 1,033 lbs. | 4.0 | 996 lbs. |
| Upland cotton, skip-row | 7.0 | 1,272 lbs. | 6.0 | 1,240 lbs. | 5.0 | 1,203 lbs. |
| Barley | 3.0 | 3,621 lbs. | 2.5 | 3,400 lbs. | 2.0 | 3,107 lbs. |
| Grain Sorghum Farm Sizes I and II | 3.29 | 4,350 lbs. | 2.75 | 4,130 lbs. | 2.17 | 3,765 lbs. |
| Grain Sorghum Farm Sizes III and IV | 3.29 | 4,550 lbs. | 2.75 | 4,330 lbs. | 2.17 | 3,965 lbs. |
| Alfalfa (without summer water) | 4.58 | 4 tons | 4.58 | 4 tons | 4.58 | 4 tons |
| Alfalfa (with summer water) | 6.58 | 6 tons | 6.58 | 6 tons | 6.58 | 6 tons |
| Wheat | 3.5 | 2,888 lbs | 3.0 | 2,688 lbs. | 2.5 | 2,424 lbs. |

Source: (15).

the yield-water use relationship Stults developed for the various crops grown in Pinal County.

## Pumping Costs in the Six Subareas

Stults estimated average pumping costs for Pinal County to be $.021524 per acre-foot per foot of lift. The method of estimation is given by Nelson and Busch (12). This pumping cost is a weighted average cost for four electrical districts and one area using natural gas.

Since economies of size also affect the efficiency with which water is used, pumping costs also differ by farm size. Water use per cropped acre by farm size is shown below as a percent of the mean rate of water used.

| | Farm Size | | | |
|---|---|---|---|---|
| | I | II | III | IV |
| Percent | 114 | 108.5 | 104 | 95.5 |

Possible reasons for this variation in efficiency of water use are given by Stults as follows:

1. Large farms tend to have a larger proportion of their ditches lined with concrete.
2. The level of management may increase as farm size increases.
3. Larger farms are usually leveled to a more optimum grade, thereby increasing irrigation efficiency.

Using data put together by Stults in his calculation of an average pumping cost for Pinal County, in combination with power costs by area, it is possible to derive approximate pumping costs in the various subareas of this study. The costs of an acre-foot of water per foot of lift determined for the six subareas are as follows:

| Subarea | Pumping Costs (AF/Foot of Lift) |
|---|---|
| Casa Grande | $.022922 |
| Coolidge | .022922 |
| Eloy | .018685 |
| Maricopa | .022497 |
| Stanfield | .022497 |
| Queen Creek | .022922 |

In order to obtain the pumping cost for a particular size farm pumping from a certain depth ("shallow," "middle," or "deep") in one of these subareas, one first multiplies the appropriate pumping cost (acre-foot per foot of lift) times the efficiency factor for that farm size. This result is then multiplied times the weighted average depth of that pumping lift to obtain the cost of one acre-foot of water.

Calculation of a weighted average depth for "shallow," "middle," and "deep" lifts in a given subarea is accomplished by arraying the wells from the survey in that subarea in ascending order according to total output and pumping depth, and a weighted average depth for "shallow" lifts in that subarea is calculated. The same is done for "middle" and "deep" lift wells. Table 4 gives the results of this type of analysis for each of the six subareas for 1966.

Table 5 gives the pumping cost for each farm size and associated pumping lift within the six subareas. The Queen Creek subarea contains no farms of Size I; the Maricopa subarea has no farms of Size I or II; and the Stanfield subarea contains no farms with "shallow" pumping lifts. "Shallow," "middle," and "deep" lifts are symbolized as S, M, and D in the table.

In addition to calculation of these pumping costs, the arraying of wells in the various subareas enables one to determine the percentages of water being pumped from "shallow," "middle," and "deep" lifts within each subarea. These percentages are given in Table 6.

## Calendars of Operations

Detailed calendars of operations necessary to calculate the technical coefficients for the linear programming model and obtain net revenue estimates for the objective function of the model are given by Stults (15). Only summary budgets derived from his calendars of operations are given here. Tables 7 through 15 present consolidated summaries of the gross revenues, variable costs, and net

Table 4. Average Pumping Lift for "Shallow," "Middle," and "Deep" Lifts in the Six Subareas, 1966

| Subarea | Weighted Average Depth |
|---|---|
| | (feet) |
| Casa Grande | |
| "Shallow" Lift | 264 |
| "Middle" Lift | 422 |
| "Deep" Lift | 500 |
| Coolidge | |
| "Shallow" Lift | 264 |
| "Middle" Lift | 398 |
| "Deep" Lift | 504 |
| Eloy | |
| "Shallow" Lift | 332 |
| "Middle" Lift | 421 |
| "Deep" Lift | 526 |
| Maricopa | |
| "Shallow" Lift | 259 |
| "Middle" Lift | 427 |
| "Deep" Lift | 570 |
| Stanfield | |
| "Shallow" Lift | -- |
| "Middle" Lift | 468 |
| "Deep" Lift | 514 |
| Queen Creek | |
| "Shallow" Lift | 320 |
| "Middle" Lift | 443 |
| "Deep" Lift | 505 |

Table 5. Pumping Costs for Six Subareas According to Farm Size and Pumping Depth, 1966

| | Subarea | | | | | |
|---|---|---|---|---|---|---|
| | Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek |
| | Dollars per acre-foot | | | | | |
| Farm Size I | | | | | | |
| S | 6.90 | 6.90 | 7.07 | -- | -- | -- |
| M | 11.03 | 10.40 | 8.97 | -- | 12.00 | -- |
| D | 13.07 | 13.17 | 11.20 | -- | 13.18 | -- |
| Farm Size II | | | | | | |
| S | 6.57 | 6.57 | 5.73 | -- | -- | 7.96 |
| M | 10.50 | 9.90 | 8.53 | -- | 11.42 | 11.02 |
| D | 12.44 | 12.53 | 10.66 | -- | 12.55 | 12.56 |
| Farm Size III | | | | | | |
| S | 6.29 | 6.29 | 6.45 | 6.06 | -- | 7.63 |
| M | 10.06 | 9.49 | 8.18 | 9.99 | 10.95 | 10.56 |
| D | 11.92 | 12.01 | 10.22 | 13.34 | 12.03 | 12.04 |
| Farm Size IV | | | | | | |
| S | 5.78 | 5.78 | 5.92 | 5.56 | -- | 7.01 |
| M | 9.24 | 8.71 | 7.51 | 9.17 | 10.05 | 9.70 |
| D | 10.95 | 11.03 | 9.39 | 12.25 | 11.04 | 11.05 |

Table 6. Percentages of Total Output of Water in Each Subarea Pumped from "Shallow," "Middle," and "Deep" Lifts, 1966

| | Pumping Lifts | | |
|---|---|---|---|
| | "Shallow" | "Middle" | "Deep" |
| | Percent | | |
| Casa Grande | 40 | 55 | 5 |
| Coolidge | 55 | 43 | 2 |
| Eloy | 10 | 50 | 40 |
| Maricopa | 30 | 50 | 20 |
| Stanfield | 0 | 55 | 45 |
| Queen Creek | 9 | 17 | 74 |

Table 7. Gross Revenue, Pumping Costs, Other Variable Costs, and Revenue Over Variable Cost Per Acre, Short Staple Cotton, Solid Planted

| | Gross Revenue | Pumping Cost | Other Variable Costs | Net Revenue |
|---|---|---|---|---|
| | Dollars | | | |
| Farm Size I | | | | |
| Shallow | 408.21 | 46.38 | 156.96 | 204.87 |
| Middle | 396.92 | 56.45 | 154.19 | 186.28 |
| Deep | 383.68 | 52.96 | 150.92 | 179.80 |
| Farm Size II | | | | |
| Shallow | 407.66 | 44.16 | 139.35 | 224.15 |
| Middle | 396.92 | 53.70 | 136.85 | 206.37 |
| Deep | 384.31 | 50.44 | 133.05 | 200.82 |
| Farm Size III | | | | |
| Shallow | 407.22 | 42.30 | 130.41 | 234.51 |
| Middle | 396.92 | 51.50 | 128.89 | 216.53 |
| Deep | 384.84 | 48.32 | 125.91 | 210.61 |
| Farm Size IV | | | | |
| Shallow | 406.37 | 38.82 | 127.74 | 239.81 |
| Middle | 396.92 | 47.25 | 125.50 | 224.17 |
| Deep | 385.83 | 44.36 | 122.81 | 218.66 |

Source: (15).

Table 8. Gross Revenue, Pumping Cost, Other Variable Costs, and Revenue Over Variable Costs Per Acre, Short Staple Cotton, Skip-Row Planted

| | Gross Revenue | Pumping Cost | Other Variable Costs | Net Revenue |
|---|---|---|---|---|
| | --------------- | --------Dollars-------- | --------------- | |
| Farm Size I | | | | |
| Shallow | 487.64 | 54.11 | 175.45 | 258.08 |
| Middle | 476.35 | 67.74 | 172.85 | 235.76 |
| Deep | 463.11 | 66.20 | 169.62 | 227.29 |
| Farm Size II | | | | |
| Shallow | 487.08 | 51.52 | 155.79 | 279.77 |
| Middle | 476.35 | 64.44 | 153.39 | 258.52 |
| Deep | 463.74 | 63.05 | 150.43 | 250.26 |
| Farm Size III | | | | |
| Shallow | 486.65 | 49.35 | 149.77 | 287.53 |
| Middle | 476.35 | 61.80 | 147.35 | 267.20 |
| Deep | 464.27 | 60.40 | 144.39 | 259.48 |
| Farm Size IV | | | | |
| Shallow | 485.80 | 45.29 | 145.24 | 295.27 |
| Middle | 476.35 | 56.70 | 143.07 | 276.58 |
| Deep | 469.88 | 55.45 | 140.40 | 274.03 |

Source: (15).

Table 9. Gross Revenue, Pumping Cost, Other Variable Costs, and Revenue Over Variable Costs Per Acre, Long Staple Cotton, Solid Planted

| | Gross Revenue | Pumping Cost | Other Variable Costs | Net Revenue |
|---|---|---|---|---|
| | ------------------Dollars------------------ | | | |
| Farm Size I | | | | |
| Shallow | 275.01 | 46.38 | 156.96 | 71.67 |
| Middle | 261.21 | 56.45 | 154.19 | 50.57 |
| Deep | 245.64 | 52.96 | 150.92 | 41.76 |
| Farm Size II | | | | |
| Shallow | 274.12 | 44.16 | 139.35 | 90.61 |
| Middle | 261.21 | 53.70 | 136.85 | 70.66 |
| Deep | 246.53 | 50.44 | 133.05 | 63.04 |
| Farm Size III | | | | |
| Shallow | 269.22 | 42.30 | 130.41 | 96.51 |
| Middle | 261.21 | 51.50 | 128.89 | 80.82 |
| Deep | 246.98 | 48.32 | 125.91 | 72.75 |
| Farm Size IV | | | | |
| Shallow | 272.34 | 38.82 | 127.74 | 105.78 |
| Middle | 261.21 | 47.25 | 125.50 | 88.46 |
| Deep | 248.31 | 44.36 | 122.81 | 81.14 |

Source: (15).

Table 10. Gross Revenue, Pumping Cost, Other Variable Costs, and Revenue Over Variable Costs Per Acre, Long Staple Cotton, Skip-Row Planted

| | Gross Revenue | Pumping Cost | Other Variable Costs | Net Revenue |
|---|---|---|---|---|
| | ------------------Dollars------------------ | | | |
| Farm Size I | | | | |
| Shallow | 334.43 | 54.11 | 175.45 | 104.88 |
| Middle | 330.63 | 67.71 | 172.85 | 90.04 |
| Deep | 315.06 | 66.20 | 169.62 | 79.24 |
| Farm Size II | | | | |
| Shallow | 343.54 | 51.52 | 155.79 | 136.22 |
| Middle | 330.63 | 64.44 | 153.39 | 112.80 |
| Deep | 315.95 | 63.05 | 150.43 | 102.47 |
| Farm Size III | | | | |
| Shallow | 343.09 | 49.35 | 149.77 | 143.97 |
| Middle | 330.63 | 61.80 | 147.35 | 121.48 |
| Deep | 316.37 | 60.40 | 144.39 | 111.60 |
| Farm Size IV | | | | |
| Shallow | 341.76 | 45.29 | 145.24 | 151.23 |
| Middle | 330.63 | 56.70 | 143.07 | 130.86 |
| Deep | 317.73 | 55.45 | 140.40 | 121.88 |

Source: (15).

Table 11. Gross Revenue, Pumping Cost, Other Variable Costs, and Revenue Over Variable Costs Per Acre, Barley

| | Gross Revenue | Pumping Cost | Other Variable Costs | Net Revenue |
|---|---|---|---|---|
| | --------------------Dollars------------------ | | | |
| Farm Size I | | | | |
| Shallow | 92.45 | 23.19 | 39.84 | 29.42 |
| Middle | 85.00 | 28.22 | 38.70 | 18.08 |
| Deep | 75.67 | 26.48 | 37.36 | 11.83 |
| Farm Size II | | | | |
| Shallow | 91.50 | 22.08 | 38.60 | 30.82 |
| Middle | 85.00 | 26.85 | 37.53 | 20.62 |
| Deep | 77.52 | 25.22 | 36.22 | 16.08 |
| Farm Size III | | | | |
| Shallow | 91.27 | 21.15 | 38.32 | 31.80 |
| Middle | 85.00 | 25.75 | 37.22 | 22.03 |
| Deep | 77.80 | 24.16 | 35.88 | 17.76 |
| Farm Size IV | | | | |
| Shallow | 90.70 | 19.41 | 38.01 | 33.28 |
| Middle | 85.00 | 23.62 | 37.02 | 24.36 |
| Deep | 78.45 | 22.18 | 35.81 | 20.46 |

Source: (15).

Table 12. Gross Revenue, Pumping Cost, Other Variable Costs, and Revenue Over Variable Costs Per Acre, Grain Sorghum

| | Gross Revenue | Pumping Cost | Other Variable Costs | Net Revenue |
|---|---|---|---|---|
| | ---Dollars--- | | | |
| Farm Size I | | | | |
| Shallow | 100.42 | 25.43 | 49.74 | 25.25 |
| Middle | 92.92 | 31.05 | 48.35 | 13.52 |
| Deep | 83.54 | 28.73 | 46.62 | 8.19 |
| Farm Size II | | | | |
| Shallow | 100.66 | 24.21 | 48.10 | 28.35 |
| Middle | 92.93 | 29.54 | 46.84 | 16.55 |
| Deep | 84.10 | 27.36 | 45.93 | 10.81 |
| Farm Size III | | | | |
| Shallow | 104.24 | 23.19 | 47.73 | 33.32 |
| Middle | 97.42 | 28.32 | 46.46 | 22.64 |
| Deep | 88.92 | 26.21 | 44.93 | 17.78 |
| Farm Size IV | | | | |
| Shallow | 103.61 | 21.28 | 48.29 | 34.04 |
| Middle | 97.42 | 25.98 | 47.16 | 24.28 |
| Deep | 89.68 | 24.06 | 45.77 | 19.85 |

Source: (15).

Table 13. Gross Revenue, Pumping Cost, Other Variable Costs, and Revenue Over Variable Costs Per Acre, Alfalfa Without Summer Water

| | Gross Revenue | Pumping Cost | Other Variable Costs | Net Revenue |
|---|---|---|---|---|
| | Dollars | | | |
| Farm Size I | | | | |
| Shallow | 109.50 | 35.42 | 60.82 | 13.26 |
| Middle | 109.50 | 51.75 | 61.14 | - 3.39 |
| Deep | 109.50 | 60.68 | 61.33 | -12.51 |
| Farm Size II | | | | |
| Shallow | 109.50 | 33.73 | 59.08 | 16.69 |
| Middle | 109.50 | 49.23 | 59.39 | .88 |
| Deep | 109.50 | 57.80 | 59.56 | - 7.86 |
| Farm Size III | | | | |
| Shallow | 109.50 | 32.31 | 57.67 | 19.52 |
| Middle | 109.50 | 47.21 | 57.96 | 4.33 |
| Deep | 109.50 | 55.37 | 58.12 | - 3.99 |
| Farm Size IV | | | | |
| Shallow | 109.50 | 29.65 | 56.71 | 23.14 |
| Middle | 109.50 | 43.31 | 56.99 | 9.20 |
| Deep | 109.50 | 50.83 | 57.14 | 1.53 |

Source: (15).

Table 14. Gross Revenue, Pumping Cost, Other Variable Costs, and Revenue Over Variable Costs Per Acre, Alfalfa With Summer Water

| | Gross Revenue | Pumping Cost | Other Variable Costs | Net Revenue |
|---|---|---|---|---|
| | --------------------Dollars------------------ | | | |
| Farm Size I | | | | |
| Shallow | 159.50 | 50.88 | 80.82 | 27.80 |
| Middle | 159.50 | 74.33 | 81.14 | 4.03 |
| Deep | 159.50 | 87.16 | 81.33 | - 8.99 |
| Farm Size II | | | | |
| Shallow | 159.50 | 50.14 | 76.89 | 32.47 |
| Middle | 159.50 | 70.71 | 79.19 | 9.90 |
| Deep | 159.50 | 83.02 | 79.06 | - 2.58 |
| Farm Size III | | | | |
| Shallow | 159.50 | 46.41 | 77.17 | 35.92 |
| Middle | 159.50 | 67.81 | 77.46 | 14.23 |
| Deep | 159.50 | 79.53 | 77.62 | 2.35 |
| Farm Size IV | | | | |
| Shallow | 159.50 | 42.59 | 75.71 | 41.20 |
| Middle | 159.50 | 62.21 | 75.99 | 21.30 |
| Deep | 159.50 | 73.01 | 76.14 | 10.35 |

Source: (15).

Table 15. Gross Revenue, Pumping Cost, Other Variable Costs, and Revenue Over Variable Costs Per Acre, Wheat

| | Gross Revenue | Pumping Cost | Other Variable Costs | Net Revenue |
|---|---|---|---|---|
| | ---------------------Dollars------------------ | | | |
| Farm Size I | | | | |
| Shallow | 81.81 | 37.05 | 40.12 | 14.64 |
| Middle | 73.92 | 33.87 | 38.84 | 1.21 |
| Deep | 67.01 | 29.79 | 37.38 | - .16 |
| Farm Size II | | | | |
| Shallow | 80.38 | 25.16 | 39.46 | 15.76 |
| Middle | 73.92 | 32.22 | 38.35 | 3.35 |
| Deep | 66.47 | 28.37 | 37.01 | 1.09 |
| Farm Size III | | | | |
| Shallow | 80.16 | 24.68 | 38.07 | 16.41 |
| Middle | 73.92 | 30.90 | 37.96 | 5.06 |
| Deep | 66.74 | 27.18 | 36.96 | 2.60 |
| Farm Size IV | | | | |
| Shallow | 79.61 | 22.64 | 38.09 | 18.88 |
| Middle | 73.92 | 28.35 | 37.12 | 8.45 |
| Deep | 67.40 | 24.95 | 35.94 | 6.51 |

Source: (15).

revenues for the alternative crops which may be grown in Pinal County, by farm size and pumping lift. These budgets shown have not been adjusted for differing pumping costs by subareas of the county. These adjustments may be seen by inspecting the linear programming matrices shown in Chapter IV of this thesis.

## CHAPTER III

## ALLOCATIONS OF RESTRICTIONS

The Stults analysis considered Pinal County as one area. This study runs the same analysis that he conducted for the county in each of six subareas comprising the county and then aggregates the results for the purpose of comparison with his study.

The restrictions used in the linear programming models of Stults were total irrigation water used during two critical periods of the year ("July water" and "January water"), total cropped acres, long staple and short staple cotton allotments, and conserving base acres.

The following is a presentation of the manner in which the aggregate data for Pinal County were distributed among the farms and pumping depths of the six subareas of this analysis.

### Distribution of Restrictions Among Subareas and Farm Sizes

Stults' restrictive resources not only had to be properly allocated to the six subareas of this analysis, but also to four farm sizes within each subarea. The economic model of this analysis, like the earlier Stults study, contains four farm sizes in order to account for economies of size. The following section indicates the means by which aggregate restrictions for Pinal County were allocated to the six subregions and to farm sizes within each subregion. The next section shows how the restrictions were further distributed among pumping lifts.

Allocation of Water to Subareas and Farm Size

The July Water restriction corresponds to water availability during a peak period of water use, running from July 1 to July 15. It largely affects possible acreages of cotton, alfalfa, and grain sorghum.

The January Water restriction is the quantity of water *typically* used by farmers in the six-week period following January 15. This restriction corresponds to water use during the period when barley and wheat are irrigated and cotton is preirrigated. Unless limited by the availability of land, barley and wheat acreages are determined by this water restriction. Distribution of these two restrictions are discussed in turn.

*Allocation to Subareas*. July Water for Pinal County as a whole was determined by Stults to be 88,163 acre-feet in 1966. Of this amount, it was calculated that 82.98 percent, or 73,158 acre-feet, are pumped from private wells and 15,005 acre-feet are supplied by the San Carlos Project.

The 73,158 acre-feet of water pumped by private wells during this two-week period was first allocated among subareas. The addresses on the schedules which Stults collected during his 1964 farm survey enable placing of the farms in his sample into the various subareas of this study. His sample consisted of 112 farms within the county. The whole county contains a total of 400 farms (15, pp. 104-105). The wells on each farm, and the maximum output of each well, were recorded on his schedules. These data allow one to calculate the total water pumped from each subarea during a specified period of time when all wells are pumping at their maximum capacity. Such a period of time is the one which runs July 1 through July 15.

Using the information on the Stults schedules, it was found that of the total water being pumped during this two-week period in July, the percentages shown in Table 16 are pumped from the various subareas of this study.

Although the above method allows one to allocate water from private wells (multiply 73,158 acre-feet by the appropriate percentage), 15,005 acre-feet of water are supplied during this two-week period by the San Carlos Project. The San Carlos Project is a surface water irrigation project in Pinal County which supplies water to farms having "water rights" connected with them. This irrigation project is located within the Casa Grande and Coolidge Areas of this study (5, Figure 1, p. 10).

It was calculated that approximately 40 percent, or 6,002 acre-feet of this 15,005 acre-feet of water is

Table 16. Percentages of Water Pumped from Subareas During Peak Pumpage Periods, 1966[a]

| Subarea | Percentage of Total Water Pumped |
|---|---|
| Casa Grande | 22.36 |
| Coolidge | 16.19 |
| Eloy | 31.48 |
| Maricopa | 13.32 |
| Stanfield | 9.04 |
| Queen Creek | 7.61 |
| Total | 100.00 |

[a]Based on well output obtained from Stults' schedules.

distributed to Indian lands. This estimate was based on data which gave the division of 165,378 acre-feet of 1962 San Carlos Project water as follows: 68,488 acre-feet to Indian lands and 96,890 acre-feet to District lands (13, p. 8). All Indian lands which are part of the San Carlos Project are located in the Coolidge Area of this study.

Thus, 9,003 acre-feet of water were left to be distributed between the Casa Grande and Coolidge areas. Since this water is distributed on the basis of priorities, or "water rights," an estimate of this nature was made based on information compiled by H. C. Schwalen and J. H.

McCormick as reported in Cox (5, p. 23). Class I priorities have rights to about 26 percent of the District project water; Class II have rights to about 28 percent of the water; and Class III have rights to about 46 percent of the project water distributed to the District. On this basis, the 9,003 acre-feet of water were first distributed on the basis of priorities with the following results:

| Priority Class | Distributed Water (acre-feet) |
|---|---|
| Class I | 2,341 |
| Class II | 2,521 |
| Class III | 4,141 |
| Total | 9,003 |

It was further estimated that Casa Grande contained about 18.8 percent of Class I priorities, 50 percent of Class II priorities, and 66.7 percent of Class III priorities. Coolidge thus had 81.2 percent of Class I priorities, 50 percent of Class II priorities, and 33.3 percent of Class III priorities. Casa Grande was allocated 4,463 acre-feet and Coolidge 4,540 acre-feet of the 9,003 acre-feet of San Carlos water distributed to the District lands during the July 1 to July 15 period.

Table 17 shows the final results obtained in allocating the aggregate July Water restriction of 88,163 acre-feet of water among the subareas of this study

Table 17. First[a] Allocation of the July Water Restriction Among Subareas

| Water Source | Subarea | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek | |
| | Acre-feet | | | | | | |
| Pumped from private wells | 16,358 | 11,844 | 23,030 | 9,745 | 6,614 | 5,567 | 73,158 |
| Project[b] water to Indian lands | | 6,002 | | | | | 6,002 |
| Project[b] water to District lands | 4,463 | 4,540 | | | | | 9,003 |
| Total | 20,821 | 22,386 | 23,030 | 9,745 | 6,614 | 5,567 | 88,163 |

[a]This is a tentative allocation. This table is adjusted as shown in Table 20.

[b]"Project" pertains to the San Carlos Irrigation Project.

according to the above methods. These estimates were later revised slightly in order to make the beginning restrictions of this study exactly match those of the Stults analysis. This revision is discussed later in this section.

January Water was allocated much more easily. The total restriction for the entire county in 1966 amounted to 185,144 acre-feet. This is exactly 2.10 times the total July Water restriction. This proportion holds in all cases for the 1966 Stults restrictions. The same proportion is therefore used in this analysis to distribute January Water to the subareas. January Water in a given area is 2.10 times the July Water in that area. (Recall that January Water is a six-week period, while July Water is only a 15-day period.)

Allocation to Farm Sizes. The water restrictions distributed to subareas have to be further allocated to the four farm sizes in each subarea. Analysis of the Stults schedules showed that of the total water pumped from each subarea, the percentages shown in Table 18 were pumped by each farm size.

However, both Casa Grande and Coolidge contain surface water. This water must also be distributed. It is assumed that the amount of surface water that should be distributed to a given farm size class within each of these two subareas is proportional to the amount of conserving

Table 18. Percentage of Water Pumped from Each Farm Size Within Each Subarea, 1966

| Farm Size | Subarea | | | | | |
|---|---|---|---|---|---|---|
| | Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek |
| | Percent | | | | | |
| I | 10.23 | 3.21 | 4.35 | 0 | 3.45 | 0 |
| II | 22.60 | 15.33 | 6.96 | 0 | 18.79 | 15.59 |
| III | 30.17 | 38.16 | 25.37 | 33.11 | 21.67 | 9.10 |
| IV | 37.00 | 43.30 | 63.32 | 66.89 | 56.09 | 75.31 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |

base and cropped acres distributed to that farm size in that subarea. It is calculated that the 4,463 acre-feet of surface water in Casa Grande should be distributed to farm sizes according to the following percentages: Farm Size I, 6.7 percent; Farm Size II, 19.0 percent; Farm Size III, 21.3 percent; and Farm Size IV, 53.0 percent. The percentages by which the 10,542 acre-feet of surface water in Coolidge are allocated are: Farm Size I, 3.1 percent; Farm Size II, 12.6 percent; Farm Size III, 33.1 percent; and Farm Size IV, 51.1 percent.

When the pumped water and surface water for the six subareas are allocated as explained above, Table 19 is the result. However, Table 19 is adjusted so that aggregate July Water allocated to Farm Size I, II, III, and IV agrees with the Stults restrictions. This is accomplished by comparing the total water allocated to each farm size (as shown in Table 19) with the restrictions used by Stults. The differences between the two restrictions are then added (or subtracted) proportionally to the pumped water of each subarea (for that farm size) according to the percentage that that subarea contained of the total restriction. Thus, Table 20 is the final result of allocating July Water among farm sizes.

January Water is easily distributed to farm sizes once July Water has been allocated. Shown in Table 21 is

Table 19. First[a] Allocation of July Water in Each Subarea Among Farm Sizes, 1966

| Farm Size | Subarea: Casa Grande Pumped | Casa Grande Surface | Coolidge Pumped | Coolidge Surface | Eloy | Mari-copa | Stan-field | Queen Creek | Total | Stults Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | Acre-feet | | | | | | | | | |
| I | 1,673 | 299 | 380 | 327 | 1,002 | -- | 228 | -- | 3,909 | 3,170 |
| II | 3,698 | 848 | 1,816 | 1,328 | 1,604 | -- | 1,243 | 866 | 11,403 | 10,520 |
| III | 4,935 | 951 | 4,520 | 3,489 | 5,842 | 3,225 | 1,433 | 507 | 24,902 | 23,097 |
| IV | 6,052 | 2,365 | 5,128 | 5,398 | 14,583 | 6,520 | 3,710 | 4,193 | 47,949 | 51,376 |
| Total | 16,358 | 4,463 | 11,844 | 10,542 | 23,030 | 9,745 | 6,615 | 5,567 | 88,163 | 88,163 |

[a]This is a tentative allocation. This table is adjusted as shown in Table 20.

Table 20. Final Allocation of July Water in Each Subarea Among Farm Sizes, 1966

| Farm Size | Subarea | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Casa Grande | | Coolidge | | | | | |
| | Pumped | Surface | Pumped | Surface | Eloy | Maricopa | Stanfield | Queen Creek |
| | Acre-feet | | | | | | | |
| I | 1,297 | 299 | 294 | 327 | 776 | 0 | 177 | 0 |
| II | 3,344 | 848 | 1,642 | 1,329 | 1,450 | 0 | 1,124 | 784 |
| III | 4,500 | 951 | 4,121 | 3,489 | 5,327 | 2,841 | 1,307 | 461 |
| IV | 6,568 | 2,365 | 5,565 | 5,398 | 15,827 | 7,076 | 4,026 | 4,551 |
| Total | 15,709 | 4,463 | 11,622 | 10,542 | 23,380 | 10,017 | 6,634 | 5,796 |

Table 21. Allocation of January Water in Each Subarea Among Farm Sizes, 1966

| Farm Size | Subarea | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Casa Grande | | Coolidge | | | | | |
| | Pumped | Surface | Pumped | Surface | Eloy | Maricopa | Stanfield | Queen Creek |
| | Acre-feet | | | | | | | |
| I | 2,724 | 628 | 618 | 687 | 1,630 | -- | 372 | -- |
| II | 7,023 | 1,781 | 3,448 | 2,789 | 3,044 | -- | 2,361 | 1,646 |
| III | 9,450 | 1,997 | 8,654 | 7,327 | 11,186 | 6,176 | 2,745 | 968 |
| IV | 13,793 | 4,967 | 11,686 | 11,336 | 33,237 | 14,860 | 8,454 | 9,557 |
| Total | 32,990 | 9,373 | 24,406 | 22,139 | 49,097 | 21,036 | 13,932 | 12,171 |

the final allocation of January Water among farm sizes calculated by multiplying July Water by 2.10.

## Allocation of Land to Subareas and Farm Sizes

Two land restrictions are required. They are called Winter Acres and Summer Acres. Both represent the number of acres cropped within Pinal County in 1966. Two restrictions, rather than one, were used because barley and wheat require only winter acreage, while grain sorghum only requires summer acreage. Long staple and short staple cotton require both winter and summer acreage. Since Summer Acres always equals Winter Acres, only "cropped acres" is discussed.

Allocation to Subareas. As explained earlier, the farms included in the Stults survey were distributed to the various subareas to which they belong. Just as water was allocated to the subareas on the basis of this sample, so were cropped acres.

Farms in the Stults survey contain a total of 89,007 cropped acres. The percentage of these acres within each subarea was determined. In 1966, total cropped acres in the county were 197,070. These acres were distributed to the subareas as shown in Table 22.

Allocation to Farm Sizes. Cropped acres (land restrictions) were then distributed according to farm sizes

Table 22. Allocation of Cropped Acres to the Subareas, 1966

| | Subarea | | | | | | |
|---|---|---|---|---|---|---|---|
| | Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek | Total |
| Percentage of Sample Cropped Acres | 22.86 | 18.82 | 24.78 | 17.58 | 8.01 | 7.95 | 100.00 |
| Total Cropped Acres | 45,050 | 37,089 | 48,834 | 34,645 | 15,785 | 15,667 | 197,070 |

within a given subarea based on the percentage of sampled acres in each subarea associated with farms of Size I, II, III, and IV. Table 23 shows the results of this distribution for the six subareas.

### Allocation of Conserving Base to Subareas and Farm Sizes

Conserving base is land which must be set aside or on which alfalfa is the only crop which may be grown. It is not likely that this acreage will ever become a restriction in the linear programming model because of the large amount of land in this area relative to available water. It is included in the matrix, however, since alfalfa can use this land rather than the more restrictive Winter or Summer Acres.

The total conserving base for Pinal County in 1966 is taken by Stults to be 263,533 acres. These acres are first distributed among subareas and farm size by noting that in the Stults model, Farm Size I conserving base acres are 132.00 percent of cropped acres, 141.94 percent for Farm Size II, 136.09 percent for Farm Size III, and 131.50 percent for Farm Size IV. These percentages were used in conjunction with the estimates of cropped acres shown in Table 23.

However, the totals did not check with the Stults estimate. After proportional adjustments were made in order to meet the control total, Table 24 resulted. In this final table, conserving base is a constant percentage of

Table 23. Allocation of Cropped Acres in Each Subarea to Farm Sizes, 1966

| Farm Size | Subarea | | | | | |
|---|---|---|---|---|---|---|
| | Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek |
| | ---Acres--- | | | | | |
| I | 3,604 | 1,038 | 1,611 | -- | 426 | -- |
| II | 9,325 | 5,007 | 3,028 | -- | 2,668 | 2,115 |
| III | 12,208 | 12,722 | 11,134 | 10,185 | 3,110 | 1,238 |
| IV | 19,913 | 18,322 | 33,061 | 24,460 | 9,581 | 12,314 |
| Total | 45,050 | 37,089 | 48,834 | 34,645 | 15,785 | 15,667 |

Table 24. Allocation of Conserving Base Acres in Each Subarea to Farm Size, 1966

| Farm Size | Subarea: Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek | County Total |
|---|---|---|---|---|---|---|---|
| | Acres | | | | | | |
| I | 4,853 | 1,397 | 2,147 | -- | 573 | -- | 8,970 |
| II | 12,557 | 6,736 | 4,033 | -- | 3,585 | 2,815 | 29,726 |
| III | 16,437 | 17,112 | 14,832 | 13,485 | 4,180 | 1,647 | 67,693 |
| IV | 26,810 | 24,646 | 44,038 | 32,380 | 12,879 | 16,391 | 157,144 |
| Total | 60,657 | 49,891 | 65,050 | 45,865 | 21,217 | 20,853 | 263,533 |
| Percent | 23.017 | 18.932 | 24.684 | 17.403 | 8.051 | 7.913 | 100.000 |

cropped acres within subarea. The percentages are: for Casa Grande, 134.64 percent; Eloy, 133.21 percent; Coolidge, 134.52 percent; Queen Creek, 133.10 percent; Maricopa, 132.39 percent; and Stanfield, 134.41 percent. Since the restriction is not effective in any model, the distribution is not crucial.

### Allocation of Cotton Allotments to Subareas and Farm Sizes

The government restricts the number of acres which can be used to grow both short staple and long staple cotton. The restrictions used in this analysis (and the Stults analysis) are based on the 1966 cotton program, assuming a 35 percent diversion rate for upland cotton. The 35 percent diversion rate is chosen because almost all farmers in Pinal County divert the maximum rate of 35 percent, since this permits the attainment of maximum income.

Allocation to Subareas. The total short staple restriction (S. S. Allotment) amounted to 83,810 acres, as calculated by Stults. Stults estimated that the county-wide Farm Size I short staple cotton allotment is 70.32 percent of cropped acres; it is 52.50 percent for Farm Size II, 41.29 percent for Farm Size III, and 39.94 percent for Farm Size IV. These percentages hold within each farm size, regardless of the depth from which water is pumped. Using these percentages, one is able to make a preliminary distribution of short staple cotton allotment according to the cropped acres allocated to farm sizes in the various subareas (see Table 23). Table 25 shows the amount and percentage distributed to each subarea on this basis, adjusted slightly to conform to Stults' total.

Long staple cotton allotment (L. S. Allotment) is distributed according to the percent it is of short staple cotton allotment. In the Stults study, long staple cotton allotment was 4.00 percent of short staple cotton allotment for Farm Size I; 8.54 percent for Farm Size II; 7.23 percent for Farm Size III; and 9.31 percent for Farm Size IV. Table 26 portrays the allocation of 1966 long staple cotton allotment to subareas through use of the above method.

Allocation to Farm Sizes. Once the distribution to the subareas had been made, it was further assumed that cotton allotments are a constant percentage of cropped acres within a given subarea, regardless of farm size or pumping lift depth. The percentage which cotton allotment bears to cropped acres is dependent upon the subarea under consideration. For each subarea, this percentage is determined by considering total cotton allotment allocated to that subarea over total cropped acres distributed to the same subarea. When considering short staple cotton allotments, the percentages for the six subareas are as follows: Casa Grande, 44.96 percent; Coolidge, 43.12 percent; Eloy, 48.72

Table 25. Amount and Percentage of Short Staple Cotton Allotment in Each Subarea, 1966

| | Subarea | | | | | | |
|---|---|---|---|---|---|---|---|
| | Casa Grande | Coolidge | Eloy[a] | Maricopa[b] | Stanfield | Queen Creek | County Total |
| Acres | 20,254 | 15,994 | 20,384 | 13,925 | 6,762 | 6,491 | 83,810 |
| Percent | 24.17 | 19.08 | 24.32 | 16.62 | 8.07 | 7.74 | 100.00 |

[a]Revised later in the analysis. See Table 27.

[b]Revised later in the analysis. See Table 27.

Table 26. Amount and Percentage of Long Staple Cotton Allotment in Each Subarea, 1966

| | Subarea | | | | | | |
|---|---|---|---|---|---|---|---|
| | Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek | County Total |
| Acres | 1,646 | 1,315 | 1,747 | 1,245 | 564 | 585 | 7,102 |
| Percent | 23.2 | 18.5 | 24.6 | 17.5 | 8.0 | 8.2 | 100.00 |

percent;[2] Maricopa, 30.36 percent;[3] Stanfield, 42.84 percent; and Queen Creek, 41.45 percent. Table 27 shows the final result of distributing short staple cotton allotments in this manner. This method of distribution allowed the ratio of cotton allotment to cropped acres to differ between subareas and provided a vehicle for allocating allotments among pumping lifts as described in the next section.

In order to distribute long staple cotton allotments according to the percentage it bears to cropped acres, the following percentages were calculated for the six subareas: Casa Grande, 3.65 percent; Coolidge, 3.55 percent; Eloy, 3.58 percent; Maricopa 3.59 percent; Stanfield, 3.57 percent; and Queen Creek, 3.73 percent. The results of distributing long staple cotton allotment according to these percentages is given in Table 28.

## Distribution of Restrictions Among Three Pumping Lifts

The economic model used in this analysis (and the earlier Stults study) allows water to be pumped from wells

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2. Calculated on the basis of total short staple cotton allotment of 23,794 acres in Eloy subarea. The short staple allotment of 20,384 acres allocated in Table 4 was adjusted in order to prevent the disposal of long staple cotton allotment acreage in the linear program.

3. Calculated on the basis of total short staple cotton allotment of 10,517 acres in Maricopa subarea. This adjustment was necessary in order to prevent the disposal of long staple cotton allotment acreage in the linear program.

Table 27. Allocation of Short Staple Cotton Allotments in Each Subarea to Farm Sizes, 1966

| Farm Size | Subarea | | | | | |
|---|---|---|---|---|---|---|
| | Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek |
| | Acres | | | | | |
| I | 1,620 | 448 | 785 | -- | 182 | -- |
| II | 4,193 | 2,159 | 1,476 | -- | 1,143 | -- |
| III | 5,488 | 5,486 | 5,425 | 3,087 | 1,332 | 511 |
| IV | 8,953 | 7,901 | 16,108 | 7,430 | 4,105 | 5,102 |
| Total | 20,254 | 15,994 | 23,794 | 10,517 | 6,762 | 6,489 |

Table 28. Allocation of Long Staple Cotton Allotment in Each Subarea Among Farm Sizes, 1966

| Farm Size | Subarea | | | | | |
|---|---|---|---|---|---|---|
| | Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek |
| | Acres | | | | | |
| I | 133 | 37 | 58 | -- | 15 | -- |
| II | 340 | 177 | 108 | -- | 96 | 78 |
| III | 446 | 451 | 399 | 366 | 111 | 47 |
| IV | 727 | 650 | 1,182 | 879 | 342 | 460 |
| Total | 1,646 | 1,315 | 1,747 | 1,245 | 564 | 585 |

having one of three possible pumping lift depths. These three pumping lifts are called "shallow," "middle," and "deep" lifts and were defined in Chapter II in the section entitled "Pumping Lifts."

This section deals with the problem of allocating all restrictions among these three pumping lifts. Water is the first restriction to be allocated.

## Allocation of Water Among Pumping Lifts

July Water is distributed among pumping lifts according to the percentages calculated for each subarea based on the surveys of Stults. Wells in each subarea are arrayed in ascending order according to pumping lift depths. See Table 6 (Chapter II) for the percentage of water pumped from "shallow," "middle," and "deep" lifts in each subarea. It is on the basis of these percentages that July Water is allocated among pumping lifts as shown in Table 29. The assumption made is that wells of different pumping lift depths are evenly distributed (percentage wise) among different farm sizes within each subarea.

January Water is distributed among pumping lifts as shown in Table 30. Since January Water is 2.10 times July Water, Table 30 is easily derived from Table 29.

## Allocation of Cropped Acres Among Pumping Lifts

For the preliminary distribution of cropped acres previously allocated to given farm sizes in each subarea,

Table 29. Final Allocation of July Water Among Subareas, Farm Sizes, and Pumping Lifts, 1966

| Farm Size and Pumping Lift | | Subarea: Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek |
|---|---|---|---|---|---|---|---|
| | | ----- | ----- | -----Acre-feet----- | ----- | ----- | ----- |
| I | "S" | 638 | 342 | 78 | -- | -- | -- |
| | "M" | 878 | 267 | 388 | -- | 97 | -- |
| | "D" | 80 | 12 | 310 | -- | 80 | -- |
| | Total | 1,596 | 621 | 776 | -- | 177 | -- |
| II | "S" | 1,677 | 1,634 | 145 | -- | -- | 71 |
| | "M" | 2,306 | 1,277 | 725 | -- | 618 | 133 |
| | "D" | 209 | 59 | 580 | -- | 506 | 580 |
| | Total | 4,192 | 2,970 | 1,450 | -- | 1,124 | 784 |
| III | "S" | 2,180 | 4,186 | 533 | 882 | -- | 42 |
| | "M" | 2,998 | 3,272 | 2,663 | 1,471 | 719 | 78 |
| | "D" | 273 | 152 | 2,131 | 588 | 588 | 341 |
| | Total | 5,451 | 7,610 | 5,327 | 2,941 | 1,307 | 461 |
| IV | "S" | 3,573 | 6,030 | 1,583 | 2,123 | -- | 410 |
| | "M" | 4,913 | 4,714 | 7,913 | 3,538 | 2,214 | 774 |
| | "D" | 447 | 219 | 6,331 | 1,415 | 1,812 | 3,367 |
| | Total | 8,933 | 10,963 | 15,827 | 7,076 | 4,026 | 4,551 |
| Subarea Total | | 20,172 | 22,164 | 23,380 | 10,017 | 6,634 | 5,796 |

Table 30. Final Allocation of January Water Among Subareas, Farm Sizes, and Pumping Lifts, 1966

| Farm Size and Pumping Lift | | Subarea: Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek |
|---|---|---|---|---|---|---|---|
| | | --- | --- | --- | Acre-feet | --- | --- |
| I | "S" | 1,340 | 718 | 164 | -- | -- | -- |
| | "M" | 1,844 | 561 | 815 | -- | 204 | -- |
| | "D" | 168 | 26 | 651 | -- | 168 | -- |
| | Total | 3,352 | 1,305 | 1,630 | -- | 372 | -- |
| II | "S" | 3,522 | 3,431 | 304 | -- | -- | 149 |
| | "M" | 4,843 | 2,682 | 1,522 | -- | 1,298 | 279 |
| | "D" | 429 | 124 | 1,218 | -- | 1,063 | 1,218 |
| | Total | 8,804 | 6,237 | 3,044 | -- | 2,361 | 1,646 |
| III | "S" | 4,578 | 8,791 | 1,119 | 1,852 | -- | 88 |
| | "M" | 6,296 | 6,871 | 5,592 | 3,089 | 1,510 | 164 |
| | "D" | 573 | 319 | 4,475 | 1,235 | 1,235 | 716 |
| | Total | 11,447 | 15,981 | 11,186 | 6,176 | 2,745 | 968 |
| IV | "S" | 7,504 | 12,663 | 3,324 | 4,458 | -- | 861 |
| | "M" | 10,317 | 9,899 | 16,618 | 7,430 | 4,649 | 1,625 |
| | "D" | 939 | 460 | 13,295 | 2,972 | 3,805 | 7,071 |
| | Total | 18,760 | 23,022 | 33,237 | 14,860 | 8,454 | 9.557 |
| Subarea Total | | 42,363 | 46,545 | 49,097 | 21,036 | 13,932 | 12,171 |

it is assumed that the cropped acres allocated to a particular pumping lift is proportional to the amount of water pumped from that lift. These preliminary allocations were adjusted slightly by taking a small proportion of cropped acres from the "shallow" lifts and adding this amount to the "deep" lifts in each subarea. This is done to adjust for the lesser amounts of water used per acre in the deep areas as was done in the Stults study. The results obtained are depicted in Table 31.

### Allocation of Conserving Base Acres Among Pumping Lifts

As described in the section entitled "Allocation of Conserving Base to Farm Sizes," conserving base acres have been calculated to be a given percentage of cropped acres in each subarea. On the basis of the percentages given in that section, conserving base acres may also be distributed among pumping lifts. See Table 32.

### Allocation of Cotton Allotments Among Pumping Lifts

Cotton allotments were determined to be a given percentage of cropped acres in each subarea. See "Allocation of Cotton Allotments to Subareas and Farm Sizes." The percentage calculated for each subarea is given in that section for both long staple and short staple cotton allotments. On the basis of those percentages, cotton allotments are further distributed to pumping lifts as given in Tables 33 and 34.

Table 31. Final Allocation of Cropped Acres Among Subareas, Farm Sizes, and Pumping Lifts, 1966

| Farm Size and Pumping Lift | | Subarea: Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek |
|---|---|---|---|---|---|---|---|
| | | Acres | | | | | |
| I | "S" | 1,442 | 556 | 146 | -- | -- | -- |
| | "M" | 1,982 | 445 | 830 | -- | 237 | -- |
| | "D" | 180 | 37 | 635 | -- | 189 | -- |
| | Total | 3,604 | 1,038 | 1,611 | -- | 426 | -- |
| II | "S" | 3,739 | 2,745 | 293 | -- | -- | 188 |
| | "M" | 5,136 | 2,151 | 1,514 | -- | 1,468 | 360 |
| | "D" | 450 | 111 | 1,221 | -- | 1,200 | 1,567 |
| | Total | 9,325 | 5,007 | 3,028 | -- | 2,668 | 2,115 |
| III | "S" | 4,865 | 7,010 | 1,123 | 3,049 | -- | 110 |
| | "M" | 6,712 | 5,489 | 5,567 | 5,092 | 1,705 | 204 |
| | "D" | 631 | 223 | 4,444 | 2,044 | 1,405 | 924 |
| | Total | 12,208 | 12,722 | 11,134 | 10,185 | 3,110 | 1,238 |
| IV | "S" | 7,974 | 10,088 | 3,321 | 7,345 | -- | 1,112 |
| | "M" | 10,948 | 7,863 | 16,506 | 12,230 | 5,272 | 2,099 |
| | "D" | 991 | 371 | 13,234 | 4,885 | 4,309 | 9,103 |
| | Total | 19,913 | 18,322 | 33,061 | 24,460 | 9,581 | 12,314 |
| Subarea Total | | 45,050 | 37,089 | 48,834 | 34,645 | 15,785 | 15,667 |

Table 32. Final Allocation of Conserving Base Acres Among Subareas, Farm Sizes, and Pumping Lifts, 1966

| Farm Size and Pumping Lift | | Subarea: Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek |
|---|---|---|---|---|---|---|---|
| | | Acres | | | | | |
| I | "S" | 1,941 | 748 | 195 | -- | -- | -- |
| | "M" | 2,669 | 599 | 1,106 | -- | 318 | -- |
| | "D" | 243 | 50 | 846 | -- | 255 | -- |
| | Total | 4,853 | 1,397 | 2,147 | -- | 573 | -- |
| II | "S" | 5,035 | 3,692 | 390 | -- | -- | 250 |
| | "M" | 6,915 | 2,894 | 2,017 | -- | 1,973 | 480 |
| | "D" | 607 | 150 | 1,626 | -- | 1,612 | 2,085 |
| | Total | 12,557 | 6,736 | 4,033 | -- | 3,585 | 2,815 |
| III | "S" | 6,551 | 9,429 | 1,496 | 4,037 | -- | 146 |
| | "M" | 9,037 | 7,384 | 7,416 | 6,742 | 2,292 | 271 |
| | "D" | 849 | 299 | 5,920 | 2,706 | 1,888 | 1,230 |
| | Total | 16,437 | 17,112 | 14,832 | 13,485 | 4,180 | 1,647 |
| IV | "S" | 10,736 | 13,570 | 4,423 | 9,723 | -- | 1,481 |
| | "M" | 14,740 | 10,577 | 21,987 | 16,190 | 7,086 | 2,794 |
| | "D" | 1,334 | 499 | 17,628 | 6,467 | 5,793 | 12,116 |
| | Total | 26,810 | 24,646 | 44,038 | 32,380 | 12,879 | 16,391 |
| Subarea Total | | 60,657 | 49,891 | 65,050 | 45,865 | 21,217 | 20,853 |

Table 33. Final Allocation of Short Staple Cotton Allotments Among Subareas, Farm Sizes, and Pumping Lifts, 1966

| Farm Size and Pumping Lift | | Subarea: Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek |
|---|---|---|---|---|---|---|---|
| | | Acres | | | | | |
| I | "S" | 648 | 240 | 71 | -- | -- | -- |
| | "M" | 891 | 192 | 404 | -- | 101 | -- |
| | "D" | 81 | 16 | 310 | -- | 81 | -- |
| | Total | 1,620 | 448 | 785 | -- | 182 | -- |
| II | "S" | 1,681 | 1,184 | 143 | -- | -- | 78 |
| | "M" | 2,309 | 927 | 738 | -- | 629 | 149 |
| | "D" | 203 | 48 | 595 | -- | 514 | 649 |
| | Total | 4,193 | 2,159 | 1,476 | -- | 1,143 | 876 |
| III | "S" | 2,187 | 3,023 | 547 | 926 | -- | 45 |
| | "M" | 3,017 | 2,367 | 2,713 | 1,544 | 730 | 84 |
| | "D" | 284 | 96 | 2,165 | 617 | 602 | 382 |
| | Total | 5,488 | 5,486 | 5,425 | 3,087 | 1,332 | 511 |
| IV | "S" | 3,585 | 4,350 | 1,618 | 2,229 | -- | 461 |
| | "M" | 4,922 | 3,391 | 8,042 | 3,715 | 2,259 | 870 |
| | "D" | 446 | 160 | 6,448 | 1,486 | 1,846 | 3,771 |
| | Total | 8,953 | 7,901 | 16,108 | 7,430 | 4,105 | 5,102 |
| Subarea Total | | 20,254 | 15,994 | 23,794 | 10,517 | 6,762 | 6,491 |

Table 34. Final Allocation of Long Staple Cotton Allotments Among Subareas, Farm Sizes, and Pumping Lifts, 1966

| Farm Size and Pumping Lift | | Subarea: Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek |
|---|---|---|---|---|---|---|---|
| | | ---------- | ---------- | ---------- | Acres | ---------- | ---------- |
| I | "S" | 53 | 20 | 5 | -- | -- | -- |
| | "M" | 73 | 16 | 30 | -- | 8 | -- |
| | "D" | 7 | 1 | 23 | -- | 7 | -- |
| | Total | 133 | 37 | 58 | -- | 15 | -- |
| II | "S" | 136 | 97 | 10 | -- | -- | 7 |
| | "M" | 188 | 76 | 54 | -- | 53 | 13 |
| | "D" | 16 | 4 | 44 | -- | 43 | 58 |
| | Total | 340 | 177 | 108 | -- | 96 | 78 |
| III | "S" | 178 | 248 | 40 | 110 | -- | 4 |
| | "M" | 245 | 195 | 199 | 183 | 61 | 8 |
| | "D" | 23 | 8 | 160 | 73 | 50 | 35 |
| | Total | 446 | 451 | 399 | 366 | 111 | 47 |
| IV | "S" | 291 | 358 | 119 | 264 | -- | 42 |
| | "M" | 400 | 279 | 590 | 439 | 188 | 78 |
| | "D" | 36 | 13 | 473 | 176 | 154 | 340 |
| | Total | 727 | 650 | 1,182 | 879 | 342 | 460 |
| Subarea Total | | 1,646 | 1,315 | 1,747 | 1,245 | 564 | 585 |

# CHAPTER IV

## THE LINEAR PROGRAMMING MODEL

Linear programming is a mathematical technique for solving a set of simultaneous linear equations given an objective to be maximized or minimized within the limits of certain given constraints.

The particular computational linear program used in this analysis was developed at the University of California at Berkeley and is called "ALPHAC VERSION I." FORTRAN IV is the symbolic language in which this source program is written. The linear programming problems were solved on the Data Control 6400 computer located on The University of Arizona campus.

Heady and Candler (7) state, "A linear programming problem has three quantitative components: an objective, alternative methods or processes for attaining the objective, and resource or other restrictions. A problem which has these three components can always be expressed as a linear programming problem."

Stults (15) summarized the objectives, alternative processes, and restrictions involved in this study as follows:

> The objective of this study is to obtain the maximum net income from the alternatives of

> producing field crops in Pinal County with the limitations of water, land, capital and other factors which Pinal County farmers typically face. The solution to the model represents estimates of cropping patterns, crop outputs, and farm income for typically Pinal County farmers. Estimates of cropping patterns, crop outputs, and farm income are projected over time by replacing the original restrictions and net revenues with projections based on the declining water supply (p. 58).

The data on alternative processes from which the objective functions are obtained were discussed in Chapter II. The allocation of restrictions for the base year 1966 was discussed in Chapter III. In this Chapter, the construction of the actual linear programming model is described along with an explanation of the necessary adjustments in restrictions between models representing different points in time.

## The Linear Programming Matrices

The complete set of linear programming matrices for the base year 1966 are given in Tables 35 through 58. Explanation of the meaning of the rows and columns is as follows: Each row of coefficients is an equation in itself. In matrix form, the variables (number of acres and number of acre-feet) have been left out of the equations and only the constants (coefficients) of the equations are given. Thus, the coefficients which define a matrix are nothing more than the constants of a group of equations which set forth the problem. In order to maximize the objective function, one

Table 35. Linear Programming Matrix, Eloy Area, Farm Size I, Shallow Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Purchase Activity | Disposal Activities | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11)-(17) | (18) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase | | Restrictions (Eloy) |
| (1) | Revenue (Eloy) | Dollars | -118.05 | -158.99 | -251.25 | -312.19 | -52.61 | -50.68 | -48.68 | -78.68 | -41.69 | 7.07 | 0. | |
| (2) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 5. |
| (3) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 71. |
| (4) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 1. | 146. |
| (5) | July Water | Acre-Feet | .68 | .77 | .68 | .77 | 0. | .67 | 0. | .57 | 0. | 0. | 1. | 78. |
| (6) | January Water | Acre-Feet | 1.37 | 1.86 | 1.37 | 1.86 | 1.03 | 0. | .57 | .57 | .99 | 0. | 1. | 164. |
| (7) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 1. | 195. |
| (8) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 1. | 146. |
| (9) | Water Balance | Acre-Feet | 6.00 | 7.00 | 6.00 | 7.00 | 3.00 | 3.29 | 4.58 | 6.58 | 3.50 | -1. | 0. | |

Table 36. Linear Programming Matrix, Eloy and Stanfield Areas, Farm Size I, Middle Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Purchase Activity | Disposal Activities | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11)-(17) | (18) | (19) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase | | Restrictions (Eloy) | Restrictions (Stanfield) |
| (1) | Revenue (Eloy) | Dollars | -107.12 | -157.78 | -242.73 | -303.50 | -46.30 | -44.57 | -48.36 | -78.36 | -35.08 | 8.97 | 0. | | |
| (2) | Revenue (Stanfield) | Dollars | -107.12 | -157.78 | -242.73 | -303.50 | -46.30 | -44.57 | -48.36 | -78.36 | -35.08 | 12.00 | 0. | | |
| (3) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 30. | 8. |
| (4) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 404. | 101. |
| (5) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 1. | 830. | 237. |
| (6) | July Water | Acre-Feet | .57 | .66 | .57 | .66 | 0. | .57 | 0. | .57 | 0. | 0. | 1. | 388. | 97. |
| (7) | January Water | Acre-Feet | 1.14 | 1.60 | 1.14 | 1.60 | .86 | 0. | .57 | .57 | .86 | 0. | 1. | 815. | 204. |
| (8) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 1. | 1106. | 318. |
| (9) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 1. | 830. | 237. |
| (10) | Water Balance | Acre-Feet | 5.00 | 6.00 | 5.00 | 6.00 | 2.50 | 2.75 | 4.58 | 6.58 | 3.00 | -1. | 0. | | |

Table 37. Linear Programming Matrix, Eloy and Stanfield Areas, Farm Size I, Deep Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Purchase Activity | Disposal Activities | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11)-(17) | (18) | (19) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase | | Restrictions (Eloy) | Restrictions (Stanfield) |
| (1) | Revenue (Eloy) | Dollars | -94.72 | -145.44 | -232.76 | -293.49 | -38.31 | -36.92 | -48.17 | -78.17 | -29.63 | 11.20 | 0. | | |
| (2) | Revenue (Stanfield) | Dollars | -94.72 | -145.44 | -232.76 | -293.49 | -38.31 | -36.92 | -48.17 | -78.17 | -29.63 | 13.18 | 0. | | |
| (3) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 23. | 7. |
| (4) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 310. | 81. |
| (5) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 1. | 635. | 189. |
| (6) | July Water | Acre-Feet | .46 | .55 | .46 | .55 | 0. | .47 | 0. | .57 | 0. | 0. | 1. | 310. | 80. |
| (7) | January Water | Acre-Feet | .91 | 1.33 | .91 | 1.33 | .68 | 0. | .57 | .57 | .72 | 0. | 1. | 651. | 168. |
| (8) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 1. | 846. | 255. |
| (9) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 1. | 635. | 189. |
| (10) | Water Balance | Acre-Feet | 4.00 | 5.00 | 4.00 | 5.00 | 2.00 | 2.17 | 4.58 | 6.58 | 2.50 | -1. | 0. | | |

Table 38. Linear Programming Matrix, Eloy and Queen Creek Areas, Farm Size II, Shallow Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Purchase Activity | Disposal Activities | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11)-(17) | (18) | (19) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase | | Restrictions (Eloy) | Restrictions (Queen Creek) |
| (1) | Revenue (Eloy) | Dollars | -134.77 | -187.74 | -268.31 | -331.29 | -52.90 | -52.56 | -50.42 | -80.92 | -40.92 | 6.73 | 0. | | |
| (2) | Revenue (Queen Creek) | Dollars | -134.77 | -187.74 | -268.31 | -331.29 | -52.90 | -52.56 | -50.42 | -80.92 | -40.92 | 6.73 | 0. | | |
| (3) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 10. | 7. |
| (4) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 143. | 78. |
| (5) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 1. | 293. | 188. |
| (6) | July Water | Acre-Feet | .65 | .73 | .65 | .73 | 0. | .64 | 0. | .54 | 0. | 0. | 1. | 145. | 71. |
| (7) | January Water | Acre-Feet | 1.30 | 1.77 | 1.30 | 1.77 | .98 | 0. | .54 | .54 | .94 | 0. | 1. | 304. | 149. |
| (8) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 1. | 390. | 250. |
| (9) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 1. | 293. | 188. |
| (10) | Water Balance | Acre-Feet | 5.00 | 7.00 | 6.00 | 7.00 | 3.00 | 3.29 | 4.58 | 6.58 | 3.50 | -1. | 0. | | |

Table 39. Linear Programming Matrix, Eloy, Queen Creek, and Stanfield Areas, Farm Size II, Middle Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Purchase Activity | Disposal Activities | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11-17) | (18) | (19) | (20) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase | | Restrictions (Eloy) | Restrictions (Queen Creek) | Restrictions (Stanfield) |
| (1) | Revenue (Eloy) | Dollars | -124.36 | -177.24 | -260.07 | -322.96 | -47.47 | -46.09 | -50.11 | -80.61 | -35.57 | 8.53 | 0. | | | |
| (2) | Revenue (Queen Creek) | Dollars | -124.36 | -177.24 | -260.07 | -322.96 | -47.47 | -46.09 | -50.11 | -80.61 | -35.57 | 11.02 | 0. | | | |
| (3) | Revenue (Stanfield) | Dollars | -124.36 | -177.24 | -260.07 | -322.96 | -47.47 | -46.09 | -50.11 | -80.61 | -35.57 | 11.42 | 0. | | | |
| (4) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 54. | 13. | 53. |
| (5) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 738. | 149. | 629. |
| (6) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 1. | 1514. | 360. | 1468. |
| (7) | July Water | Acre-Feet | .54 | .62 | .54 | .62 | 0. | .54 | 0. | .54 | 0. | 0. | 1. | 725. | 133. | 618. |
| (8) | January Water | Acre-Feet | 1.09 | 1.52 | 1.09 | 1.52 | .81 | 0. | .54 | .54 | .81 | 0. | 1. | 1522. | 279. | 1298. |
| (9) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 1. | 2017. | 480. | 1973. |
| (10) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 1. | 1514. | 360. | 1468. |
| (11) | Water Balance | Acre-Feet | 5.00 | 6.00 | 5.00 | 6.00 | 2.50 | 2.75 | 4.58 | 6.58 | 3.00 | -1. | 0. | | | |

Table 40. Linear Programming Matrix, Eloy, Queen Creek, and Stanfield Areas, Farm Size II, Deep Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Purchase Activity | Disposal Activities | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11-17) | (18) | (19) | (20) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase | | Restrictions (Eloy) | Restrictions (Queen Creek) | Restrictions (Stanfield) |
| (1) | Revenue (Eloy) | Dollars | -113.48 | -165.52 | -251.26 | -313.31 | -41.30 | -38.17 | -49.94 | -80.44 | -29.46 | 10.66 | 0. | | | |
| (2) | Revenue (Queen Creek) | Dollars | -113.48 | -165.52 | -251.26 | -313.31 | -41.30 | -38.17 | -49.94 | -80.44 | -29.46 | 12.56 | 0. | | | |
| (3) | Revenue (Stanfield) | Dollars | -113.48 | -165.52 | -251.26 | -313.31 | -41.30 | -38.17 | -49.94 | -80.44 | -29.46 | 12.55 | 0. | | | |
| (4) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 44. | 58. | 43. |
| (5) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 595. | 649. | 514. |
| (6) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 1. | 1221. | 1567. | 1200. |
| (7) | July Water | Acre-Feet | .43 | .52 | .43 | .52 | 0. | .44 | 0. | .54 | 0. | 0. | 1. | 580. | 580. | 506. |
| (8) | January Water | Acre-Feet | .87 | 1.27 | .87 | 1.27 | .65 | 0. | .54 | .54 | .68 | 0. | 1. | 1218. | 1218. | 1063. |
| (9) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 1. | 1628. | 2085. | 1612. |
| (10) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 1. | 1221. | 1567. | 1200. |
| (11) | Water Balance | Acre-Feet | 4.00 | 5.00 | 4.00 | 5.00 | 2.00 | 2.17 | 4.58 | 6.58 | 2.50 | -1. | 0. | | | |

Table 41. Linear Programming Matrix, Eloy, Queen Creek, and Maricopa Areas, Farm Size III, Shallow Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Purchase Activity | Disposal Activities | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11-17) | (18) | (19) | (20) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase | | Restrictions (Eloy) | Restrictions (Queen Creek) | Restrictions (Maricopa) |
| (1) | Revenue (Eloy) | Dollars | -138.81 | -193.32 | -276.81 | -336.88 | -52.95 | -56.51 | -51.83 | -82.33 | -41.09 | 6.45 | 0. | | | |
| (2) | Revenue (Queen Creek) | Dollars | -138.81 | -193.32 | -276.81 | -336.88 | -52.95 | -56.51 | -51.83 | -82.33 | -41.09 | 7.63 | 0. | | | |
| (3) | Revenue (Maricopa) | Dollars | -138.81 | -193.32 | -276.81 | -336.88 | -52.95 | -56.51 | -51.83 | -82.33 | -41.09 | 6.06 | 0. | | | |
| (4) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 40. | 4. | 110. |
| (5) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 547. | 45. | 926. |
| (6) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 1. | 1123. | 110. | 3049. |
| (7) | July Water | Acre-Feet | .62 | .70 | .62 | .70 | 0. | .61 | 0. | .52 | 0. | 0. | 1. | 533. | 42. | 882. |
| (8) | January Water | Acre-Feet | 1.25 | 1.70 | 1.25 | 1.70 | .94 | 0. | .52 | .52 | .91 | 0. | 1. | 1119. | 88. | 1852. |
| (9) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 1. | 1496. | 146. | 4037. |
| (10) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 1. | 1123. | 110. | 3049. |
| (11) | Water Balance | Acre-Feet | 6.00 | 7.00 | 6.00 | 7.00 | 3.00 | 3.29 | 4.58 | 6.58 | 3.50 | -1. | 0. | | | |

Table 42. Linear Programming Matrix, Eloy, Queen Creek, Maricopa, and Stanfield Areas, Farm Size III, Middle Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Purchase Activity | Disposal Activities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11-17) | (18) | (19) | (20) | (21) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase | | Restrictions (Eloy) | Restrictions (Queen Creek) | Restrictions (Maricopa) | Restrictions (Stanfield) |
| (1) | Revenue (Eloy) | Dollars | -132.32 | -183.28 | -268.03 | -329.00 | -47.78 | -50.96 | -51.54 | -82.04 | -35.96 | 8.18 | 0. | | | | |
| (2) | Revenue (Queen Creek) | Dollars | -132.32 | -183.28 | -268.03 | -329.00 | -47.78 | -50.96 | -51.54 | -82.04 | -35.96 | 10.56 | 0. | | | | |
| (3) | Revenue (Maricopa) | Dollars | -132.32 | -183.28 | -268.03 | -329.00 | -47.78 | -50.96 | -51.54 | -82.04 | -35.96 | 9.99 | 0. | | | | |
| (4) | Revenue (Stanfield) | Dollars | -132.32 | -183.28 | -268.03 | -329.00 | -47.78 | -50.96 | -51.54 | -82.04 | -35.96 | 10.95 | 0. | | | | |
| (5) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 199. | 8. | 183. | 61. |
| (6) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 2713. | 84. | 1544. | 730. |
| (7) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 1. | 5567. | 204. | 5092. | 1705. |
| (8) | July Water | Acre-Feet | .52 | .60 | .52 | .60 | 0. | .52 | 0. | .52 | 0. | 0. | 1. | 2663. | 78. | 1471. | 719. |
| (9) | January Water | Acre-Feet | 1.04 | 1.46 | 1.04 | 1.46 | .78 | 0. | .52 | .52 | .78 | 0. | 1. | 5592. | 164. | 3089. | 1510. |
| (10) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 1. | 7416. | 271. | 6742. | 2292. |
| (11) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 1. | 5567. | 204. | 5092. | 1705. |
| (12) | Water Balance | Acre-Feet | 5.00 | 6.00 | 5.00 | 6.00 | 2.50 | 2.75 | 4.58 | 6.58 | 3.00 | -1. | 0. | | | | |

Table 43. Linear Programming Matrix, Eloy, Queen Creek, Maricopa, and Stanfield Areas, Farm Size III, Deep Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Purchase Activity | Disposal Activities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11-17) | (18) | (19) | (20) | (21) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase | | Restrictions (Eloy) | Restrictions (Queen Creek) | Restrictions (Maricopa) | Restrictions (Stanfield) |
| (1) | Revenue (Eloy) | Dollars | -121.07 | -172.00 | -258.93 | -319.88 | -41.92 | -43.99 | -51.38 | -81.88 | -29.78 | 10.22 | 0. | | | | |
| (2) | Revenue (Queen Creek) | Dollars | -121.07 | -172.00 | -258.93 | -319.88 | -41.92 | -43.99 | -51.38 | -81.88 | -29.78 | 12.04 | 0. | | | | |
| (3) | Revenue (Maricopa) | Dollars | -121.07 | -172.00 | -258.93 | -319.88 | -41.92 | -43.99 | -51.38 | -81.88 | -29.78 | 13.34 | 0. | | | | |
| (4) | Revenue (Stanfield) | Dollars | -121.07 | -172.00 | -258.93 | -319.88 | -41.92 | -43.99 | -51.38 | -81.88 | -29.78 | 12.03 | 0. | | | | |
| (5) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 160. | 35. | 73. | 50. |
| (6) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 2165. | 382. | 617. | 602. |
| (7) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 1. | 4444. | 924. | 2044. | 1405. |
| (8) | July Water | Acre-Feet | .42 | .50 | .42 | .50 | 0. | 1. | 0. | .52 | 0. | 0. | 1. | 2131. | 341. | 588. | 588. |
| (9) | January Water | Acre-Feet | .83 | 1.22 | .83 | 1.22 | .62 | 0. | .52 | .52 | .66 | 0. | 1. | 4475. | 716. | 1235. | 1235. |
| (10) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 1. | 5920. | 1230. | 2706. | 1888. |
| (11) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 1. | 4444. | 924. | 2044. | 1405. |
| (12) | Water Balance | Acre-Feet | 4.00 | 5.00 | 4.00 | 5.00 | 2.00 | 2.17 | 4.58 | 6.58 | 2.50 | -1. | 0. | | | | |

Table 44. Linear Programming Matrix, Eloy, Queen Creek, and Maricopa Areas, Farm Size IV, Shallow Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Purchase Activity | Disposal Activities | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11-17) | (18) | (19) | (20) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase | | Restrictions (Eloy) | Restrictions (Queen Creek) | Restrictions (Maricopa) |
| (1) | Revenue (Eloy) | Dollars | -144.60 | -196.52 | -278.63 | -340.56 | -52.69 | -55.32 | -52.79 | -83.79 | -41.50 | 5.92 | 0. | | | |
| (2) | Revenue (Queen Creek) | Dollars | -144.60 | -196.52 | -278.63 | -340.56 | -52.69 | -55.32 | -52.79 | -83.79 | -41.50 | 7.01 | 0. | | | |
| (3) | Revenue (Maricopa) | Dollars | -144.60 | -196.52 | -278.63 | -340.56 | -52.69 | -55.32 | -52.79 | -83.79 | -41.50 | 5.56 | 0. | | | |
| (4) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 119. | 42. | 264. |
| (5) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1618. | 461. | 2229. |
| (6) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 1. | 3321. | 1112. | 7345. |
| (7) | July Water | Acre-Feet | .57 | .64 | .57 | .64 | 0. | 0. | 0. | .48 | 0. | 0. | 1. | 1583. | 410. | 2123. |
| (8) | January Water | Acre-Feet | 1.15 | 1.56 | 1.15 | 1.56 | .86 | .56 | .48 | .48 | .83 | 0. | 1. | 3324. | 861. | 4458. |
| (9) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 1. | 4423. | 1481. | 9723. |
| (10) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 1. | 3321. | 1112. | 7345. |
| (11) | Water Balance | Acre-Feet | 6.00 | 7.00 | 6.00 | 7.00 | 3.00 | 3.29 | 4.58 | 6.58 | 3.50 | -1. | 0. | | | |

Table 45. Linear Programming Matrix, Eloy, Queen Creek, Maricopa, and Stanfield Areas, Farm Size IV, Middle Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Purchase Activity | Disposal Activities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11-17) | (18) | (19) | (20) | (21) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase | | Restrictions (Eloy) | Restrictions (Queen Creek) | Restrictions (Maricopa) | Restrictions (Stanfield) |
| (1) | Revenue (Eloy) | Dollars | -135.71 | -187.56 | -271.42 | -333.28 | -47.98 | -50.26 | -52.51 | -83.51 | -36.80 | 7.51 | 0. | | | | |
| (2) | Revenue (Queen Creek) | Dollars | -135.71 | -187.56 | -271.42 | -333.28 | -47.98 | -50.26 | -52.51 | -83.51 | -36.80 | 9.70 | 0. | | | | |
| (3) | Revenue (Maricopa) | Dollars | -135.71 | -187.56 | -271.42 | -333.28 | -47.98 | -50.26 | -52.51 | -83.41 | -36.80 | 9.17 | 0. | | | | |
| (4) | Revenue (Stanfield) | Dollars | -135.71 | -187.56 | -271.42 | -333.28 | -47.98 | -50.26 | -52.51 | -83.41 | -36.80 | 10.05 | 0. | | | | |
| (5) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 590. | 78. | 439. | 188. |
| (6) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 8042. | 870. | 3715. | 2259. |
| (7) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 1. | 16506. | 2099. | 12230. | 5272. |
| (8) | July Water | Acre-Feet | .48 | .55 | .48 | .55 | 0. | .48 | 0. | .48 | 0. | 0. | 1. | 7913. | 774. | 3538. | 2214. |
| (9) | January Water | Acre-Feet | .95 | 1.34 | .95 | 1.34 | .72 | 0. | .48 | .48 | .72 | 0. | 1. | 16618. | 1625. | 7430. | 4649. |
| (10) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 1. | 21987. | 2794. | 16190. | 7086. |
| (11) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 1. | 16506. | 2099. | 12230. | 5272. |
| (12) | Water Balance | Acre-Feet | 5.00 | 6.00 | 5.00 | 6.00 | 2.50 | 2.75 | 4.58 | 6.58 | 3.00 | -1. | 0. | | | | |

Table 46. Linear Programming Matrix, Eloy, Queen Creek, Maricopa, and Stanfield Areas, Farm Size IV, Deep Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Purchase Activity | Disposal Activities | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11-17) | (18) | (19) | (20) | (21) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase | | Restrictions (Eloy) | Restrictions (Queen Creek) | Restrictions (Maricopa) | Restrictions (Stanfield) |
| (1) | Revenue (Eloy) | Dollars | -125.50 | -177.33 | -263.02 | -329.48 | -42.64 | -43.91 | -52.36 | -83.36 | -31.46 | 9.39 | 0. | | | | |
| (2) | Revenue (Queen Creek) | Dollars | -125.50 | -177.33 | -263.02 | -329.48 | -42.64 | -43.91 | -52.36 | -83.36 | -31.46 | 11.05 | 0. | | | | |
| (3) | Revenue (Maricopa) | Dollars | -125.50 | -177.33 | -263.02 | -329.48 | -42.64 | -43.91 | -52.36 | -83.36 | -31.46 | 12.25 | 0. | | | | |
| (4) | Revenue (Stanfield) | Dollars | -125.50 | -177.33 | -263.02 | -329.48 | -42.64 | -43.91 | -52.36 | -83.36 | -31.46 | 11.04 | 0. | | | | |
| (5) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 473. | 340. | 176. | 154. |
| (6) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 6448 | 3771 | 1486. | 1846. |
| (7) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 1. | 13234. | 9103. | 4885. | 4309. |
| (8) | July Water | Acre-Feet | .38 | .46 | .38 | .46 | 0. | .39 | 0. | .48 | 0. | 0. | 1. | 6331 | 3367. | 1415. | 1812. |
| (9) | January Water | Acre-Feet | .76 | 1.12 | .76 | 1.12 | .57 | 0. | .48 | .48 | .60 | 0. | 1. | 13295. | 7071. | 2972. | 3805. |
| (10) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 1. | 17628. | 12116. | 6467. | 5793. |
| (11) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 1. | 13234. | 9103. | 4885. | 4309. |
| (12) | Water Balance | Acre-Feet | 4.00 | 5.00 | 4.00 | 5.00 | 2.00 | 2.17 | 4.58 | 6.58 | 2.50 | -1. | 0. | | | | |

Table 47. Linear Programming Matrix, Casa Grande and Coolidge Areas, Farm Size I, Shallow Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Water Purchase Activities | | | Disposal Activities | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13-22) | (23) | (24) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase (Pumped) | Water Purchase (Project) | Free Water (Project) | | Restrictions (Casa Grande) | Restrictions (Coolidge) |
| (1) | Revenue (Casa Grande) | Dollars | -118.05 | -158.99 | -251.25 | -312.19 | -52.61 | -50.68 | -48.68 | -78.68 | -41.69 | 6.90 | .50 | 0. | | | |
| (2) | Revenue (Coolidge) | Dollars | -118.05 | -158.99 | -251.25 | -312.19 | -52.61 | -50.68 | -48.68 | -78.68 | -41.69 | 6.90 | .50 | 0. | 0. | | |
| (3) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 53. | 20. |
| (4) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 648. | 240. |
| (5) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 1. | 1442. | 556. |
| (6) | July Water | Acre-Feet | .68 | .77 | .68 | .77 | 0. | .67 | 0. | .57 | 0. | 0. | 0. | 0. | 1. | 638. | 342. |
| (7) | January Water | Acre-Feet | 1.37 | 1.86 | 1.37 | 1.86 | 1.03 | 0. | .57 | .57 | .99 | 0. | 0. | 0. | 1. | 1340. | 718. |
| (8) | Conserving Base | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1941. | 748. |
| (9) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1442. | 556. |
| (10) | Water Balance | Acre-Feet | 6.00 | 7.00 | 6.00 | 7.00 | 3.00 | 3.29 | 4.58 | 6.58 | 3.50 | -1. | -1. | -1. | 0. | | |
| (11) | Project Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 1. | 466. | 700. |
| (12) | Free Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1. | 931. | 1399. |
| (13) | Pumped Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 1. | 6057. | 1888. |

Table 48. Linear Programming Matrix, Casa Grande and Coolidge Areas, Farm Size I, Middle Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Water Purchase Activities | | | Disposal Activities | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13-22) | (23) | (24) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase (Pumped) | Water Purchase (Project) | Free Water (Project) | | Restrictions (Casa Grande) | Restrictions (Coolidge) |
| (1) | Revenue (Casa Grande) | Dollars | -107.12 | -157.78 | -242.73 | -303.50 | -46.30 | -44.57 | -48.36 | -78.36 | -35.08 | 11.03 | .50 | 0. | 0. | | |
| (2) | Revenue (Coolidge) | Dollars | -107.12 | -157.78 | -242.73 | -303.50 | -46.30 | -44.57 | -48.36 | -78.36 | -35.08 | 10.40 | .50 | 0. | 0. | | |
| (3) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 73. | 16. |
| (4) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 891. | 192. |
| (5) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 1. | 1982. | 445. |
| (6) | July Water | Acre-Feet | .57 | .66 | .57 | .66 | 0. | .57 | 0. | .57 | 0. | 0. | 0. | 0. | 1. | 878. | 267. |
| (7) | January Water | Acre-Feet | 1.14 | 1.60 | 1.14 | 1.60 | .86 | 0. | .57 | .57 | .86 | 0. | 0. | 0. | 1. | 1844. | 561. |
| (8) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 1. | 2669. | 599. |
| (9) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1982. | 445. |
| (10) | Water Balance | Acre-Feet | 5.00 | 6.00 | 5.00 | 6.00 | 2.50 | 2.75 | 4.58 | 6.58 | 3.00 | -1. | -1. | -1. | 0. | | |
| (11) | Project Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 1. | 640. | 547. |
| (12) | Free Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1. | 1280. | 1094. |
| (13) | Pumped Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 1. | 8328. | 1475. |

Table 49. Linear Programming Matrix, Casa Grande and Coolidge Areas, Farm Size I, Deep Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Water Purchase Activities | | | Disposal Activities | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13-22) | (23) | (24) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase (Pumped) | Water Purchase (Project) | Free Water (Project) | | Restrictions (Casa Grande) | Restrictions (Coolidge) |
| (1) | Revenue (Casa Grande) | Dollars | -94.72 | -145.44 | -232.76 | -293.49 | -38.31 | -36.92 | -48.17 | -78.17 | -29.63 | 13.07 | .50 | 0. | 0. | | |
| (2) | Revenue (Coolidge) | Dollars | -94.72 | -145.44 | -232.76 | -293.49 | -38.31 | -36.92 | -48.17 | -78.17 | -29.63 | 13.17 | .50 | 0. | 0. | | |
| (3) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 7. | 1. |
| (4) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 81. | 16. |
| (5) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 1. | 180. | 37. |
| (6) | July Water | Acre-Feet | .46 | .55 | .46 | .55 | 0. | .47 | 0. | .57 | 0. | 0. | 0. | 0. | 1. | 80. | 12. |
| (7) | January Water | Acre-Feet | .91 | 1.33 | .91 | 1.33 | .68 | 0. | .57 | .57 | .72 | 0. | 0. | 0. | 1. | 168. | 26. |
| (8) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 1. | 243. | 50. |
| (9) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 180. | 37. |
| (10) | Water Balance | Acre-Feet | 4.00 | 5.00 | 4.00 | 5.00 | 2.00 | 2.17 | 4.58 | 6.58 | 2.50 | -1. | -1. | -1. | 0. | | |
| (11) | Project Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 1. | 58. | 25. |
| (12) | Free Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1. | 116. | 51. |
| (13) | Pumped Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 1. | 757. | 69. |

Table 50. Linear Programming Matrix, Casa Grande and Coolidge Areas, Farm Size II, Shallow Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Water Purchase Activities | | | Disposal Activities | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13-22) | (23) | (24) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase (Pumped) | Water Purchase (Project) | Free Water (Project) | | Restrictions (Casa Grande) | Restrictions (Coolidge) |
| (1) | Revenue (Casa Grande) | Dollars | -134.77 | -187.74 | -268.31 | -331.29 | -52.90 | -52.56 | -50.42 | -80.92 | -40.92 | 6.57 | .50 | 0. | 0. | | |
| (2) | Revenue (Coolidge) | Dollars | -134.77 | -187.74 | -268.31 | -331.29 | -52.90 | -52.56 | -50.42 | -80.92 | -40.92 | 6.57 | .50 | 0. | 0. | | |
| (3) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 136. | 97. |
| (4) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1681. | 1184. |
| (5) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 1. | 3739. | 2745. |
| (6) | July Water | Acre-Feet | .65 | .73 | .65 | .73 | 0. | .64 | 0. | .54 | 0. | 0. | 0. | 0. | 1. | 1677. | 1634. |
| (7) | January Water | Acre-Feet | 1.30 | 1.77 | 1.30 | 1.77 | .98 | 0. | .54 | .54 | .94 | 0. | 0. | 0. | 1. | 3522. | 3431. |
| (8) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 1. | 5035. | 3692. |
| (9) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 3739. | 2745. |
| (10) | Water Balance | Acre-Feet | 6.00 | 7.00 | 6.00 | 7.00 | 3.00 | 3.29 | 4.58 | 6.58 | 3.50 | -1. | -1. | -1. | 0. | | |
| (11) | Project Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 1. | 1320. | 2843. |
| (12) | Free Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1. | 2640. | 5686. |
| (13 | Pumped Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 1. | 15612. | 10545. |

Table 51. Linear Programming Matrix, Casa Grande and Coolidge Areas, Farm Size II, Middle Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Water Purchase Activities | | | Disposal Activities | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13-22) | (23) | (24) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase (Pumped) | Water Purchase (Project) | Free Water (Project) | | Restrictions (Casa Grande) | Restrictions (Coolidge) |
| (1) | Revenue (Casa Grande) | Dollars | -124.36 | -177.24 | -260.07 | -322.96 | -47.47 | -46.09 | -50.11 | -80.61 | -35.57 | 10.50 | .50 | 0. | 0. | | |
| (2) | Revenue (Coolidge) | Dollars | -124.36 | -177.24 | -260.07 | -322.96 | -47.47 | -46.09 | -50.11 | -80.61 | -35.57 | 9.90 | .50 | 0. | 0. | | |
| (3) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 188. | 76. |
| (4) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 2309. | 927. |
| (5) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 1. | 5136. | 2151. |
| (6) | July Water | Acre-Feet | .54 | .62 | .54 | .62 | 0. | .54 | 0. | .54 | 0. | 0. | 0. | 0. | 1. | 2306. | 1277. |
| (7) | January Water | Acre-Feet | 1.09 | 1.52 | 1.09 | 1.52 | 1.00 | 0. | .54 | .54 | .81 | 0. | 0. | 0. | 1. | 4843. | 2682. |
| (8) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 1. | 6915. | 2894. |
| (9) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 5136. | 2151. |
| (10) | Water Balance | Acre-Feet | 5.00 | 6.00 | 5.00 | 6.00 | 2.50 | 2.75 | 4.58 | 6.58 | 3.00 | -1. | -1. | -1. | 0. | | |
| (11) | Project Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 1. | 1814. | 2223. |
| (12) | Free Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1. | 3629. | 4446. |
| (13) | Pumped Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 1. | 21465. | 8243. |

Table 52. Linear Programming Matrix, Casa Grande and Coolidge Areas, Farm Size II, Deep Pumping Lift, 1966

| Row Number | Objective Functions and Restrictions | Unit | Revenue Producing Activities (1) Long Staple Solid-Planted Cotton | (2) Long Staple Skip-Row Cotton | (3) Short Staple Solid-Planted Cotton | (4) Short Staple Skip-Row Cotton | (5) Barley | (6) Grain Sorghum | (7) Alfalfa Without Summer Water | (8) Alfalfa With Summer Water | (9) Wheat | Water Purchase Activities (10) Water Purchase (Pumped) | (11) Water Purchase (Project) | (12) Free Water (Project) | Disposal Activities (13-22) | (23) Restrictions (Casa Grande) | (24) Restrictions (Coolidge) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | Revenue (Casa Grande) | Dollars | -113.48 | -165.52 | -251.26 | -313.21 | -41.30 | -38.17 | -49.94 | -80.44 | -29.46 | 12.44 | .50 | 0. | 0. | | |
| (2) | Revenue (Coolidge) | Dollars | -113.48 | -165.52 | -251.26 | -313.21 | -41.30 | -38.17 | -49.94 | -80.44 | -29.46 | 12.53 | .50 | 0. | 0. | | |
| (3) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 16. | 4. |
| (4) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 203. | 48. |
| (5) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 1. | 450. | 111. |
| (6) | July Water | Acre-Feet | .43 | .52 | .43 | .52 | 0. | .44 | 0. | .54 | 0. | 0. | 0. | 0. | 1. | 209. | 59. |
| (7) | January Water | Acre-Feet | .87 | 1.27 | .87 | 1.27 | .65 | 0. | .54 | .54 | .68 | 0. | 0. | 0. | 1. | 439. | 124. |
| (8) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 1. | 607. | 150. |
| (9) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 450. | 111. |
| (10) | Water Balance | Acre-Feet | 4.00 | 5.00 | 4.00 | 5.00 | 2.00 | 2.17 | 4.58 | 6.58 | 3.00 | -1. | -1. | -1. | 0. | | |
| (11) | Project Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 1. | 165. | 103. |
| (12) | Free Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1. | 330. | 207. |
| (13) | Pumped Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 1. | 1951. | 383. |

Table 53. Linear Programming Matrix, Casa Grande and Coolidge Areas, Farm Size III, Shallow Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Water Purchase Activities | | | Disposal Activities | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13-22) | (23) | (24) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase (Pumped) | Water Purchase (Project) | Free Water (Project) | | Restrictions (Casa Grande) | Restrictions (Coolidge) |
| (1) | Revenue (Casa Grande) | Dollars | -138.81 | -193.32 | -276.81 | -336.88 | -52.95 | -56.51 | -51.83 | -82.33 | -41.09 | 6.29 | .50 | 0. | 0. | | |
| (2) | Revenue (Coolidge) | Dollars | -138.81 | -193.32 | -276.81 | -336.88 | -52.95 | -56.51 | -51.83 | -82.33 | -41.09 | 6.29 | .50 | 0. | 0. | | |
| (3) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 178. | 248. |
| (4) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 2187. | 3023. |
| (5) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 1. | 4865. | 7010. |
| (6) | July Water | Acre-Feet | .62 | .70 | .62 | .70 | 0. | .61 | 0. | .52 | 0. | 0. | 0. | 0. | 1. | 2180. | 4186. |
| (7) | January Water | Acre-Feet | 1.25 | 1.70 | 1.25 | 1.70 | .94 | 0. | .52 | .52 | .91 | 0. | 0. | 0. | 1. | 4578. | 8791. |
| (8) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 1. | 6551. | 9429. |
| (9) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 4865. | 7010. |
| (10) | Water Balance | Acre-Feet | 6.00 | 7.00 | 6.00 | 7.00 | 3.00 | 3.29 | 4.58 | 6.58 | 3.50 | -1. | -1. | -1. | 0. | | |
| (11) | Project Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 1. | 1480. | 7469. |
| (12) | Free Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1. | 2960. | 14937. |
| (13) | Pumped Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 1. | 21008. | 26461. |

Table 54. Linear Programming Matrix, Casa Grande and Coolidge Areas, Farm Size III, Middle Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Water Purchase Activities | | | Disposal Activities | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13-22) | (23) | (24) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase (Pumped) | Water Purchase (Project) | Free Water (Project) | | Restrictions (Casa Grande) | Restrictions (Coolidge) |
| (1) | Revenue (Casa Grande) | Dollars | -132.32 | -183.28 | -268.03 | -329.00 | -47.78 | -50.96 | -51.54 | -82.04 | -35.96 | 10.06 | .50 | 0. | 0. | | |
| (2) | Revenue (Coolidge) | Dollars | -132.32 | -183.28 | -268.03 | -329.00 | -47.78 | -50.96 | -51.54 | -82.04 | -35.96 | 9.49 | .50 | 0. | 0. | | |
| (3) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 245. | 195. |
| (4) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 3017. | 2367. |
| (5) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 1. | 6712. | 5489. |
| (6) | July Water | Acre-Feet | .52 | .60 | .52 | .60 | 0. | .52 | 0. | .52 | 0. | 0. | 0. | 0. | 1. | 2998. | 3272. |
| (7) | January Water | Acre-Feet | 1.04 | 1.46 | 1.04 | 1.46 | .78 | 0. | .52 | .52 | .78 | 0. | 0. | 0. | 1. | 6296. | 6871. |
| (8) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 1. | 9037. | 7384. |
| (9) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 6712. | 5489. |
| (10) | Water Balance | Acre-Feet | 5.00 | 6.00 | 5.00 | 6.00 | 2.50 | 2.75 | 4.58 | 6.58 | 3.00 | -1. | -1. | -1. | 0. | | |
| (11) | Project Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 1. | 2035. | 5839. |
| (12) | Free Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1. | 4071. | 11678. |
| (13) | Pumped Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 1. | 28886. | 20687. |

Table 55. Linear Programming Matrix, Casa Grande and Coolidge Areas, Farm Size III, Deep Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Water Purchase Activities | | | Disposal Activities | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13-22) | (23) | (24) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase (Pumped) | Water Purchase (Project) | Free Water (Project) | | Restrictions (Casa Grande) | Restrictions (Coolidge) |
| (1) | Revenue (Casa Grande) | Dollars | -121.07 | -172.00 | -258.93 | -319.88 | -41.92 | -43.99 | -51.38 | -81.88 | -29.78 | 11.92 | .50 | 0. | 0. | | |
| (2) | Revenue (Coolidge) | Dollars | -121.07 | -172.00 | -258.93 | -319.88 | -41.92 | -43.99 | -51.38 | -81.88 | -29.78 | 12.01 | .50 | 0. | 0. | | |
| (3) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 23. | 8. |
| (4) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 284. | 96. |
| (5) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 1. | 631. | 223. |
| (6) | July Water | Acre-Feet | .42 | .50 | .42 | .50 | 0. | .43 | 0. | .52 | 0. | 0. | 0. | 0. | 1. | 273. | 152. |
| (7) | January Water | Acre-Feet | .83 | 1.22 | .83 | 1.22 | .62 | 0. | .52 | .52 | .66 | 0. | 0. | 0. | 1. | 573. | 319. |
| (8) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 1. | 849. | 299. |
| (9) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 631. | 223. |
| (10) | Water Balance | Acre-Feet | 4.00 | 5.00 | 4.00 | 5.00 | 2.00 | 2.17 | 4.58 | 6.58 | 2.50 | -1. | -1. | -1. | 0. | | |
| (11) | Project Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 1. | 185. | 272. |
| (12) | Free Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1. | 370. | 543. |
| (13) | Pumped Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 1. | 2626. | 962. |

Table 56. Linear Programming Matrix, Casa Grande and Coolidge Areas, Farm Size IV, Shallow Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Water Purchase Activities | | | Disposal Activities | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13-22) | (23) | (24) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase (Pumped) | Water Purchase (Project) | Free Water (Project) | | Restrictions (Casa Grande) | Restrictions (Coolidge) |
| (1) | Revenue (Casa Grande) | Dollars | -144.60 | -196.52 | -278.63 | -340.56 | -52.69 | -55.32 | -52.79 | -83.79 | -41.50 | 5.78 | .50 | 0. | 0. | | |
| (2) | Revenue (Coolidge) | Dollars | -144.60 | -196.52 | -278.63 | -340.56 | -52.69 | -55.32 | -52.79 | -83.79 | -41.50 | 5.78 | .50 | 0. | 0. | | |
| (3) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 291. | 358. |
| (4) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 3585. | 4350. |
| (5) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 1. | 7974. | 10088. |
| (6) | July Water | Acre-Feet | .57 | .64 | .57 | .64 | 0. | .56 | 0. | .48 | 0. | 0. | 0. | 0. | 1. | 3573. | 6030. |
| (7) | January Water | Acre-Feet | 1.15 | 1.56 | 1.15 | 1.56 | .86 | 0. | .48 | .48 | .83 | 0. | 0. | 0. | 1. | 7504. | 12663. |
| (8) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 1. | 10736. | 13570. |
| (9) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 7974. | 10088. |
| (10) | Water Balance | Acre-Feet | 6.00 | 7.00 | 6.00 | 7.00 | 3.00 | 3.29 | 4.58 | 6.58 | 3.50 | -1. | -1. | -1. | 0. | | |
| (11) | Project Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 1. | 3681. | 11553. |
| (12) | Free Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1. | 7362. | 23106. |
| (13) | Pumped Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 1. | 30650. | 35728. |

Table 57. Linear Programming Matrix, Casa Grande and Coolidge Areas, Farm Size IV, Middle Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Water Purchase Activities | | | Disposal Activities | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13-22) | (23) | (24) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase (Pumped) | Water Purchase (Project) | Free Water (Project) | | Restrictions (Casa Grande) | Restrictions (Coolidge) |
| (1) | Revenue (Casa Grande) | Dollars | -135.71 | -187.56 | -271.42 | -333.28 | -47.98 | -50.26 | -52.51 | -83.51 | -36.80 | 9.24 | .50 | 0. | 0. | | |
| (2) | Revenue (Coolidge) | Dollars | -135.71 | -187.56 | -271.42 | -333.28 | -47.98 | -50.26 | -52.51 | -83.51 | -36.80 | 8.71 | .50 | 0. | 0. | | |
| (3) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 400. | 279. |
| (4) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 4922. | 3391. |
| (5) | Winter Acres | Acres | 1. | 1. | 1. | 1, | 1. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 1. | 10948. | 7863. |
| (6) | July Water | Acre-Feet | .48 | .55 | .48 | .55 | 0. | .48 | 0. | .48 | 0. | 0. | 0. | 0. | 1. | 4913. | 4714. |
| (7) | January Water | Acre-Feet | .95 | 1.34 | .95 | 1.34 | .72 | 0. | .48 | .48 | .72 | 0. | 0. | 0. | 1. | 10317. | 9899. |
| (8) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 1. | 14740. | 10577. |
| (9) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 10948. | 7863. |
| (10) | Water Balance | Acre-Feet | 5.00 | 6.00 | 5.00 | 6.00 | 2.50 | 2.75 | 4.58 | 6.58 | 3.00 | -1. | -1. | -1. | 0. | | |
| (11) | Project Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 1. | 5061 | 9032. |
| (12) | Free Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1. | 10122. | 18065. |
| (13) | Pumped Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 1. | 42145. | 27933. |

Table 58. Linear Programming Matrix, Casa Grande and Coolidge Areas, Farm Size IV, Deep Pumping Lift, 1966

| | | | Revenue Producing Activities | | | | | | | | | Water Purchase Activities | | | Disposal Activities | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13-22) | (23) | (24) |
| Row Number | Objective Functions and Restrictions | Unit | Long Staple Solid-Planted Cotton | Long Staple Skip-Row Cotton | Short Staple Solid-Planted Cotton | Short Staple Skip-Row Cotton | Barley | Grain Sorghum | Alfalfa Without Summer Water | Alfalfa With Summer Water | Wheat | Water Purchase (Pumped) | Water Purchase (Project) | Free Water (Project) | | Restrictions (Casa Grande) | Restrictions (Coolidge) |
| (1) | Revenue (Casa Grande) | Dollars | -125.50 | -177.33 | -263.02 | -329.48 | -42.64 | -43.91 | -52.36 | -83.36 | -31.46 | 10.95 | .50 | 0. | 0. | | |
| (2) | Revenue (Coolidge) | Dollars | -125.50 | -177.33 | -263.02 | -329.48 | -42.64 | -43.91 | -52.36 | -83.36 | -31.46 | 11.03 | .50 | 0. | 0. | | |
| (3) | L. S. Allotment | Acres | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 36. | 13. |
| (4) | S. S. Allotment | Acres | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 446. | 160. |
| (5) | Winter Acres | Acres | 1. | 1. | 1. | 1. | 1. | 0. | 0. | 0. | 1. | 0. | 0. | 0. | 1. | 991. | 371. |
| (6) | July Water | Acre-Feet | .38 | .46 | .38 | .46 | 0. | .39 | 0. | .48 | 0. | 0. | 0. | 1. | 1. | 447. | 219. |
| (7) | January Water | Acre-Feet | .76 | 1.12 | .76 | 1.12 | .57 | 0. | .48 | .48 | .60 | 0. | 0. | 0. | 1. | 939. | 460. |
| (8) | Conserving Base | Acres | 0. | 1. | 0. | 1. | 0. | 0. | 1. | 1. | 0. | 0. | 0. | 0. | 1. | 1334. | 499. |
| (9) | Summer Acres | Acres | 1. | 1. | 1. | 1. | 0. | 1. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 991. | 371. |
| (10) | Water Balance | Acre-Feet | 4.00 | 5.00 | 4.00 | 5.00 | 2.00 | 2.17 | 4.58 | 6.58 | 2.50 | -1. | -1. | -1. | 0. | | |
| (11) | Project Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 1. | 460. | 420. |
| (12) | Free Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 1. | 920. | 840. |
| (13) | Pumped Water | Acre-Feet | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 0. | 1. | 0. | 0. | 1. | 3831. | 1299. |

must find the values which simultaneously satisfy all the equations in the matrix and allow the highest attainable value for the objective function.

The rows labeled "Revenue" constitute the objective functions. These rows give the net revenue over variable costs, excluding variable water costs, for each acre of the revenue producing activities 1 through 9. For the activities labeled "Water Purchase," the entries are the variable costs of one acre-foot of water. Where multiple "Revenue" rows are shown, the same set of technical coefficients shown in the balance of the table applies to the different areas. Restrictions for the different areas are shown in the right hand columns.

The objective is net revenue maximization. Since ALPHAC VERSION I is a minimization program, it is computationally necessary to enter net revenues as negative quantities. By reversing the signs of the coefficients in the objective function, a problem stated in terms of maximization is converted into a minimization problem.

Net revenues for the various crops are shown as equal between subareas. However, these revenues are before water costs are deducted. The water cost per acre foot of water is given in the water purchase column(s). These costs vary between subareas, pumping lifts, and farm size. The program automatically maximizes net revenue over variable costs <u>including</u> the variable cost of water.

The remaining rows contain the technical coefficients that allocate the resource restrictions. For example, in Table 35 Row 2, one acre of long staple solid-planted cotton requires one acre of allotment; one acre of long staple skip-row cotton requires one acre of allotment; one acre of each of the other real activities requires zero acres of allotment; one acre of allotment is disposed of it it is not used; and finally, five acres of allotment are available for use. The technical coefficients for water use vary with pumping lift.

The "Water Balance" row insures that the total amount of water used equals the amount of water purchased. The coefficients for the real activities are the acre-foot requirements per acre of crop per year. The minus one in the water purchase column says that for each acre-foot used, one acre-foot is purchased.

In four of the subareas, only pumped water is available. In the Coolidge and Casa Grande subareas, water may be pumped or purchased at two alternative prices. Thus, three water purchase activities and three additional water restrictions are included for these areas. Since a certain amount of the surface water is available for a fixed charge per acre, its variable price is zero. Additional surface water is available for a variable price of $.50 per acre-foot. The restrictions on total pumped water in these two subareas were necessary on an early version of the model and simply were not eliminated in the final version. In this version, they are redundant.

The alternative enterprises ("activities") open to Pinal County farmers for purposes of this analysis are: long staple cotton (solid-planted), long staple cotton (skip-row planted), short staple cotton (solid-planted), short staple cotton (skip-row planted), barley, grain sorghum, alfalfa (without summer water), alfalfa (with summer water), and wheat. These are the same crops, including alternative growing techniques, used by Stults (15) in his analysis.

Although there are other minor crops grown in Pinal County, Stults (15) chose to include only these crops because of their relative importance in the county. He states that

> The above listed crops accounted for 86 percent of the cropped acres in Pinal County in 1965. Another 10 percent was in other miscellaneous low-value crops, such as sudan grass, irrigated pasture, green chop, safflower, corn, other small grains, etc. Omission of these crops is not serious because the net returns and resource requirements for these crops are very similar to the low-value crops included in the model (p. 59).

Since the resources used to produce the low-value crops omitted are included in the model, acreage and output of the low-value crops (alfalfa, barley, grain sorghum, and wheat) included in the model will be over-estimated by the approximate amount of the crops omitted from the model.

About four percent of Pinal County acreage is used to grow high-value crops which are not included as possible activities in either this study or the prior study by Stults. These high-value crops are mainly vegetables. These crops are not included in the linear programming model because they are not part of a typical general crop farm operation and because water costs have little influence on the amount of these crops grown.

Each subarea of this study is divided into 12 separate operational models because differences in efficiency and rates of water use occur between farm sizes and pumping lifts. Thus, a separate model is developed for each farm size with its associated pumping lift. These differences are reflected in the technical coefficients of each model. If all possible combinations existed in reality, 72 economic models (12 models per subarea times six subareas) would be necessary to depict the entire farming structure within Pinal County. In fact, because there are no Size I farms in the Maricopa and Queen Creek subareas, no Size II farms in the Maricops subarea, and no shallow pumping lifts in the Stanfield subarea, only 59 models were required.

## Adjustment of Restrictions Over Time

This analysis makes projections as to what crops will be grown, in what quantities, by what methods, and what net incomes Pinal County farmers will receive for the years 1966, 1976, 1986, 1996, and 2006. In so doing, adjustments in the restrictions of the various models are needed as time passes. The three factors which affect restriction adjustments as this analysis continues over time are: (a) a declining water table, (b) decisions on well replacements, and (c) cotton allotment transfers. The manner in which each factor is adjusted is discussed below.

Declining Water Table

The variable factor in this analysis is water costs. Since most water used in Pinal County is pumped, water costs will increase over time (given the assumption of fixed technology) because the withdrawal of groundwater is greatly in excess of the rate of replenishment of the groundwater basin. Hence, some wells which were previously of "shallow" depth will become "middle" depth, and some which were "middle" depth will become "deep." At some point in time, economic considerations may result in the stabilization of the water table at some level.

The declining water table changes water availability among the pumping lifts. For example, while 10 percent of the water pumped for irrigation purposes in the Eloy Area in 1966 is pumped from wells with "shallow" pumping lifts, by 1986 no water is being pumped by "shallow" lift wells in this subarea. Therefore, as the water table declines, the water availability restrictions are adjusted in the model. The land and cotton allotment restrictions are adjusted in the same proportion as is water. If 10 percent of the water in a given subarea is transferred from "shallow" to "middle" pumping lifts, then 10 percent of the cropped acres, cotton allotments, and conserving base acres are also transferred from "shallow" to "middle" pumping lift models for that subarea.

The declining water table in the six subareas also causes pumping costs to change over time. The pumping lift of all wells arrayed for each subarea is increased by the corresponding decline in the water table of that subarea as determined by the analog model. A new weighted average of pumping lift depth is then calculated for the "shallow," "middle," and "deep" pumping lifts of each subarea. The average cost of pumping water from "middle" and/or "deep" pumping lifts may actually decrease during a given period due to the fact that the weighted average pumping lift depth may decrease as the proportion of total water pumped from these lifts increases over time. The new water costs calculated by this method are incorporated into the linear programming models.

## Well Replacement Decisions

Although the cost of replacing a well is considered a fixed cost in the short run, in the long run this cost becomes variable and must therefore be considered in this analysis. In general, the decision to abandon land comes when the farmer is faced with the decision of drilling a new well. Stults assumed well life to be 40 years. It is assumed so for this analysis also. The profitability of replacing a well in both studies is determined by comparing the net revenue over variable costs from the crops which would go out of production if the well were not replaced with the investment cost of the well for typical farms in each size group and pumping lift. When it is determined that it is not profitable to replace a well in a given sub-area, this is reflected in the model by decreasing the percentage of the water available to that farm size and related pumping lift. Correspondingly, cropped acres and conserving base restrictions for that model are reduced in the same proportion.

Stults developed a table of break-even pumping lifts for the various crops in Pinal County (see Table 59). This table greatly facilitates the making of well replacement decisions. The most efficient sized farms are those of Farm Size IV. When a small farmer cannot afford to replace a well, but larger farmers can, cotton allotments, water, and land resources are transferred to the most efficient size group. Rather than dividing these resources among all farm size groups which can afford to replace the wells, resources are transferred to the largest size group since this group can best afford to acquire these resources.

Table 59. Break-even Pumping Lifts and Net Returns Over Variable Costs Including Fixed Well Costs per Cropped Acre at Selected Pumping Lifts, Pinal County

| | Returns | | | |
|---|---|---|---|---|
| | Farm Size | | | |
| | I | II | III | IV |
| Upland cotton[ab] | (Dollars) | | | |
| 0 Water cost | 312.20 | 331.29 | 336.88 | 340.56 |
| 315' Lift | 235.11 | 258.18 | 226.57 | 276.04 |
| 460' Lift | 204.37 | 228.64 | 288.56 | 248.28 |
| 540' Lift | 199.13 | 223.48 | 233.80 | 250.42 |
| | (Feet) | | | |
| Break-even Lift | 1,679 | 1,885 | 2,007 | 2,249 |
| American-Egyptian cotton[a] | (Dollars) | | | |
| 0 Water cost | 168.99 | 187.74 | 193.32 | 196.52 |
| 315' Lift | 91.90 | 114.33 | 123.01 | 132.00 |
| 460' Lift | 60.16 | 82.92 | 92.84 | 104.56 |
| 540' Lift | 52.47 | 76.70 | 85.92 | 98.27 |
| | (Feet) | | | |
| Break-even Lift | 840 | 1,001 | 1,079 | 1,111 |
| Barley | (Dollars) | | | |
| 0 Water cost | 52.61 | 52.90 | 52.95 | 52.69 |
| 315' Lift | 19.58 | 21.43 | 22.82 | 25.05 |
| 460' Lift | 5.00 | 8.18 | 10.10 | 15.60 |
| 540' Lift | .57 | 5.36 | 7.49 | 11.03 |
| | (Feet) | | | |
| Break-even Lift | 548 | 620 | 657 | 728 |
| Grain Sorghum | (Dollars) | | | |
| 0 Water cost | 50.68 | 52.56 | 56.51 | 55.32 |
| 315' Lift | 14.45 | 18.07 | 23.47 | 25.00 |
| 460' Lift | -1.03 | 2.88 | 9.52 | 12.19 |
| 540' Lift | -4.01 | -.80 | 6.62 | 9.63 |
| | (Feet) | | | |
| Break-even Lift | 463 | 500 | 635 | 691 |
| Alfalfa | (Dollars) | | | |
| 0 Water cost | 40.89 | 43.00 | 44.74 | 46.26 |
| 315' Lift | -3.15 | 1.06 | 4.56 | 9.38 |
| 460' Lift | -24.32 | -17.04 | -14.76 | -8.33 |
| 540' Lift | -33.80 | -26.16 | -21.56 | -14.58 |
| | (Feet) | | | |
| Break-even Lift | 294 | 323 | 351 | 395 |

Table 59.--Continued

| | | | | |
|---|---|---|---|---|
| Wheat | | (Dollars) | | |
| 0 Water cost | 40.69 | 40.72 | 41.09 | 41.52 |
| 315' Lift | 3.15 | 4.62 | 5.93 | 9.27 |
| 460' Lift | -14.49 | -11.62 | -9.26 | -4.67 |
| 540' Lift | -15.23 | -12.49 | -10.81 | -5.39 |
| | | (Feet) | | |
| Break-even Lift | 345 | 361 | 377 | 420 |

Source: (15).

[a]Skip row (4 X 4) planting pattern.

[b]Includes Government payments.

Cotton Allotment Transfers

In some cases, when the short staple cotton allotment becomes large relative to the January water available, long staple cotton allotment is disposed of in the model. If allotments could not be transferred from farm to farm, this would be a correct profit maximizing decision. Because short staple cotton is the highest valued crop, it would be grown to the exclusion of long staple cotton if January water were in short supply, with any excess July water being used on extra acres of grain sorghum. Long staple cotton requires both January and July water, while grain sorghum requires only summer water.

Since in reality long staple allotments never go unused, and since recent legislation allows the sale of cotton allotments between farmers in Pinal County, long staple cotton allotments which are disposed of by the model are transferred to farms in that subarea which can afford to pay the highest price for these allotments. The model is then re-run. Value of a cotton allotment to a certain size farm is given by the "shadow price" provided by the linear programming solution. In almost every case, the value placed upon an additional acre of long staple cotton allotment is greatest for farms of Size IV with "deep" pumping lifts. Therefore, disposed cotton allotments were transferred to this group of farms in the model.

# CHAPTER V

## THE ANALOG MODEL

The effect that pumping water from an aquifer has on the water level cannot be so easily determined as if one were merely pumping water from a lake. Many special factors must be considered in the case of an aquifer. Skibitzke (14) analyzes the problem as follows:

> The development of groundwater resources in arid regions is a quantity problem. A given fixed quantity of groundwater is available stored in the pore spaces of the rocks beneath the surface of the ground. It is possible to install pumps in the aquifer and pump this water at almost any desired rate. However, the length of time which the resource can be pumped is set by the amount of water stored in the reservoir. For example, the quantity of water that underlies Southwestern Arizona is roughly comparable to that in Lake Michigan. But the Southwestern Arizona aquifer is a peculiar kind of reservoir as compared with Lake Michigan. If water were pumped out of Lake Michigan, the surface of the whole lake would be expected to lower uniformly. Thus, it would be possible to deplete all of the water in the lake. Such uniform lowering of the surface cannot be done in the lake of groundwater beneath Southwestern Arizona. The water can move only in the most sluggish manner. Its motion is so slow that it is virtually possible to bore holes in the water body. These holes, called "drawdown cones," persist, to a verying degree, over many years. Drawdown cones may cause wells to refuse to function during short periods of time even while larger quantities of water remain stored in the vicinity. Large amounts of the groundwater stored in Southwestern Arizona can never be removed from the pore spaces. Some of it is so tightly bound in clay materials that the movement outward becomes so slow that the water will never be available for use by

> man. Part of it is at a depth too great for economic development, and some of it is in rocks so impermeable it cannot be removed. The resulting complex rate of removal presents an engineering problem different from that which would be encountered in the pumping of Lake Michigan. As a matter of fact, only a small part of the total volume of water stored in Southwestern Arizona can be made available to man (p. 45).

In an effort to provide a means of analyzing the effects of pumpage from the central Arizona area, the U.S U.S.G.S. constructed an electric-analog model of the hydrologic system.

An analog model is a physical representation of some system by means of another system. The analog model employed in this study uses a resistor-capacitor network to represent the groundwater system underlying the Salt River Valley and the lower Santa Cruz River basin. (Pinal County falls within the latter region.) This electrical-analog model makes it possible to predict future groundwater levels under conditions of continued withdrawal in excess of the rate of replenishment. The model is described in detail by Anderson (1) in <u>Electrical-Analog Analysis of Groundwater Depletion in Central Arizona</u>. That paper reports on a projection as to the probable water table conditions that will exist in this the Central Arizona area in 1974 and 1984 given that pumpage remains at the rate as in the years 1958-64. A brief description of the characteristics of this model, derived from the Anderson report is set forth in the following sections.

## The Geologic and Hydrologic Setting

Central Arizona is characterized by low mountains surrounded by very broad flat-lying valleys. The mountains, which are composed mainly of impermeable crystalline and minor sedimentary rocks, form hydrologic boundaries to groundwater flow. The valleys are underlain by thousands of feet of unconsolidated to consolidated alluvial deposits which range in size from gravel to clay. The alluvium is an aquifer which stores large quantities of water that may be removed by wells.

The alluvium may be divided into an upper sand and gravel unit 0 to 600 feet thick, a middle silt and clay unit 0 to 2,000 feet thick, and a lower sand and gravel unit 0 to 500 feet thick. In most of central Arizona, the water table is in the highly permeable upper sand and gravel unit, and most of the water is produced from this unit. The middle silt and clay unit is less permeable and yields less water to wells; this unit, however, does not extend over the entire area. The lower sand and gravel unit is more permeable than the middle silt and clay unit but is not as productive as the upper sand and gravel unit.

Information simulated into the analog model was gathered mainly from wells which tap only the uppermost

1,000 to 1,200 feet of the alluvium. Thus, the model dominantly reflects or interprets groundwater conditions only in the upper sand and gravel and part of the silt and clay units.

## Data Required for the Model

If a physical analysis of water level changes is to be made, a physical description of the environment in which the water flows must be put into the problem. This physical description should include a complete description of the nature of the permeability and storage coefficients for all the aquifers involved in the flow system. If one knows the quantities or the numbers that describe the permeability and storage coefficients in every spot that the water might flow through, it would be possible, at least theoretically, to predict the changes in head due to pumping (14). The magnitude of the permeability coefficient of the sediments is of particular importance. Permeability refers to the resistance of the sediments to the flow of groundwater within them. The lower the permeability, the higher will be the hydraulic gradient necessary to move the water in the aquifer. Also, the hydraulic gradient will be steeper near a well; this results in greater drawdowns closer to the well. However, this low permeability restricts the drawdown effects in the vicinity of the pumped well, resulting in less immediate effects on adjacent wells.

Conversely, in more permeable materials, the drawdown effect upon neighboring wells is more pronounced initially, but the final effect on both the pumped well and adjacent wells is not as great (14, p. 47).

A measure of permeability is the coefficient of transmissibility. This coefficient is defined "as the rate of flow water, in gallons per day, through a vertical strip of the aquifer one foot wide extending the full saturated height of the aquifer under a hydraulic gradient of 100 percent" (1, p. 9). A map portraying the regional transmissibility pattern must be prepared before analog techniques may be utilized since such a map provides the basis for the construction of an electrical-resistor network analogous to the aquifer system. Although the ideal means of developing a quantitative pattern of regional transmissibility is provided by aquifer tests, Anderson based his calculation on known values of specific capacity because of a lack of sufficient aquifer-test data. Specific capacity is the yield of a well, in gallons per minute divided by the pumping drawdown in the well, in feet. These data were readily available and can be related to transmissibility. He calculated an approximate areal pattern of transmissibility ranging from 10,000 to 200,000 gallons per day per foot for central Arizona. This pattern of transmissibility was determined for only the upper 1,000 to 1,200 feet of alluvial material, as the wells from which specific-capacity data were obtained penetrated less than 1,200 feet.

The storage coefficient of an aquifer is defined as "the volume of water it releases from or takes into storage per unit change in the component of head normal to that surface" (1, p. 10). Storage coefficients had been computed for large areas in central Arizona based on the ratio of a known volume of pumpage to a known volume of sediments dewatered by that amount of pumpage. These storage coefficients ranged from 15 to 20 percent. A storage coefficient of 19 percent was calculated and used in the electrical-analog model, except where further refinement based on known subsurface characteristics was possible (1, p. 10).

There are other factors that affect the groundwater system. For instance, evapotranspiration and recharge are important considerations. These two occur at different rates as pumping changes. Increased pumping results in water level declines but also causes reduced evapotranspiration and changes in recharge. These factors were also simulated into the electrical-analog model used in this study (1, pp. 8-9).

## Assumptions Underlying the Analog Model

In the construction of the analog model, the following assumptions were made (1, pp. 14-15):

1. The coefficient of transmissibility is assumed to be uniform throughout the upper 1,200 feet of the aquifer.
2. The coefficient of storage is assumed to be uniform throughout the upper 1,200 feet of the aquifer.
3. It is assumed that the water table never drops below the upper 1,200 feet of the aquifer during the course of the analysis.
4. Average annual pumpage is simulated into the model rather than considering variations that occur during the year as a function of the growing season. Hence, it is assumed that water is pumped at a constant rate throughout the course of the year.

For the purpose of this study, the following additional assumption was simulated into the electrical-analog model: It is assumed that total pumpage occurring within each subarea is distributed equally among the pumpage points in that subarea. In other words, after the linear programming model used in this study determines the amount of water pumped within each subarea over a given time period, the total pumpage determined for a particular subarea is divided equally among pumpage points simulated into the model for that subarea. One repercussion of this assumption is that there will be a more uniform lowering of the water table within Pinal County than actually occurs, thus eliminating or lessening some of the large cones of depression in certain regions of the county. In order to avoid this simplifying assumption, it would be necessary to have a representative farm linear programming model for each pumping point of the electric analog--an obvious impossibility.

## Physical Components of the Analog Model

The resistor-capacitor network is the basic element in the analysis of a groundwater system by electrical-analog techniques. The network is merely a scaled-down electrical version of the actual groundwater system. The resistors represent the energy-dissipation characteristics of the rock matrix through which the groundwater flows, and their value is inversely proportional to the transmissibility. Capacitors store electrical energy in a way that is analogous to the storage of groundwater in the pore spaces of the aquifer. The capacitor values are directly proportional to the storage coefficient of the aquifer (1, p. 10).

Withdrawal of water from the groundwater system is simulated electrically by the withdrawal of electric current. The change in voltage that occurs in the model as a result of the current withdrawal is analogous to the change in water levels that occurs when groundwater is pumped. In similar fashion, voltage and current in the electrical system are equivalent to the head and volume rate of flow in the groundwater system. The analogous units of the electrical and hydrologic system are summarized in Table 60.

Table 60. Analogy Between Hydrologic and Electrical Systems

| Hydrologic System | Electrical System |
|---|---|
| Transmissibility, in gallons per day per foot | Electrical resistance, in ohms |
| Storage coefficient | Electrical capacitance, in forads |
| Pressure on head of water, in feet | Voltage potential, in volts |
| Time, in years | Time, in microseconds |
| Volume of water, in gallons | Coulombs of electrical charge |

Source: (1, p. 11).

The response of the model to simulated pumping stresses is shown on an oscilloscope in a form called a hydrograph. The oscilloscope thus acts as a water level recorder, continually measuring the level in an observation well. Time units are given on the horizontal scale of the hydrograph, and the vertical scale is in voltage. Applying the appropriate constants enables one to convert voltage to feet of water level change. By means of measuring with the oscilloscope at different points, it is possible to prepare a contour map of water table changes caused by a specific stress applied for any specific length of time (1, p. 11).

Figure 2 depicts the front view of part of the electrical-analog model used in this study. It was constructed on a scale of one inch to the mile. Resistor junctions are placed at one-inch intervals. Since each resistor in the network represents the resistance to flow of water in a specific part of the aquifer, local variations in transmissibility can be simulated by merely changing the value of a resistor. Each resistor represents the average transmissibility for the upper part of the aquifer to a maximum depth of about 1,200 feet. As seen in Figure 2, the resistor grid is superimposed on the base map. The dark areas indicate land under cultivation (1, pp. 12-13).

The reverse side of the model with the pumpage-programming board attached is shown in Figure 3. The board consists of a half-scale map, and pumpage centers (or points) are represented by the black junctions. Some additional resistors on the back of this board control the amount of current withdrawn from the analog system.

Figure 2 is a picture of the lower part of the model which is the Tucson Basin. The upper part of Figure 3 shows the Santa Cruz Basin which is the actual area studied in this thesis.

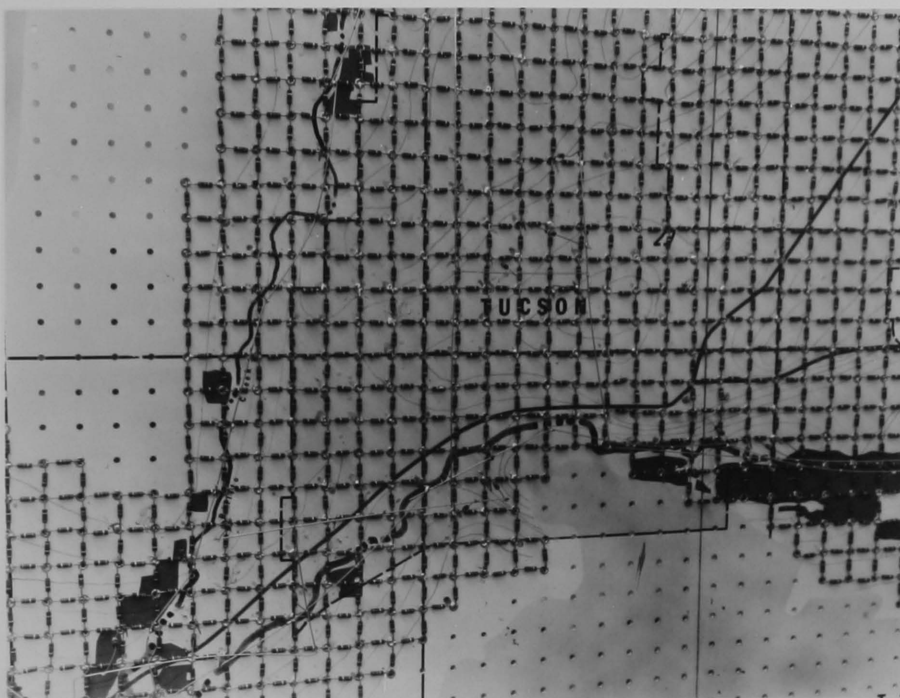


Figure 2. Front view of electrical-analog model.

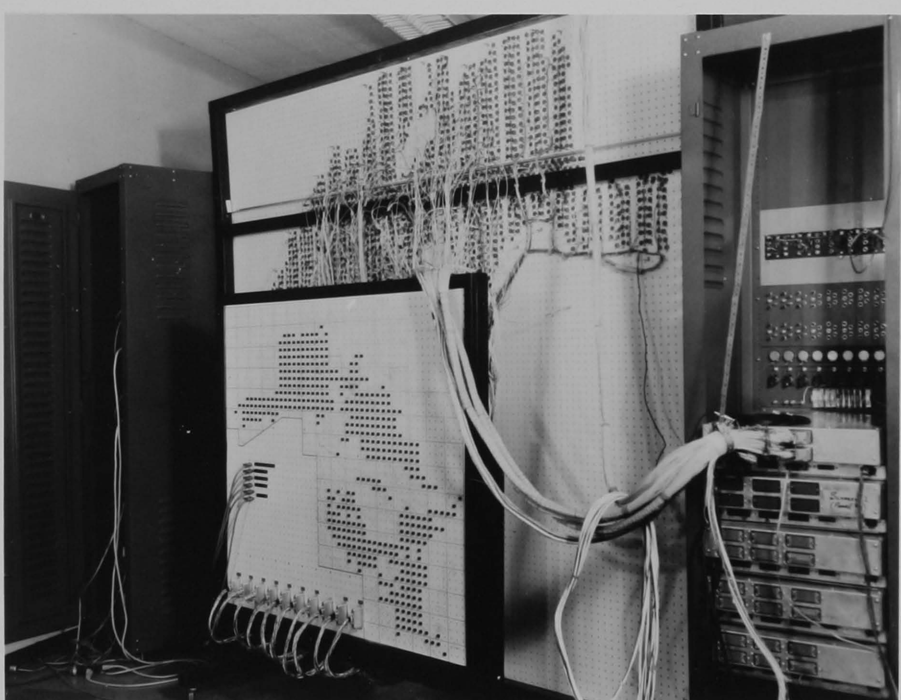

Figure 3. Back view of electrical-analog model.

# CHAPTER VI

# RESULTS OF THE ANALYSIS

The main objective of this analysis, as stated in Chapter I, is to project probable changes in cropping patterns, water use, and net income within Pinal County as the water table in this region of Arizona continues to decline. This analysis is an attempt at improving the accuracy of an earlier study of the same area by using a method which integrates the use of a digital and an analog computer.

In this study, Pinal County is divided into six subareas for separate analysis. This makes it possible to project agricultural adjustments within various regions of the county. A comparison of the changes occurring in the different subareas of Pinal County is made in the first section of this chapter. A later section deals with a comparison of the aggregate results of this analysis with the results of the earlier analysis by Stults. The last section puts forth the general conclusions reached as a result of this study.

## Comparison of Subareas

Dividing the county into six subareas allows separate analysis of each subarea differing substantially as to its cost of water. It is theorized that agricultural adjustments will occur at different rates within the six subareas. A summary of the results obtained from the linear programming model for each subarea for each of the ten-year periods from 1966 to 2006 is given in Tables 61 through 66.[4]

Water Use in the Subareas

The extent to which a resource is acquired and used usually varies inversely with the cost of the resource. Agricultural water offers no exception to this "law of demand." Hence, as the cost of water increases, water usage by farmers decreases.

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4. An incorrect price for alfalfa was entered in the original linear programming models for Casa Grande and Coolidge. This mistake resulted in underestimating pumpage in 1966 by 4.0 percent in the Casa Grande subarea and 8.2 percent in the Coolidge subarea, with a 3.2 percent underestimate for the whole county. The mistake was not discovered until after all of the analog simulations were complete.

It was impossible to re-run the analog simulations. (The time and personnel for the original runs had been generously contributed by the U. S. Geological Survey.) Therefore, the linear programming models were re-run for these two subareas using the original outputs of analog model to estimate the decline in the groundwater table. This procedure would result in slightly overestimating water use and total cropped acres after the period 1966-1976. Net revenue could be either underestimated or overestimated slightly because although more acres would tend to cause overestimation, deeper pumping depths would cause underestimates.

In fact, both the original and corrected runs give exactly the same net revenue at the end of 50 years. Because only barley and alfalfa acreage is affected at all, and all estimates are tending to converge throughout the 50-year projection period, the final results are thought to be within a two to three percent error.

Table 61. Projected Acreage of Field Crops, Net Revenue Over Variable Costs and Water Use, Casa Grande Subarea, 1966-2006[a]

| Year | American-Egyptian Cotton | Upland Cotton | Barley | Grain Sorghum | Alfalfa | Wheat | Total Cropped Acres | Net Revenue Over Variable Costs | Water Use[b] | Mean Lift in "Deep" Wells |
|---|---|---|---|---|---|---|---|---|---|---|
| | ----------Acres---------- | | | | | | | (Thousands of Dollars) | (1,000 acre-feet) | (Feet) |
| 1966 | 1,646 | 20,254 | 10,136 | 12,561 | 2,846 | 0 | 47,443 | 6,901.8 | 213.4 | 500 |
| 1976 | 1,646 | 20,254 | 13,132 | 14,901 | 2,697 | 0 | 52,630 | 6,892.6 | 213.2 | 532 |
| 1986 | 1,646 | 20,254 | 11,678 | 12,370 | 473 | 0 | 46,421 | 6,653.6 | 182.9 | 574 |
| 1996 | 1,646 | 20,254 | 5,633 | 7,599 | 561 | 0 | 35,693 | 6,277.2 | 155.7 | 621 |
| 2006 | 1,646 | 20,254 | 3,098 | 5,463 | 113 | 0 | 30,574 | 6,055.7 | 136.0 | 642 |

[a]Based on results of linear programming model.

[b]Includes surface water supplied by the San Carlos Project.

Table 62. Projected Acreage of Field Crops, Net Revenue Over Variable Costs and Water Use, Coolidge Subarea, 1966-2006[a]

| Year | American-Egyptian Cotton | Upland Cotton | Barley | Grain Sorghum | Alfalfa | Wheat | Total Cropped Acres | Net Revenue Over Variable Costs | Water Use[b] | Mean Lift in "Deep" Wells |
|---|---|---|---|---|---|---|---|---|---|---|
| | ------------------------ | -------- | ------ | Acres | ------ | -------- | ------------------------ | (Thousands of Dollars) | (1,000 acre-feet) | (Feet) |
| 1966 | 1,315 | 15,994 | 18,132 | 18,422 | 7,559 | 0 | 61,422 | 6,880.8 | 256.4 | 504 |
| 1976 | 1,315 | 15,994 | 18,202 | 18,787 | 6,663 | 0 | 60,961 | 6,829.9 | 253.7 | 523 |
| 1986 | 1,315 | 15,994 | 18,697 | 19,050 | 7,287 | 0 | 62,343 | 6,782.8 | 250.9 | 527 |
| 1996 | 1,315 | 15,994 | 15,565 | 15,825 | 8,505 | 0 | 57,204 | 6,542.9 | 232.7 | 551 |
| 2006 | 1,315 | 15,994 | 13,032 | 13,870 | 6,814 | 0 | 51,025 | 6,394.4 | 209.1 | 544 |

[a]Based on results of linear programming model.

[b]Includes surface water supplied by the San Carlos Project.

Table 63. Projected Acreage of Field Crops, Net Revenue Over Variable Costs and Water Use, Eloy Subarea, 1966-2006[a]

| Year | American-Egyptian Cotton | Upland Cotton | Barley | Grain Sorghum | Alfalfa | Wheat | Total Cropped Acres | Net Revenue Over Variable Costs | Water Use | Mean Lift in "Deep" Wells |
|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | | | | | | | (Thousands of Dollars) | (1,000 acre-feet) | (Feet) |
| 1966 | 1,747 | 23,974 | 18,673 | 17,685 | 6,030 | 0 | 67,929 | 7,999.7 | 264.4 | 526 |
| 1976 | 1,747 | 23,794 | 15,443 | 14,357 | 2,344 | 0 | 57,685 | 7,688.1 | 226.7 | 552 |
| 1986 | 1,747 | 23,794 | 11,481 | 10,957 | 4,694 | 0 | 52,673 | 7,404.1 | 216.6 | 569 |
| 1996 | 1,747 | 23,794 | 7,459 | 8,100 | 60 | 0 | 41,160 | 7,088.1 | 173.8 | 594 |
| 2006 | 1,747 | 23,794 | 8,861 | 8,525 | 1,870 | 0 | 44,797 | 7,077.2 | 180.3 | 588 |

[a]Based on results of linear programming model.

Table 64. Projected Acreage of Field Crops, Net Revenue Over Variable Costs and Water Use, Maricopa Subarea, 1966-2006[a]

| Year | American-Egyptian Cotton | Upland Cotton | Barley | Grain Sorghum | Alfalfa | Wheat | Total Cropped Acres | Net Revenue Over Variable Costs | Water Use | Mean Lift in "Deep" Wells |
|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | | | | | | | (Thousands of Dollars) | (1,000 acre-feet) | (Feet) |
| 1966 | 1,245 | 10,517 | 5,926 | 5,743 | 1,282 | 0 | 24,713 | 3,570.4 | 108.2 | 570 |
| 1976 | 1,245 | 10,517 | 4,313 | 4,734 | 1,272 | 0 | 22,081 | 3,450.7 | 98.3 | 575 |
| 1986 | 1,245 | 10,517 | 3,751 | 4,117 | 430 | 0 | 20,060 | 3,246.4 | 86.2 | 602 |
| 1996 | 1,245 | 10,517 | 2,502 | 3,515 | 2 | 0 | 17,781 | 3,169.1 | 76.3 | 623 |
| 2006 | 1,245 | 10,517 | 601 | 2,229 | 0 | 0 | 14,592 | 3,099.2 | 69.1 | 647 |

[a]Based on results of linear programming model.

Table 65. Projected Acreage of Field Crops, Net Revenue Over Variable Costs and Water Use, Stanfield Subarea, 1966-2006[a]

| Year | American-Egyptian Cotton | Upland Cotton | Barley | Grain Sorghum | Alfalfa | Wheat | Total Cropped Acres | Net Revenue Over Variable Costs | Water Use | Mean Lift in "Deep" Wells |
|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | | | | | | | (Thousands of Dollars) | (1,000 acre-feet) | (Feet) |
| 1966 | 564 | 6,762 | 6,371 | 5,810 | 519 | 0 | 20,026 | 2,271.2 | 71.3 | 514 |
| 1976 | 564 | 6,762 | 5,811 | 5,351 | 0 | 0 | 18,488 | 2,229.9 | 66.8 | 522 |
| 1986 | 564 | 6,762 | 5,442 | 5,013 | 261 | 0 | 18,042 | 2,206.7 | 66.6 | 532 |
| 1996 | 564 | 6,762 | 6,248 | 5,456 | 768 | 0 | 19,798 | 2,130.1 | 65.1 | 527 |
| 2006 | 564 | 6,762 | 5,564 | 4,737 | 0 | 0 | 17,627 | 2,104.0 | 58.5 | 548 |

[a]Based on results of linear programming model.

Table 66. Projected Acreage of Field Crops, Net Revenue Over Variable Costs and Water Use, Queen Creek Subarea, 1966-2006[a]

| Year | American-Egyptian Cotton | Upland Cotton | Barley | Grain Sorghum | Alfalfa | Wheat | Total Cropped Acres | Net Revenue Over Variable Costs | Water Use | Mean Lift in "Deep" Wells |
|---|---|---|---|---|---|---|---|---|---|---|
| | Acres | | | | | | | (Thoudands of Dollars) | (1,000 acre-feet) | (Feet) |
| 1966 | 584 | 6,489 | 5,729 | 5,078 | 172 | 0 | 18,052 | 2,164.9 | 62.1 | 505 |
| 1976 | 584 | 6,489 | 5,782 | 5,116 | 163 | 0 | 18,134 | 2,147.2 | 62.3 | 513 |
| 1986 | 584 | 6,489 | 5,725 | 5,079 | 0 | 0 | 17,877 | 2,099.4 | 60.8 | 522 |
| 1996 | 584 | 6,489 | 5,800 | 5,214 | 0 | 0 | 18,087 | 2,095.9 | 61.1 | 539 |
| 2006 | 584 | 6,489 | 6,249 | 5,495 | 0 | 0 | 18,817 | 2,105.6 | 61.3 | 553 |

[a]Based on results of linear programming model.

Water usage in the various subareas is presented in Table 67 as a percentage of what it was in the base year for five periods of time. Almost without exception, the amount of water used for growing crops in each subarea decreases in each succeeding time period. This is because of the increasing cost of water in these regions as the water levels decline over time.

Table 67. Water Use in the Six Subareas as a Percentage of the Base Year (1966), 1966-2006

| Year | Subarea | | | | | |
|---|---|---|---|---|---|---|
| | Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek |
| | Percent | | | | | |
| 1966 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 1976 | 99.9 | 98.9 | 85.7 | 90.8 | 93.7 | 100.3 |
| 1986 | 85.7 | 97.9 | 81.9 | 79.7 | 93.4 | 97.9 |
| 1996 | 73.0 | 90.8 | 65.7 | 70.5 | 91.3 | 98.4 |
| 2006 | 63.7 | 81.6 | 68.2 | 63.9 | 82.0 | 98.7 |

However, in several instances water use increases in later lears relative to what it was in earlier years. For example, water use within the Queen Creek subarea is greater in year 1976 relative to what it was in 1966, and greater in years 1996 and 2006 relative to what it was in 1986. The reasons for this are: (a) the very slow rate of water table decline projected for this subarea (hence, water costs rise very slowly), combined with (b) some of the "middle" lift models in this subarea actually experience a decrease in the <u>average</u> water cost over time due to "shallow" lifts becoming "middle" lifts and hence, lowering the average depths of lifts classified as "middle." This causes certain low value crops to come into production on these "middle" lift farms, whereas in earlier years they had not been profitable.

The Maricopa and Casa Grande subareas experience the greatest curtailment of water use over time. In year 2006, water use in these subareas is only 63.9% and 73.7% of what it was in 1966. This substantial reduction in water use occurs because of the large depth to which the water table is projected to decline in these subareas. In the early years of the analysis (1966-1976), the water table in the Maricopa subarea declines at the rate of 5.6 feet per year, or faster than projected for any of the other five subareas. The water table in the Casa Grande subarea then begins to decline at a faster rate than did the Maricopa or any other subarea, and water use in the Casa Grande area declines more rapidly in the later projection periods.

Water Table Declines in the Subareas

Average declines in the water level of the six subareas were determined for four ten-year periods: 1966-1976, 1976-1986, 1986-1996, and 1996-2006. These are shown in Table 68. The average decline in the water level in the Casa Grande area is relatively constant during the first 30 years (1966-1996) of the analysis. Over this period, the water level in this subarea declines at the rate of 50 feet per decade (or five feet each year). It is not until the last ten-year period (1996-2006) that a significant decrease in the rate of decline can be seen. During this later period, the water table declines at the reduced rate of 3.4 feet per year. The reduction in the rate of decline is caused by a substantial decrease in water use (see Table 67) in this subarea in later years.

Table 68. Average Declines in the Water Level in the Six Subareas of Pinal County, 1966-2006

| Period | Subarea | | | | | |
|---|---|---|---|---|---|---|
| | Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek |
| | Feet | | | | | |
| 1966-1976 | 50 | 29 | 31 | 56 | 8 | 8 |
| 1976-1986 | 49 | 27 | 29 | 40 | 9 | 9 |
| 1986-1996 | 51 | 28 | 29 | 36 | 17 | 17 |
| 1996-2006 | 34 | 21 | 21 | 25 | 21 | 21 |

The Eloy subarea exhibits the same pattern in its water table decline as does the Casa Grande subarea. However, the rate of decline in this subarea is much less, falling at the rate of only 3.1 feet per year during the early years of the analysis and then experiencing a drop in the rate of decline to 2.1 feet per year around year 1996.

As with the other two subareas discussed, the water level decline is more or less constant in the Coolidge subarea over the first 30 years (1966-1996). The water level decline in this region, just as in the Eloy subarea, occurs at the rate of approximately 3 feet per year in the early years and then, around 1996, experiences a reduction in the rate of decline to 2.1 feet per year.

The Maricopa region undergoes a continuous reduction in the rate of decline of its water table. Early in the analysis (1966-1976), this subarea declines at a faster rate than any of the other subareas (i.e., 5.6 feet per year). By the second ten-year period (1976-1986) the water table is falling only 4.0 feet per year. The rate of decline in the water table of this subarea drops to 2.5 feet per year by 1996, less than half of what it was in 1966. Even so, by 2006, the Maricopa subarea finds itself with water pumped from wells with "deep" lifts.

As mentioned previously, the water level in the Queen Creek area is assumed to decline at the same rate as the water table in the Stanfield subarea. In these two subareas a noticeable increase in the rate of decline of the water levels is seen, beginning in the 1986-1996 period. This is due to the fact that the pumpage determined by the L. P. model for this region is much less than originally simulated in Anderson's analog model. Hence, for many regions of this subarea, the large cones of depression actually rise during the early periods. By the 1986-1996 period, however, this effective recovery is no longer occurring and hence, the water level in this subarea begins to decline more rapidly (1.7 feet per year) than it had previously (.8 feet per year).

Cropped Acres in the Subareas

Total cropped acres decline over time in the various subareas. This can be seen by referring to Table 69 which shows cropped acres in the six subareas as a percentage of cropped acres in that subregion in the base year (1966).

Cropped acres decrease most noticeably in the Maricopa subarea with this subarea containing only 59% of its original (1966) cropped acreage by 2006. This subarea contains no source of surface water; hence, 100% of the water used for irrigation in this area is pumped.

It was expected that the greatest decrease in cropped acres would be witnessed in the Stanfield subarea. However, by 2006 the Stanfield subarea still contains 88% of its original 1966 cropped acres. The explanation is that in

Table 69. Total Cropped Acres in the Six Subareas as a Percentage of Total Cropped Acres in the Base Year (1966), 1966-2006

| Year | Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek |
|---|---|---|---|---|---|---|
| | Subarea | | | | | |
| | Percent | | | | | |
| 1966 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 1976 | 110.9 | 99.2 | 84.9 | 89.3 | 92.3 | 101.0 |
| 1986 | 97.8 | 101.5 | 77.5 | 81.2 | 90.1 | 99.0 |
| 1996 | 75.2 | 93.1 | 60.6 | 71.9 | 98.9 | 100.0 |
| 2006 | 64.4 | 83.1 | 65.9 | 59.0 | 88.0 | 104.0 |

the future the Stanfield subarea experiences the slowest water table decline of all the subareas since it already is one of the deepest areas. Therefore, most adjustments have already been made and the crops that are grown during the first ten-year period (1966-1976) tend not to fall out of production due to increasing water costs or the need to replace wells.

The Queen Creek subarea finds itself with more cropped acres in year 2006 than it had in the beginning years of the analysis. Cropped acres in this subarea are at this time 104% of what they were in the base year 1966. There are two underlying causes for this effect: (a) the subarea has a very slow rate of water table decline and (b) some of the low value crops which are not profitable to produce on smaller size farms become profitable to grow as acreage transfers to Size IV farms.

Cropped acres increase in later years relative to what they were earlier in some subareas. Review of the Stanfield subarea, for example, shows acres of crops grown actually increasing from 1986 to 1996. This occurs due to adjustments in the economic models of the L. P. program which cause the average pumping costs in "middle" and "deep" lift models to decline over time due to deep wells in the "middle" lift classification being moved into the "deep" lift classification. In some instances, this results in enough additional crops being grown in these models to offset the increase in the average cost of water in the sub-area as a whole.

## Net Income in the Subareas

Net incomes in the subareas decline over time due to the declining water table, increasing water costs, and decline in cropped acreage. The rates at which incomes decrease in the six subareas are depicted in Table 70.

The Maricopa subarea experiences the greatest loss of farm income over the 50-year period. After five decades, the net income to farmers has declined to 86.8% of what it was in 1966. This is a relatively small decrease when one

Table 70. Net Income in the Six Subareas as a Percentage of Net Income in the Base Year (1966), 1966-2006

| Year | Casa Grande | Coolidge | Eloy | Maricopa | Stanfield | Queen Creek |
|---|---|---|---|---|---|---|
| | Percent | | | | | |
| 1966 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| 1976 | 99.8 | 99.3 | 96.1 | 96.6 | 98.2 | 99.2 |
| 1986 | 96.4 | 98.6 | 92.6 | 90.9 | 97.2 | 97.0 |
| 1996 | 91.0 | 95.1 | 88.6 | 88.8 | 93.8 | 96.8 |
| 2006 | 87.7 | 92.9 | 88.5 | 86.8 | 92.6 | 97.3 |

considers that over the same period, cropped acres have decreased to 59% and water use has decreased to 64% of what they were in the base year.

Although net incomes do decline in each of the subareas over time, cropped acres decline at a rate more than twice as fast in most cases. This is due to the tendency of low-value crops (which often use a high percentage of the resources) to drop out of production relatively fast as the cost of resources increases. As can be seen from a comparison of Tables 69 and 70, a given decrease in cropped acres does not result in a proportionate decrease in net income.

Net income in the Queen Creek subarea actually increases from 1996 to 2006. Income increases despite increased water costs because of economics of size realized as resources are transferred to larger farms (Size IV). Larger farms can generate more income from a given quantity of resources than can smaller farms given the same resources. In this instance, the economics of size overbalance the increased cost of water, resulting in a net gain in income. This tendency was at work in all subareas, mitigating the decrease in aggregate net income.

Queen Creek is the subarea in which farm income decreases the least over the years. In 2006, net income in this subarea is projected to be 97.3% of what it was in 1966.

## Comparison of Aggregate Results With Stults' Projections

A major objective of this study was to make a comparison of the results with those obtained by Stults in an earlier analysis of the same county. Comparisons between the two studies are made possible by aggregating the results obtained in the six subareas of this study. Table 71 summarizes the results of this analysis on a county basis, while Table 72 gives the results of Stults.

### Cropped Acres in Pinal County

Stults projects more cropped farmland during the first two decades (1966-1986); the present analysis projects more cropped acres during the last thirty years (1986-2016).

Table 71. Projected Acreage of Field Crops, Net Revenue Over Variable Costs and Water Use, Pinal County (Aggregate of Subareas), 1966-2006[a]

| Year | American-Egyptian Cotton | Upland Cotton | Barley | Grain Sorghum | Alfalfa | Wheat | Total Cropped Acres | Net Revenue Over Variable Costs | Water Use |
|---|---|---|---|---|---|---|---|---|---|
| | ----------------------1,000 acres---------------------- | | | | | | | (Million Dollars) | (1,000 acre-feet) |
| 1966 | 7 | 84 | 65 | 65 | 18 | 0 | 239 | 29.8 | 976 |
| 1976 | 7 | 84 | 63 | 63 | 13 | 0 | 230 | 29.2 | 921 |
| 1986 | 7 | 84 | 57 | 57 | 13 | 0 | 218 | 28.4 | 864 |
| 1996 | 7 | 84 | 43 | 46 | 10 | 0 | 190 | 27.3 | 765 |
| 2006 | 7 | 84 | 37 | 40 | 9 | 0 | 177 | 26.8 | 714 |

[a]Based on results of linear programming model described in this report.

Table 72. Projected Acreage of Field Crops, Net Revenue Over Variable Costs, and Water Use, Pinal County, 1966-2006[a]

| Year | American-Egyptian Cotton | Upland Cotton | Barley | Grain Sorghum | Alfalfa | Wheat | Total Cropped Acres | Net Revenue Over Variable Costs | Water Use |
|---|---|---|---|---|---|---|---|---|---|
| | ----------1,000 acres---------- | | | | | | | (Million Dollars) | (1,000 acre-feet) |
| 1966 | 7 | 84 | 68 | 79 | 21 | 0 | 259 | 26.7 | 985 |
| 1976 | 7 | 84 | 75 | 74 | 13 | 0 | 253 | 25.5 | 919 |
| 1986 | 7 | 84 | 45 | 57 | 8 | 0 | 201 | 23.5 | 780 |
| 1996 | 7 | 84 | 29 | 39 | 5 | 0 | 167 | 21.6 | 658 |
| 2006 | 7 | 84 | 18 | 15 | 5 | 0 | 129 | 21.3 | 570 |

[a]Based on results of linear programming model used by Stults (15, Table 17, p. 75).

Table 73 allows further comparison of the total cropped acres projected by the two analyses. When cropped acres are presented as a percentage of what they were in the base year, the rate of decline of total cropped acres in the two studies becomes more evident. This study projects 96.2% of base year (1966) acreage in 1976; Stults' analysis predicts a slower rate of decline with 97.7% of base year acreage still existing in 1976. By 2006, however, this analysis p ojects that nearly 75% of 1966 cropped acres will still be grown while Stults' study projects that only half of the acres cropped in 1966 will be used in 2006 for growing crops.

Table 73. Total Cropped Acres in Pinal County as a Percentage of Total Cropped Acres in the Base Year (1966); Comparison With Stults, 1966-2006

| Year | Present Analysis[a] | Stults' Analysis[b] |
|---|---|---|
| | ------------Percent------------ | |
| 1966 | 100.0 | 100.0 |
| 1976 | 96.2 | 97.7 |
| 1986 | 91.2 | 77.6 |
| 1996 | 79.5 | 64.5 |
| 2006 | 74.1 | 49.8 |

[a]Based on the results of the linear programming model used in this study.

[b]Based on the results of the linear programming model used by Stults.

Both American-Egyptian and Upland cotton cropped acres are projected at exactly the same level by the two analyses. The reason is that cotton allotments on these two crops are held constant and at the same level in both studies; with cotton having a very high net return per acre, acreage grown always equals the total acreage allotted. Therefore, crop acreage adjustments are always for the other crops.

This study projects an average of about 6,000 more acres of barley in the decades to come than does the Stults study. Although in the relatively early future (1976) Stults' models are projecting 12,000 more acres of barley than does this study, after 1986 this analysis projects greater barley acreages.

Stults' analysis projects more acreage of grain sorghum in early decades than does this study, the same amount of grain sorghum acreage (57,000) in the decade beginning 1986, and a significantly less acreage of grain sorghum by the year 2006.

This study projects 3,000 acres less alfalfa than projected by Stults in 1966. In 1986, the projections of both studies are identical with more alfalfa projected by this study in later years.

Both studies project wheat as a non-existent activity throughout the entire period of analysis. The fact that wheat actually is grown in Pinal County in small amounts is merely indicative of certain human factors which are too complicated to take into account in these studies, such as a farmer's decision to reduce risk, even at the cost of reducing net income, by "not putting all his eggs in one basket." The quantity of barley acreage may actually be considered a "stand-in" for all of the minor crops, including wheat.

## Net Income in Pinal County

This analysis projects a greater absolute net income to Pinal County farmers (Tables 71 and 72) and a slower rate of decline in net income (Table 74) than does the earlier analysis by Stults. Not only are farmers shown as averaging approximately $5,000,000 more per year, but we see their incomes declining at only one-half the rate (90% versus 80% of base income in 2006) that was previously projected in the earlier study.

The reason that higher incomes are projected by this study are twofold: (a) the analog model projects a slower rate of water table decline than was projected by the Stults study using historical data and (b) the models used in this study take into account differences in water costs, farm sizes, and distribution of pumping lifts within six subregions of Pinal County instead of using averaged data to represent the entire county. Thus, a more sophisticated analysis was possible.

Table 74. Net Income of Farmers in Pinal County as a Percentage of Net Income in the Base Year (1966); Comparison With Stults, 1966-2006

| Year | Present Analysis[a] | Stults' Analysis[b] |
|---|---|---|
| | ------------------Percent------------------- | |
| 1966 | 100.0 | 100.0 |
| 1976 | 98.1 | 95.5 |
| 1986 | 95.3 | 88.0 |
| 1996 | 91.6 | 80.9 |
| 2006 | 90.2 | 79.8 |

[a]Based on the results of the linear programming model used in this study.

[b]Based on the results of the linear programming model used by Stults.

Water Use in Pinal County

Although Stults' study projects a higher rate of water use over the first two decades (1966-1986), this analysis projects greater water use by farmers in Pinal County during the last three decades (1986-2016) of the period being analyzed. The reason for this difference is that water costs projected by this study are substantially lower in later years than those projected by the Stults analysis.

## Summary

Previous empirical projections of either hydrologic or economic activity have taken the other activity as largely given. For example, White, Stulik, and Rauh (20) and Anderson (1) (the latter using an electric-analog) projected groundwater levels in central Arizona given that pumpage in these areas remained at the same annual rate as during the few past years. The effects that the falling groundwater table would have on water costs and thus on agricultural demand for water were not recognized in the projections. Other instances can be cited. An example is work of the California Department of Water Resources (3).

Economists, for their part, have adopted similar simplified models in their approaches to groundwater basin management. Thus, Stults (15, 16, 17) in projecting agricultural activity in central Arizona for the next 50 years, assumed "that water withdrawals would have the same impact on the declining water table as had been recorded in the past" (15). Stults projected changing water demand in response to changing pumping depths (and thus changing water cost), but assumed that the water table decline was in direct proportion to the quantity of pumpage, in effect assuming that the aquifer was homogenous throughout with respect to its transmissibility and storage characteristics, and that no irregularities in its boundaries existed. Burt (2) is one of several economists adopting similar postulates.

The research reported here represents a refinement of Stults' (15, 16, 17) analysis of Pinal County, an area in central Arizona whose agricultural economy is primarily dependent upon groundwater. Pinal County contains about 21 percent of Arizona's irrigated agriculture, and represents roughly half of Arizona's "water problem" in terms of groundwater table decline. Stults' work was an earlier contribution to a larger program on water resources in relation to social and economic growth in an arid environment and his basic economic model, the empirical data relating to the economic activities of the area, and procedures for injecting certain dynamic elements into the water demand model (changing farm size and well replacement decisions) were adopted directly for the analysis reported here.

The objective of this thesis was to develop and use a procedure whereby the partial analyses of the economists and the hydrologists would be integrated into a total system approach. This system, expressing the interactions between the irrigated farming sector of the economy and the physical state of the aquifer was described and compared to the results of the earlier Stults analysis of the same area.

The basis of the economic model is a detailed description of the organizations, costs, and returns of the farms in Pinal County, Arizona, developed by Stults from a 17-page personal interview questionnaire taken from a random sample of 120 farmers in the area. The sample accounted for 30 percent of all farms over 25 acres in size and, because a larger proportion of large sized farms was sampled, 38 percent of the field crop acreage. The study area is divided into six subareas. The choice of the number of subareas and their boundaries reflects a compromise between the aims of achieving homogeneity in hydrologic parameters and a high degree of statistical reliability in the demand model. Four farm sizes are taken as representative of the farms in each area. Within each farm size, three levels of pumping depths were allowed. Thus, 72 linear programs are solved in the process of estimating water demand for each time period. (Ninety-six percent of Pinal County's irrigated crop acreage is in general field crops--cotton, forages, and grains. Hence, no further disaggregation into farm types was judged necessary.) Net returns over variable costs for each crop activity were based on the assumption that present government agricultural programs would continue unchanged.

The hydrologic model was the relevant portion of the electric-analog of the central Arizona groundwater system developed by Anderson (1).

Projected total cropped acres fall by 25.9 percent over the 50-year period. This is entirely because of rising water costs rather than from a physical shortage of water. Less acres of the low-valued crops will be grown. Acreage of high-valued crops, including cotton, vegetables, and citrus will not be affected.

Water use will fall by 26.8 percent during this period. Use falls slightly faster than acreage because less water is used per acre as water costs rise and as farms become larger and more efficient water users. Use would fall even faster except that the high-valued, high-water-using crops become a larger percent of total cropped acres.

Net income over variable costs drops by only 10.1 percent during the same period. There are several reasons. Adjustments in total acreage are entirely of low-valued crops which are even presently contributing little to net income. In 2006, a much larger proportion of the farms are large farms with lower costs of production. Finally, a larger proportion of total water use is from the one surface supply in the area, the San Carlos Irrigation District. This surface supply is about 17 percent of total use in 1966, about 25 percent by 2006.

If one compares these results with the earlier economic analysis of the same area (Stults, 15, 17), one finds that the integrated model projects all the variables of interest--acres, net revenues, and water use--to decline less rapidly than he had projected. In fact, the estimates of declines shown herein, are only about one-half as severe. Part of these differences may be ascribed to refinement in the economic portion of the model. But part is because of the use of the analog model of the aquifer to make estimates of the rate of water level decline. Stults starts with a higher rate of water use and groundwater decline and ends up with lower water use and a slower rate of decline in 2006. The new estimates show less use in the original period but more use in 2006 since less total groundwater decline is projected.

Obviously, the estimates of groundwater decline are less than those of the hydrologic model of Anderson (1) since he was basing his projections on a pumpage rate unadjusted for water cost.

An original hypothesis of this thesis was that the integrated model would show slower declines than the hydrologic model alone and faster declines than the economic model alone. As it happened, the declines are slower than for either partial model.

## Policy Implications

The decline in net income over the coming 50 years in a major water-short area of Arizona was shown to be gradual and relatively small. Adjustments come about through fewer acres of the low-valued, marginal crops. Since adjustments to the falling water table take place with the marginal crops, any new additional water supplies must also be valued at that margin. Additional supplies of water to Pinal County would, in effect, be used to expand or maintain the acreage of hay and feed grains. High-valued crops will continue to be grown up to the limit of their allotment (for cotton) or market (for vegetables) for many decades without additional water supplies. Thus, farmers would benefit from additional water only to the extent that the additional supply of water contributed to their net income by reducing their water cost or by allowing additional profitable acreage of low-valued crops.

To obtain any sizable amount of additional water, water would need to be imported. Imported water is expensive, and it has been shown that the social costs of such an importation operation would be greater than warranted by the gains (11, 21). It is also not clear that other water management schemes other than "hands off" would prove superior if maximization of present worth of farmers of the area is the policy goal. In any case, this study provides the tools to test these hypotheses about alternative management schemes for this and other groundwater basins.

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