AGRICULTURAL RESPONSE TO CHANGING WATER PRICES IN ARIZONA

by

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ABSTRACT

Water management strategies are currently being developed in Arizona. Arguments exist over which strategies are most effective and efficient to supply future growth of Arizona's population and economy. Some strategies rely on importation of new water supplies, while other strategies propose reducing total water demanded so existing supplies will be adequate in the future. Agricultural water use has been determined the primary target for demand management strategies since it accounts for 89% of all water depletions and is a relatively economically ineffecient use.

No comprehensive management of Arizona's agricultural water use has been attempted. However, economic projections have indicated that changing variable prices for water will cause water use changes in the agricultural sector. Reviewing these projections in light of historical data shows that manipulating the variable price of water to affect use changes may be too unpredictable for effective water management and control in the agricultural sector.

CHAPTER I

INTRODUCTION

Sixty percent of Arizona's water supply comes from ground water aquifers. Many government and private concerns are trying to reduce the rapid depletion of these aquifers.

Agriculture accounts for 89% of all water use in Maricopa, Pima, and Pinal Counties of Arizona (Arizona Water Commission, 1975). However, irrigated agriculture returns the lowest amount of personal income per acre-foot of water among the major Arizona economic sectors (Young and Martin, 1967). Many wish to reallocate water from irrigated agriculture since it is the largest and most economically inefficient user (City of Tucson, 1974; Arizona Water Commission, 1975; Clark, 1974). This thesis analyzes some of the current strategies proposed to reallocate Arizona's water resources.

Arizona's Water Resources

Many familiar with Arizona's water situation recognize that there is a problem. Disagreement arises about the exact definition of the problem. However, basically all agree that there is essentially uncontrolled exploitation of the ground water aquifers. The implications of this will be discussed later.

There is at this time political pressure to develop policy establishing equilibrium between supply and use of Arizona's water resources (Arizona State Senate, 1975a, b; Arizona State House of Representatives, 1975; City of Tucson, 1974; Clark, 1974). Also many strategies to implement this policy are under consideration.

Water Conservation Strategies

Strategies to establish equilibrium between supply and use fall into two major categories: increase supply, or decrease use to conserve existing supplies. This paper will focus on the strategies which decrease use by managing water demand. Many strategies which will be reviewed propose economic measures to reduce agricultural water use. Demand management strategies focus on agriculture's water demand because the agricultural sector is the single largest user and most sensitive to change in water prices (Kelso, Martin, and Mack, 1973; Porter, 1972; Hirshleifer, DeHaven, and Milliman, 1960).

Two strategies are dominant in reducing agricultural water use. The first is to monitor and tax water use. Politicians who advocate state management and control of water feel that the added cost of water would not allow the production of low return crops of high water consumption.

The second strategy is to let "free market" conditions control agricultural water use. Agricultural economic projections indicate that the price for water will increase as municipalities and industrial demands continue to grow. Agriculturalists will not be able to afford the water at higher prices and will reduce their water use as marginal crops are taken from production.

Economic Projections

Both these strategies have been justified in part on comprehensive economic projections by Kelso et al. (1973). They concluded that increasing water costs due to increasing depths to water would force agriculture to substitute higher return crops for crops of lower return, and total acreage and water use would decline as the variable costs of water increased.

The models which were used to draw these conclusions were constrained by general economic assumptions which held technology and prices of outputs as compared to inputs constant. These assumptions are not unusual and are made to define future economic uncertainties. Economists have empirical evidence that these assumptions will cause less error than if they were to incorporate guesses for future economic conditions (Kelso et al., 1973). Strategies based on these projections are constrained by the assumptions.

Thesis Statement

Assumptions made to facilitate recent agricultural economic projections by Kelso et al. (1973) have been violated. Therefore the projections are incorrect.

These projections supported agricultural water management strategies which relied on pricing to control use. Since the projections are incorrect, these strategies may be ineffective management methods.

Procedure

Economic projections made by Kelso et al. (1973) will be summarized and compared to the actual occurrences for the last decade. It will be shown that the economic assumptions which constrained the projections were violated. The implications that these violations have on management strategies will be analyzed.

Data Source

Arizona agricultural statistics will be summarized for Maricopa, Pima, and Pinal Counties from 1966 through 1974. The summary will include type of crop, number of acres produced, average gross value per acre, energy cost for water pumped at various depths, and consumptive use of water.

Crop information came from Arizona Agricultural Statistics publications of the Arizona Crop and Livestock Reporting Service (1972, 1974). Energy cost data were obtained from personal interviews with officials of Arizona Public Service, Tucson Gas and Electric Co., Electrical Districts 2, 4, and 5 of Pinal County, and the Southwest Gas Corporation. Water consumption data were synthesized from the crop information using the Blaney-Criddle method (Erie, French, and Harris, 1965).

CHAPTER II

POLICIES AND STRATEGIES TO RELIEVE ARIZONA'S WATER PROBLEM

Policies and strategies to relieve Arizona's water problem originate at the Federal, state and local government levels. The problem which these policies address is: Arizona's water use is far greater than its long-term rate of supply.

Physically, ground water exploitation results in falling static water levels, increasing pumping lifts, land subsidence and continuing exhaustion of Arizona's non-renewable water resource. Consequently, municipalities, industries and irrigated agriculture face higher water costs plus long run instability due to dwindling water supplies. Federal, state, and municipal governments basically agree with this definition of Arizona's water problem (U. S. Senate, 1967; U. S. House of Representatives, 1968; Arizona Water Commission, 1975; City of Tucson, 1974). However, solutions tend to vary between the groups.

Federal Policies and Strategies

Federal involvement with Arizona's water problem results from the Colorado River Basin Project Act, P. L. 90-537 (1970), and the Central Arizona Project (CAP) Contract (1970) between the Department of Interior and the Central Arizona Water Conservation District (CAWCD). This act, of which the CAP was the largest portion, was proposed to augment Central Arizona's (Maricopa, Pinal, and Pima Counties) water supply by importation from the Colorado River. This water was to be substituted for water drawn from Arizona's aquifers. One intent of the act was to reduce irrigated agriculture's dependence on ground water. The effect of this would give agriculture more secure water supplies and reduce the rate of aquifer depletions.

Provisions to insure substitution of CAP water for ground water included: 1) prohibition of the use of CAP water on land not having a recent history of irrigation; 2) requirement that a water user relinquish his present source of water if he desires to use CAP water; and 3) imposing water conservation restrictions on CAP users (CAP Contract, 1970).

At the present time, Arizona's water law is inadequate to implement these provisions (Egbert, 1972). If the Secretary of Interior feels that the CAP provisions are not enforceable under existing law he may withhold delivery of CAP water. The powers of the Secretary are broad in this respect and include: discretion in distributing Colorado River water in the various states of the Colorado River Basin; refusal to make project waters available to areas which have no controls preventing non-conservation; imposition of conservation measures on Colorado River water even if those measures conflict with state statutes and judicial law (U. S. House of Representatives, 1968; Egbert, 1972).

That the Federal government can force changes in Arizona's water management is documented by the passage of the 1945 Ground Water Act in Arizona. The Bureau of Reclamation stated that the CAP would not be forthcoming in the absence of a ground water code which would control depletion rates (Mann, 1963; Chalmers, 1974). Also, the Secretary of Interior intimated the CAP could be held up because Arizona has not improved its ground water laws and conservation (City of Tucson, 1974; Arizona Daily Star, Feb. 18, 1973).

The Federal strategy then is to reduce agriculture's depletion of ground water aquifers by importation of new supplies and forcing the state to take positive legislative action to reduce use by managing and conserving its renewable water resource.

State Policies and Strategies

Arizona has no centralized natural resource or conservation agency similar to many other states (Straayer, 1970; Mann, 1963). The authority over water is divided among many agencies including the State Land Department, the Arizona Outdoor Recreation Coordinating Commission, the State Health Department, the Arizona Power Authority, and the Arizona Water Commission.

The most important agency at this time is the Arizona Water Commission. The Commission has two main responsibilities. The first is to plan for the development and utilization of interstate and intrastate waters, surface and ground waters (Arizona Water Commission, 1975).

Secondly, the Commission is responsible for recommending the proper allocation and distribution of CAP water to the Secretary of Interior. The Commission's broad water planning and coordination responsibilities allow it to be instrumental in development of water policy and management strategies.

However, water planning and management are difficult in Arizona due to the water rights doctrine governing ground water use (Mann, 1963). Ground water distribution, allocation and management are not centralized, as is the case with large importation schemes such as the CAP. It is relatively easy with the present law to drill and pump water for private use (Straayer, 1970). Also, since decisions regarding ground water use are made by private users there is a tendency to disregard the long-term social benefits of use in favor of short-term personal economic gains (Porter, 1972). One of the necessary prerequisites for effective water planning and management in Arizona is development of statutory water policy and strategies for management by the State Legislature.

The Water Commission and State Legislature are most active in the field of water resource management. Proposals and recommendations developed by these two institutions will shape the future ground water management strategies of Arizona.

The Arizona Water Commission

The Water Commission states the fundamental problem is that of imbalance between supply and long-term use (Briggs, 1976). Their basic solution is to use CAP water to augment supply. Water Commission figures show that this will reduce the ground water overdraft by two-thirds in Maricopa, Pima and Pinal counties. Recommended action to reduce the remaining overdraft will include further augmentation and modifying use habits and water laws. For many parts of the state the Commission suggests limited development, hinting at constraining growth with water availability (Arizona Water Commission, 1975).

The non-structural management strategies focus on modifying agricultural use habits. The Commission has developed four alternative futures for agricultural development. In future publications the Commission will display the water demand of each alternative future and the water supply deficiencies. From these data, water resource development and management options will be identified and evaluated (Briggs, 1976).

The following alternatives for agricultural development will be projected by the Commission: 1) a development level where Arizona produces its historic share of the nation's food and fiber; 2) the current level of water use by agriculture; 3) a level which decreases with urban expansion on croplands; 4) a level where agricultural water use is equal to the dependable supply (Briggs, 1976). The Commission does not detail how each level will be attained.

The Water Commission is restricted to planning by State statute. The only management possibilities open to the Commission are through cooperation with the Bureau of Reclamation and Secretary of Interior, or increased responsibility delegated from the state legislature. Any modifications in use habits, law, or development patterns which the Commission can affect would most probably be related to Federal and state policies.

The Arizona State Legislature

The Arizona State Legislature has done little in comparison to other states of the southwest to develop statutory law to effectively manage Arizona's water resources (Chalmers, 1974; Radosevich and Sutton, 1972). Arizona ground water law is mostly judicial law based on precedents and definitions which hinders effective comprehensive management and conservation of Arizona's water resource (Clark, 1974; Chalmers, 1974; Porter, 1972; Null, 1974; McBride, 1972; Straayer, 1970).

The judicial branch cannot be expected to make new law. This insitution is based on case-by-case judgment. It is not geared to make decisions which affect comprehensive planning of the resource but adjudicates conflicts between users of the resource (Cowan, 1963). The legislature must establish prerequisite statutory authority to make effective management possible.

Various governors and legislatures have tried to develop statutory definitions of water rights. However, the only success has been the 1945 Ground Water Act (Chalmers, 1974). The efficacy of this act for water management has been highly criticized (Clark, 1974; Chalmers, 1974; McBride, 1972).

At the present time, certain legislators are trying to pass bills which would set policy for Arizona's water resources and define strategies to modify use habits. The bills are authored by Pima County legislators and are similar to recommendations of the Tucson city staff (City of Tucson, 1974).

Most of the bills propose a tax on ground water use (Arizona State Senate, 1975a,b; Arizona State House of Representatives, 1975; Arizona Daily Star, May 4, 1976b). The purpose of the tax is to finance the Central Arizona Project and raise the economic value of ground water. The greatest incidence of the tax would be on irrigated agriculture since they use the greatest portion of ground water supplies. It is also implied that a tax will force agriculture to substitute less water intensive crops for those crops which use more water and are economically marginal. In addition, it is felt farmers would use better water conservation technologies if the water were valued higher (Davidson and Farr, 1976).

The presumption of this strategy is that decreasing agricultural water use will solve Arizona's water problem. This presumption is disputed by agricultural organizations (Arizona Farmer-Ranchman, 1957). The political power of the agricultural lobbies has stymied attempts to revise water law (Arizona Daily Star, May 1, 1976a). Agricultural strategies favor importation over water use modifications (Null, 1970).

Summary

Emerging state policies and strategies to reduce overdrafting of Arizona's aquifers favor importation of Central Arizona Project waters and modifying use habits.

Strategies to reduce water use incorporate ground water taxes to raise the cost of water to agriculture. Authors of ground water tax bills assume that agriculturalists will increase efficiency and reduce marginal uses of water if water prices are increased. In fact, some legislators consider irrigated agriculture as a marginal use of water and that raising the cost of water will force agriculture out of the market. This would free water for allocation and distribution to industry and municipalities (Young and Martin, 1967).

Free Market Strategies

Competition between cities and agricultural users for water has intensified the perception of Arizona's water problem. In eastern Pima County where this competition is most severe, the City of Tucson feels agriculture should reduce their water use to insure future supplies for the City (City of Tucson, 1974; Pima Association of Governments, 1975). In fact some city officials allude that retirement of all agricultural production would solve the overdraft problem in this area.

Some economists feel that this reallocation will happen without artificially raising the price of water by taxation. Two mechanisms are at work. First, as cities value water more, they will be willing to pay higher prices for water thus allowing farmers to sell their rights if the property right structures allow (Porter, 1972; McBride, 1972; Hirshleifer et al., 1960).

Second, economists predict that higher energy costs and increasing depths to water will retire all but the highest return crops. This will reduce total acreage and water use by agriculture. The water not used by agriculture can then be reallocated to more efficient uses (Kelso et al., 1973; Young and Martin, 1967).

These two positions are supported theoretically (Hirshleifer et al., 1960; Kelso et al., 1973). However, comprehensive studies of Arizona agricultural economics has supplied the major support for the efficacy of these theories (Kelso et al., 1973; Mack, 1969; Stultz, 1968; Burdak, 1970).

Many who propose management strategies using taxing schemes (Maddock and Haimes, 1975; City of Tucson, 1974) or free market schemes to reallocate water rely on projections made by Kelso et al. (1973) for justification.

The next chapter will compare these projections with the actual agricultural responses to increasing prices for water in the last ten years. It will be shown that the projections on which the above strategies have been based have not been accurate.

CHAPTER III

COSTS OF WATER AND IRRIGATED CROP PRODUCTION

Recently, sophisticated and detailed economic projections were made about irrigated crop production and water use in Arizona (Kelso et al., 1973; Stulz, 1968; Burdak, 1970; Mack, 1969). The projections were based on linear programming models which used data from Arizona Crop and Livestock Reporting Service, 600 detailed personal interview questionnaires, and other Federal and State data sources.

These models used 1966 for the base year and made predictions in 10 year increments through 2015. Information from these projections have been used as arguments in the growing controversy over management of Arizona's water resources. Basically, the projections indicate that agricultural water prices will rise relative to other inputs in crop production as ground water levels decline. The impact of this price rise will cause: water to become economically scarce; water use to decrease; and water to be shifted from low value per unit of production crops such as alfalfa, barley, and feed grains to higher value crops such as cotton.

Standard economic assumptions were used to hold certain variables constant. However, these assumptions have been severely violated in the last 9 years. The resulting variations in agricultural water use and cropping patterns from the projected have ramifications for stated government water management strategies.

Projections of 1966

Before reviewing the projections of economic impacts caused by falling ground water levels, assumptions which facilitated the projections will be reviewed. Violations of these assumptions have caused the observed variances from the projections.

Assumptions

The economic assumptions made by Kelso et al. (1973) were:

1. There will be no changes in relative prices of Arizona outputs as compared to inputs required for production or compared to prices of outputs produced elsewhere that are competitive with outputs when produced in Arizona.
2. There will be no change in national agricultural policies.
3. There will be no change in tastes or preferences of Arizona producers and consumers.
4. There will be no change in technology.

Given these assumptions and others, Kelso et al. (1973) projected the following declines in agriculture.

Aggregate Projected Declines in Agriculture

1. Economic decline due only to rising ground water costs will occur in irrigated agriculture in the Santa Cruz Valley (Pinal and Pima Counties) and outside the Salt River Project in Maricopa County and in Cochise County.

2. Acres in crops will decline by 4.4% per decade until 2005 (0.5% per year). Alfalfa, barley and sorghum accounted for 79% of the decline, while 21% of the decline will occur in wheat, sugar beets and safflower.
3. Water used in agriculture will decline at 4.4% per decade (0.5% per year) due to rising ground water costs until 2005.

Projected Declines for Maricopa, Pima, and Pinal Counties

Table 3.1 summarizes the projected crop acreage declines for Maricopa, Pima, and Pinal Counties between 1966 and 1975. It also summarizes the projected water use reduction for the three counties. The impact of urban growth is included in these projections.

The total cropped acreage in Maricopa County was projected to decline 14% from 1966 to 1975. Pima County would have negligible decline in acreage, while Pinal County would have a 4% decline in total acreage. The acres of cotton and sugar beets were projected to remain at their 1966 levels, but alfalfa, barley, sorghum, wheat, and safflower would decrease.

Maricopa agricultural water use would decrease by 11% during this period. Pima County would remain constant. Pinal County would have a 6% reduction in water use. Urban growth was considered the major reason for the high acreage and water use decrease in Maricopa County.

Projected Variable Cost of Water

Table 3.2 shows the projected ground water level decline and percent increase in variable costs to pump an acre foot of water. The

Table 3.1 1966 and 1975 Projected Total and Individual Crop Acreages, Plus Total Water Use for Maricopa, Pinal, and Pima Counties.[1]

	Total Acres of Crops	Cotton	Barley	Wheat	Sorghum	Alfalfa	Safflower	Sugar Beets	Vegetables and Fruits	Total Water Use (ac-ft)[2]
Maricopa County										
1966	393,700	90,291	80,454	13,500	38,446	101,419	26,300	13,116	35,280	2,049
% of total	100	23	20	3	10	26	7	3	9	100
1975	336,900	90,291	56,114	13,500	14,451	96,461	18,463	13,116	35,380	1,826
% of 1966	86	100	70	100	38	95	70	100	100	89
% of total	100	27	17	4	4	29	5	4	10	-
Pinal County										
1966	246,900	90,911	64,497	0	65,497	18,511	0	0	7,500	976
% of total	100	37	26	0	27	7	0	0	3	100
1975	237,700	90,908	62,358	0	63,401	13,540	0	0	7,500	921
% of 1966	96	100	97	-	97	43	-	-	100	94
% of total	100	38	26	27	27	6	-	-	-	100
Pima County										
1966	48,500	17,495	9,167	686	17,039	1,916	0	0	2,200	210
% of total	100	36	19	1	35	4	0	0	5	100
1975	48,500	17,495	9,167	686	17,039	1,888	0	0	2,200	210
% of 1966	100	100	100	100	100	99	100	100	100	100
% of total	100	36	19	1	35	4	-	-	5	100

1. Source: Kelso et al. (1973).
2. Figures are in units of 1000 ac-ft.

Table 3.2 Projected Declines of Ground Water Levels and Increases in Variable Pumping Costs for Selected Areas of Maricopa, Pima, and Pinal Counties (1966 to 1975).[1]

	Projected Ground Water Decline, 1966-1975 (ft)	Variable Pumping Costs (1966) per Ac-Ft ($)	Projected Variable Pumping Costs (1975) per Ac-Ft ($)	Percent Increase in Variable Pumping Costs
Maricopa County[2]				
MAR/AD/LMP	69	9.97	11.22	12
TON	32	6.48	7.05	9
HAR	153	6.54	8.64	32
AG	39	12.03	12.75	6
RB	49	5.22	5.89	13
QC	58	10.89	11.93	10
Average	67	8.52	9.58	12
Pima County[2]				
A	26	3.55	4.17	17
B	45	6.52	7.56	16
C	45	7.10	7.94	12
Average	39	5.73	6.56	14
Pinal County[2]				
CG	45	10.06	11.11	10
Co	27	9.49	10.12	7
El	28	8.18	8.71	6
Mar	50	9.99	11.16	12
St	7	10.95	11.12	2
QC	7	10.56	10.71	1
Average	27	9.87	10.49	6

1. Source: Kelso et al. (1973).
2. See Appendix Figures A.1, A.2, and A.3 for maps of areas.

average increase in variable costs is 12% for Maricopa ground water areas, 14% for Pima County ground water users, and 6% for Pinal irrigators.

Conclusions of Projections

Kelso et al. (1973) projections showed that an average increase of 11% in the price of water would cause a reduction in agricultural acreage. Coupled with urban expansion this would cause a slight decrease in alfalfa, barley, wheat, sorghum, and safflower but no decrease in cotton or sugar beet acreage.

Historical Events of the Last Decade

The economic assumptions which constrained the earlier projections have been violated. Government allotment programs have changed, the U. S. has demand inflation and energy rates have increased significantly. Specifically, pumping costs have risen sharply, yet gross returns per acre of crop have risen even faster.

Total acreage has increased in the three counties during the last decade, rather than decreased. At the same time, however, low value crops have decreased and high value crops have increased.

Total agricultural water use has increased also. There was a 10% increase in water use in Maricopa County, 17% increase in Pima County and 41% increase in Pinal County.

Figures 3.1, 3.2, and 3.3 show the cropping pattern changes from 1966 through 1974. These figures graphically display information from Tables A-1 through A-9 in Appendix A.

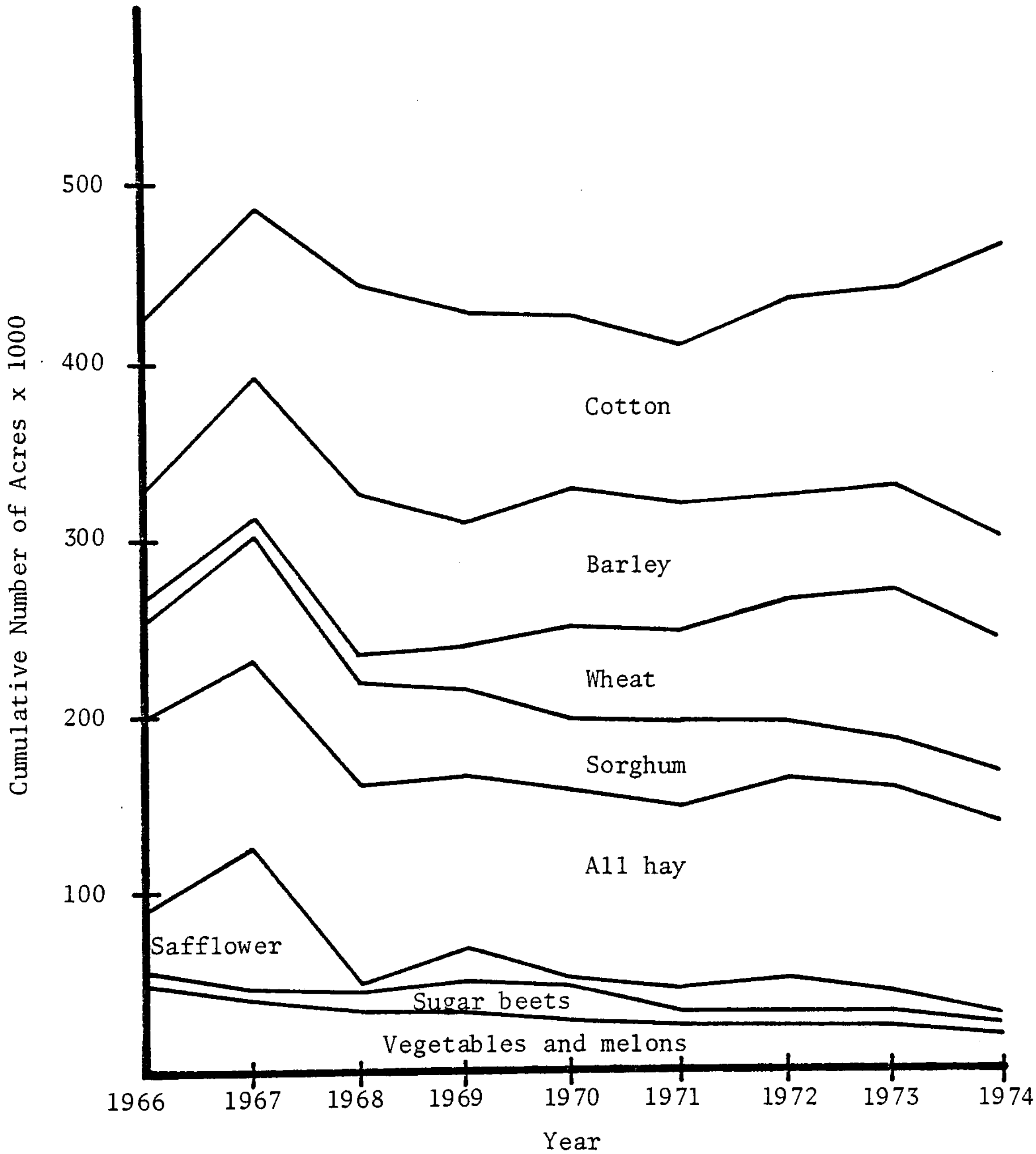

Figure 3.1 Cumulative Maricopa County Yearly Crop Acreages from 1966 to 1974. -- Source: Arizona Crop and Livestock Reporting Service (1972, 1974).

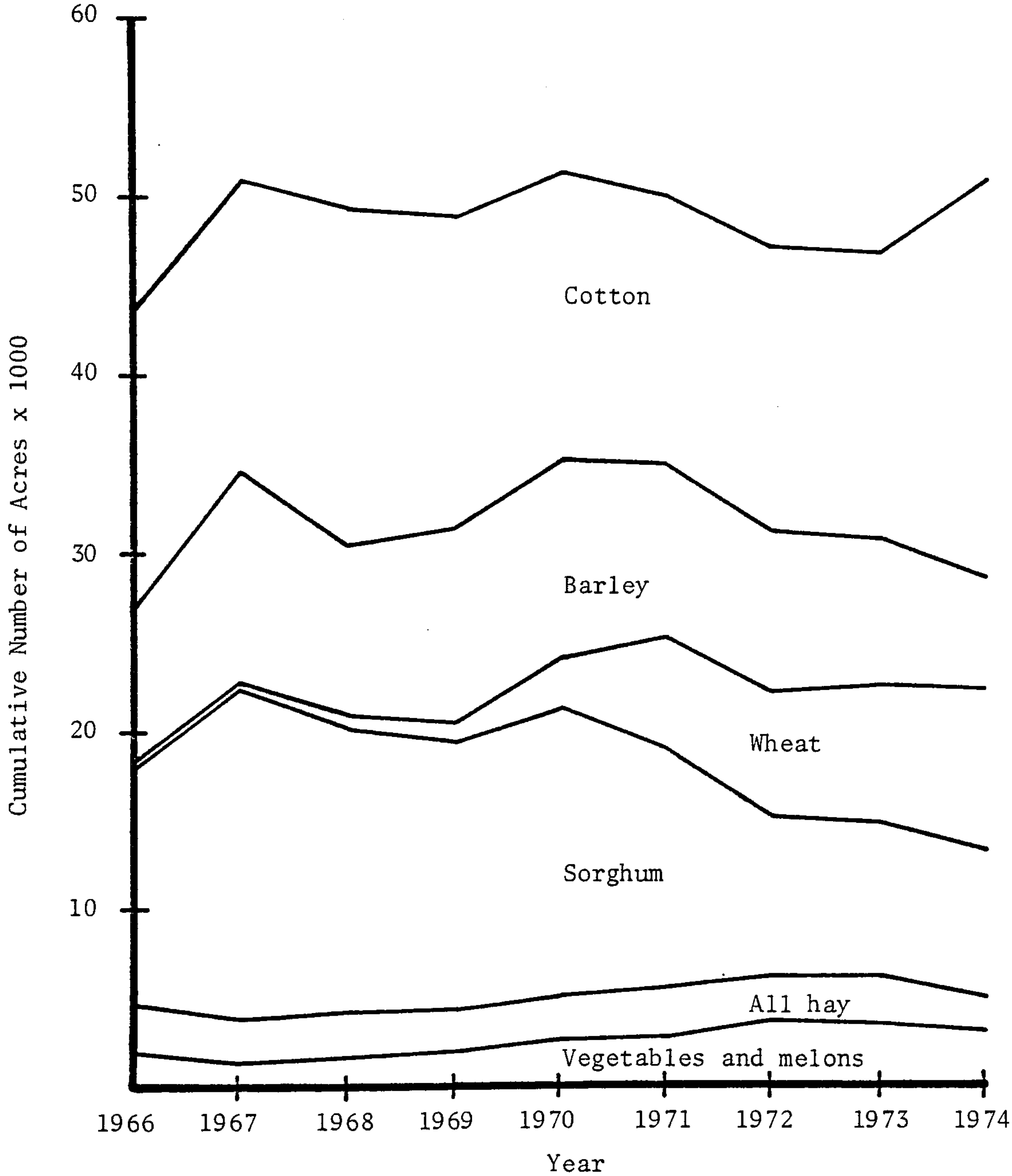

Figure 3.2 Cumulative Pima County Yearly Crop Acreages from 1966 to 1974. -- Source: Arizona Crop and Livestock Reporting Service (1972, 1974).

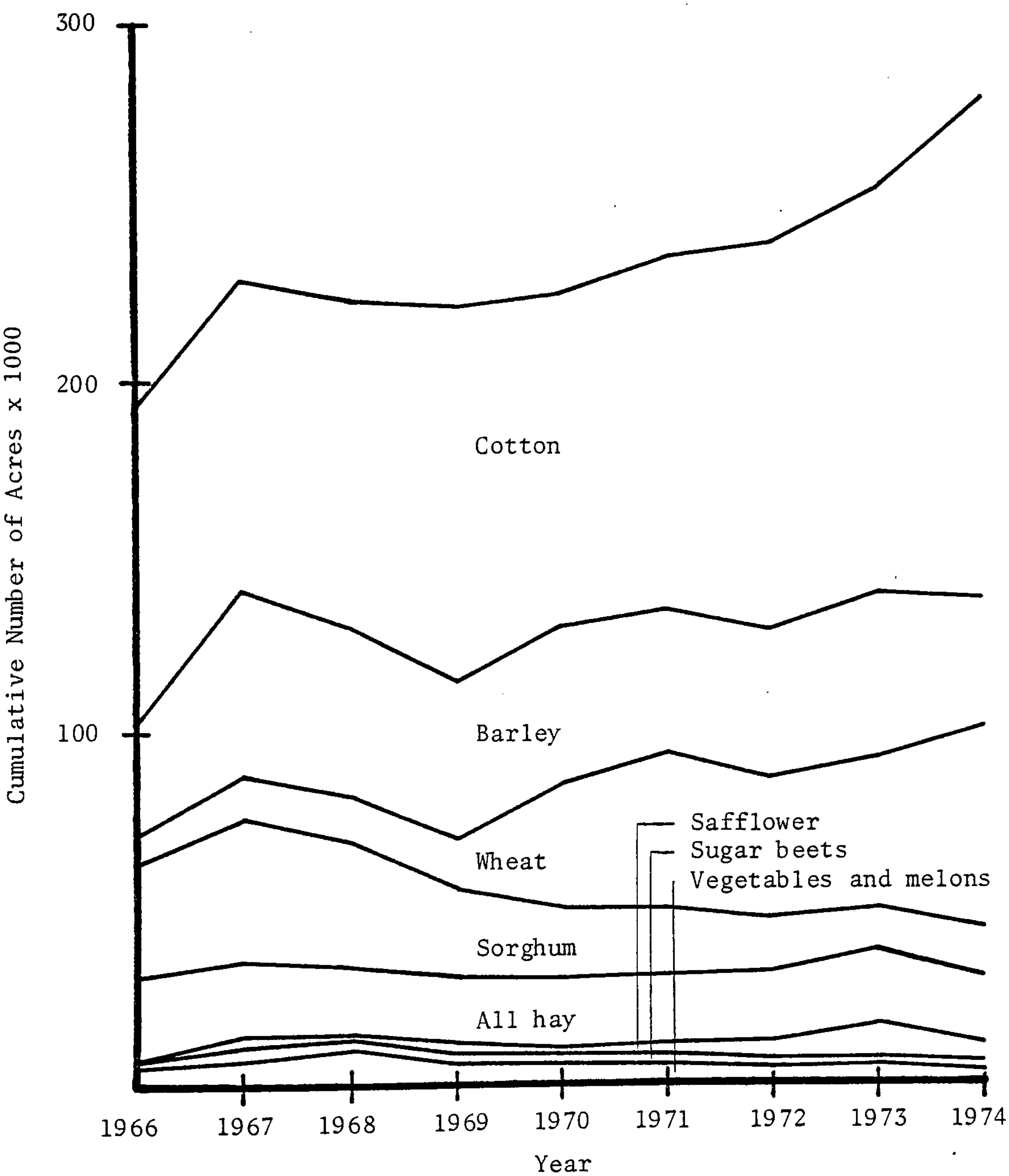

Figure 3.3 Cumulative Pinal County Yearly Crop Acreages from 1966 to 1974. -- Source: Arizona Crop and Livestock Reporting Service (1972, 1974).

Change in Energy Rates

Figures 3.4, 3.5, and 3.6 display the increased energy rates from 1966 to 1975 for wells of various lifts. Maricopa energy rates were 153% of 1966 rates. Pima and Pinal County rates were 162% of 1966 levels.

Energy costs of water, as a percent of the gross return for a crop, are displayed in Figure 3.7 and Table 3.3. The average cost as a percent of the gross return for a crop has decreased by 39%, even though energy rates have increased 50% to 60% over the past 9 years. This is because the average value for an acre of crop tripled (see Figures 3.8 and 3.9).

Cropping Pattern Changes: 1966 to 1975

Figures 3.1 through 3.3 and Table 3.4 summarize the cropping pattern trends of the last decade. All three counties exhibited similar trends. The most notable trend is the increase in wheat production.

Maricopa County. Maricopa County had 8% more land production in 1974 than 1966. Cotton (22%), alfalfa (22%), barley (15%), and sorghum (13%) were the dominate crops of 1966. In 1974, cotton (35%), alfalfa (20%), wheat (16%), and barley (10%) were the dominate crops. However, all crops decreased in acreage except cotton and wheat. Cotton increased by 73% while wheat increased 7-fold.

Barley acreage has decreased steadily since 1970. The 1974 acreage total was only 76% of the 1966 figures. Sorghum has decreased since 1967. Its 1974 acreage was 56% of the 1966 acreage.

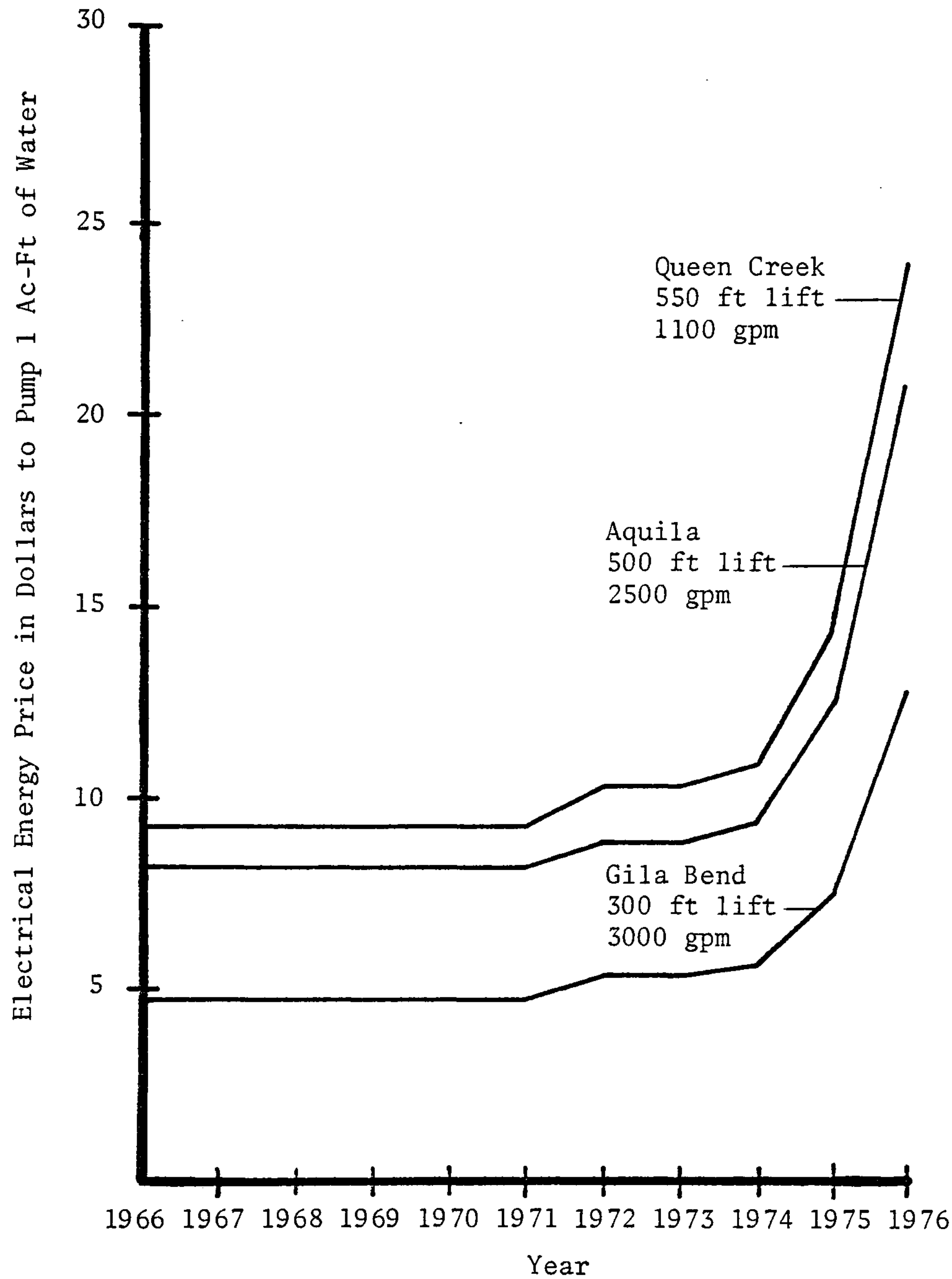

Figure 3.4 Maricopa County Electrical Energy Prices per Acre-Foot at Various Depths and Productions. -- Source: Hathorn and Willett (1975a). See Appendix B (Figure B.1) for area definition.

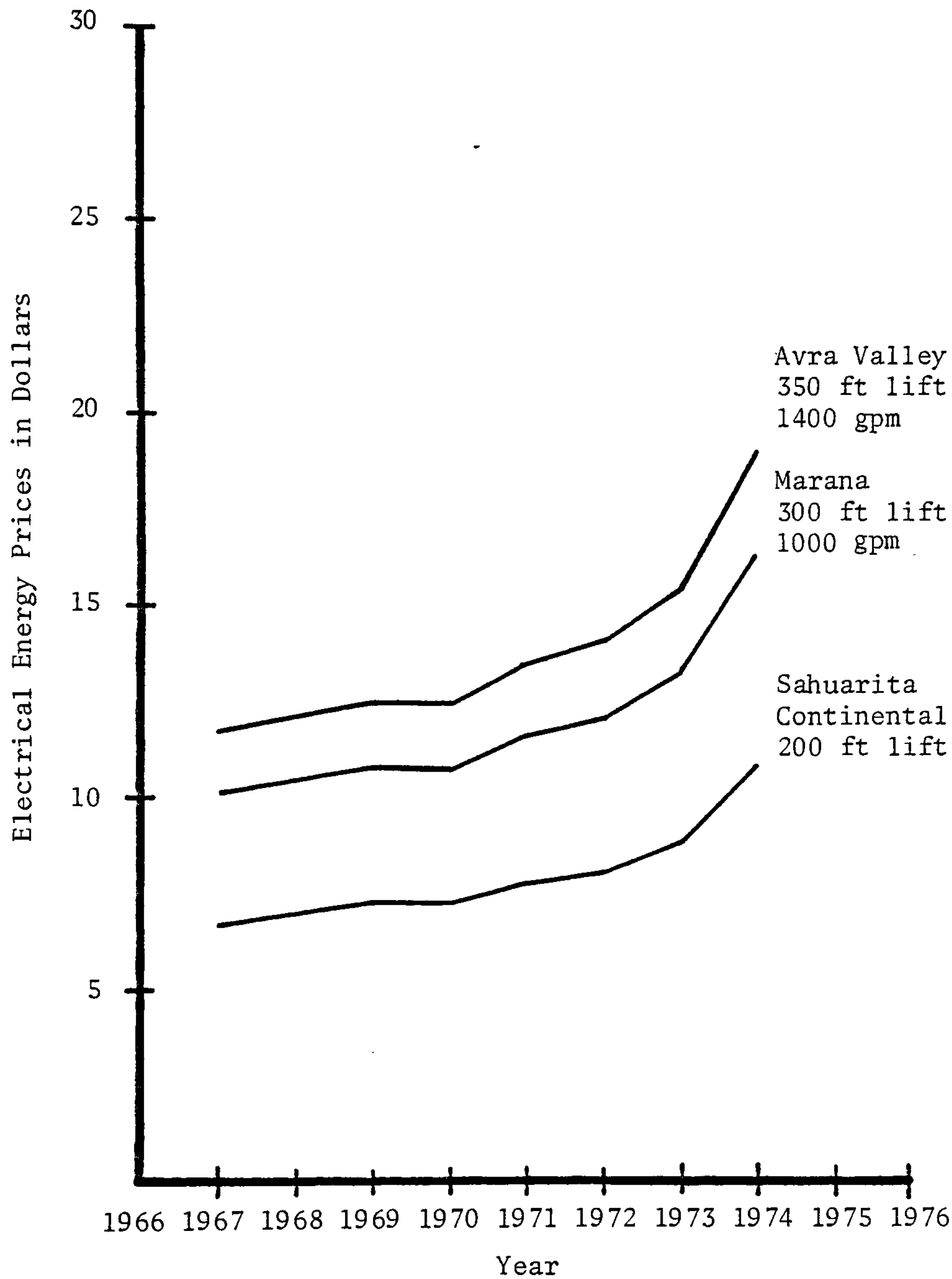

Figure 3.5 Pima County Electrical Energy Prices per Acre-Foot at Various Depths and Productions. -- Source: Hathorn and Willett (1975b). See Appendix B (Figure B.2) for area definition.

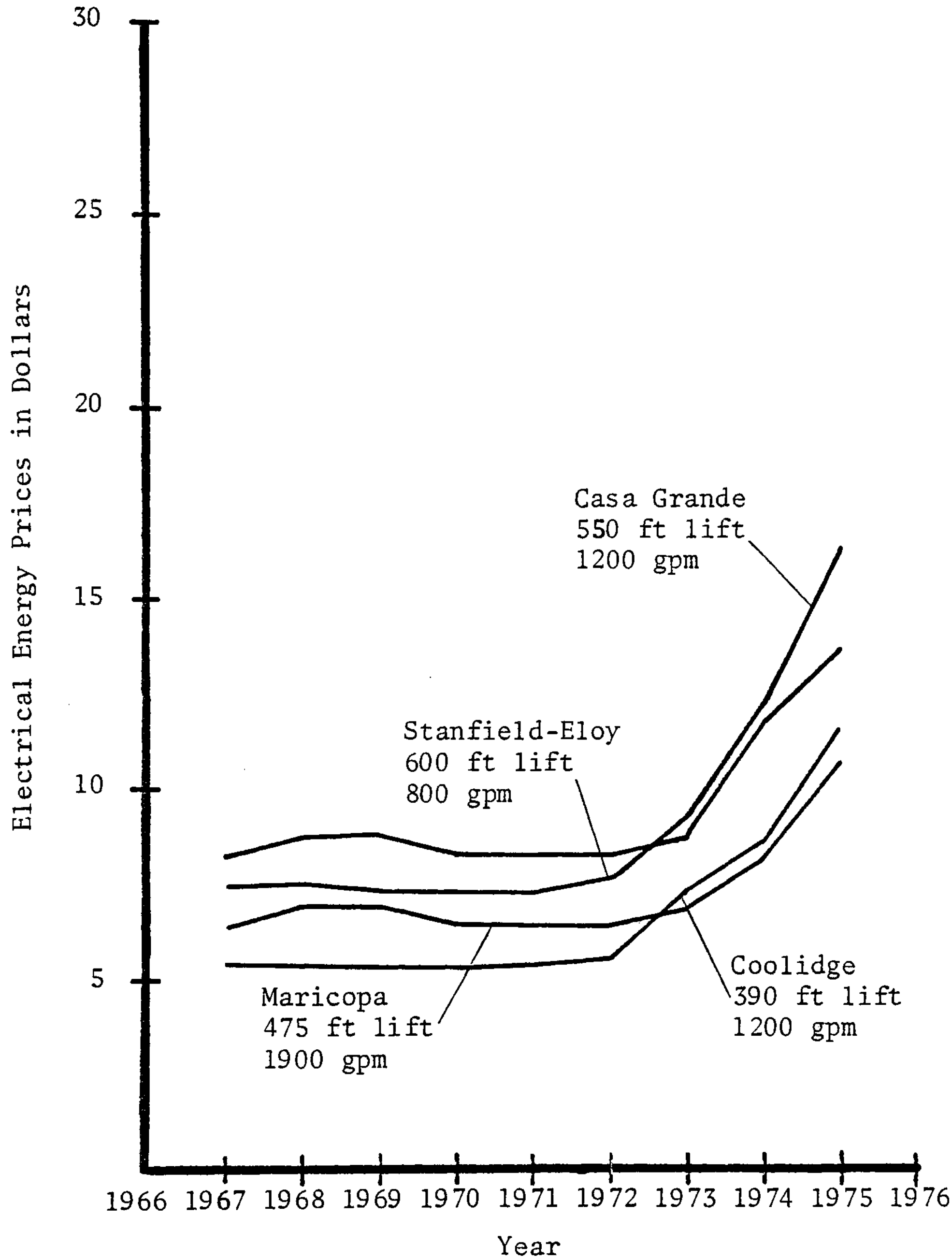

Figure 3.6 Pinal County Electrical Energy Prices per Acre-Foot at Various Depths and Productions. -- Source: Hathorn and Willett (1975c). See Appendix B (Figure B.1) for area definition.

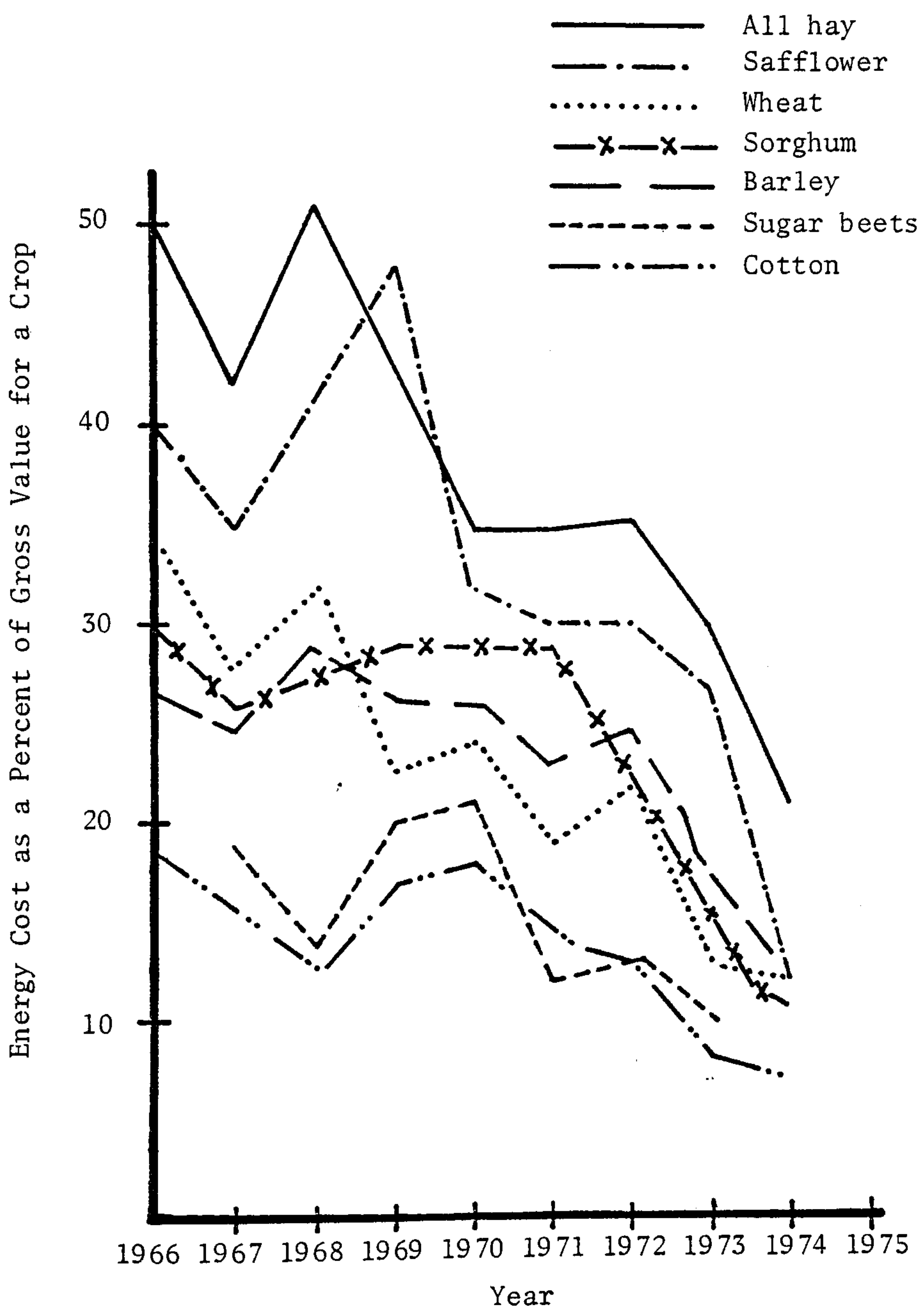

Figure 3.7 Energy Cost Trends of Water for Various Crops in Arizona.

Table 3.3 Energy Cost as a Percent of Average Gross Value for Selected Crops in 1966, 1970, and 1974.[1]

	Cotton	Barley	Wheat	Sorghum	Safflower	Sugar Beets	Hay
Maricopa County							
1966	19	27	35	30	41	-[2]	50
1970	18	26	24	29	32	21	35
1974	7	12	12	11	12	10	21
Pima County							
1966	19	34	42	24	-[2]	-[2]	81
1970	35	43	38	41	-	-	67
1974	18	28	30	22	-	-	53
Pinal County							
1966	10	19	19	18	-[2]	-[2]	36
1970	11	16	16	19	23	-	29
1974	7	16	13	9	12	-	24

1. Source: Arizona Crop and Livestock Reporting Service (1972, 1974).
2. Crop not reported because of limited or no production.

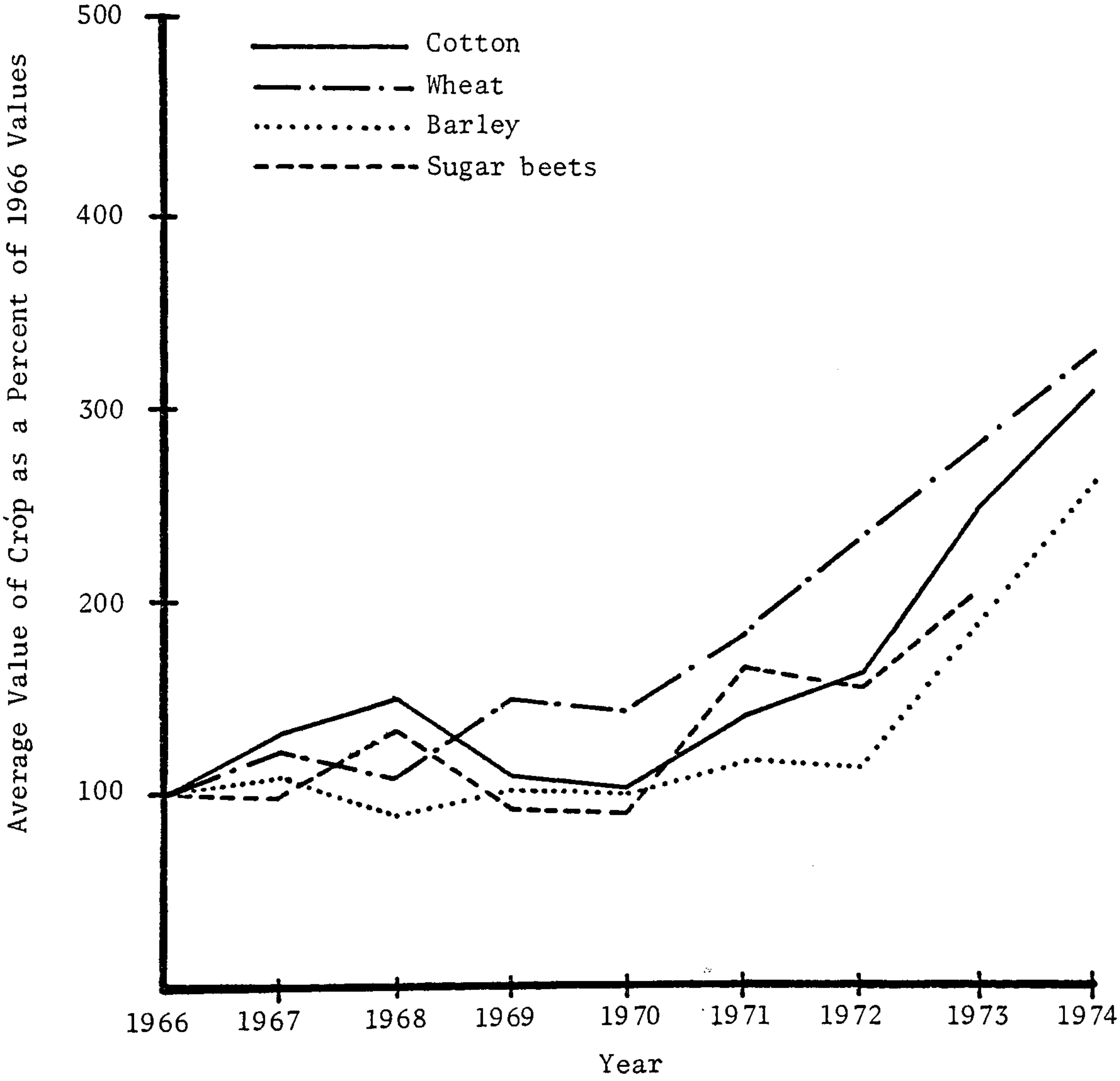

Figure 3.8 Average Value of Crops (Cotton, Wheat, Barley, and Sugar Beets) as a Percent of 1966 Value for Maricopa, Pima, and Pinal Counties. -- Source: Arizona Crop and Livestock Reporting Service (1972, 1974).

Figure 3.9 Average Value of Crops (Safflower, Sorghum, and All Hay) as a Percent of 1966 Value for Maricopa, Pima, and Pinal Counties. -- Source: Arizona Crop and Livestock Reporting Service (1972, 1974).

Table 3.4 1966 and 1974 Total and Individual Crop Acreages, Plus Total Water Use for Maricopa, Pinal, and Pima Counties.[1]

	Total Acres of Crops	Cotton	Barley	Wheat	Sorghum	Alfalfa	Safflower	Sugar Beets	Vegetables and Melons	Total Water Use (ac-ft)[2]
Maricopa County										
1966	437,000	95,700	66,000	9,500	57,500	98,100	34,800	13,100	49,100	1,474
% of total	100	22	15	2	13	22	8	3	11	100
1974	437,000	166,100	50,000	74,000	32,000	95,000	7,700	4,700	25,000	1,640
% of 1966	108	173	76	779	56	97	22	36	51	111
% of total	100	35	10	16	7	20	2	1	5	100
Pinal County										
1966	191,900	90,900	30,000	7,800	31,200	20,600	0	2,700	5,400	620
% of total	100	47	16	4	16	11	0	1	3	100
1974	280,300	142,000	38,000	56,000	14,000	17,000	6,800	1,500	3,100	872
% of 1966	146	156	79	718	45	83	-	56	57	141
% of total	100	51	14	20	5	6	2	0[3]	1	100
Pima County										
1966	44,800	16,900	8,800	250	13,400	1,300	0	200	1,900	124
% of total	100	38	20	0[3]	30	3	0	0[3]	4	100
1974	51,600	22,200	6,000	9,100	8,500	2,200	0	0	2,500	146
% of 1966	115	130	68	3,640	63	170	-	-	132	118
% of total	100	33	11	18	16	4	-	-	5	100

1. Source: Arizona Crop and Livestock Reporting Service (1972, 1974).
2. Figures are in units of 1,000 ac-ft.
3. This figure was less than 1%.

Alfalfa and other hay fluctuated over the decade but its acreage has remained relatively constant from an aggregate viewpoint.

Pima County. Pima County had 15% more land in production than in 1966. Cotton (38%), sorghum (30%), and barley (20%), were the dominate crops of Pima County in 1966. This changed to cotton (33%), wheat (18%), and sorghum (16%) in 1974.

Barley and sorghum acres decreased steadily from 1970. Wheat increased steadily from 1966. Again wheat and cotton had the major increase over the decade. Alfalfa and vegetables and melons also increased but had less impact on the total acreages. However, proportionately more water is being diverted to alfalfa. Alfalfa consumption in 1974 was 9% of the total water consumption versus 6.5% in 1966.

Total water consumption increased 17% over the decade. This percentage reflects 13% more water used for wheat, 4% more used for cotton, and 3% more used for alfalfa than in 1966.

Pinal County. Pinal County increased its acreage by 46% between 1966 and 1974. Cotton (47%), barley (16%), sorghum (16%), and alfalfa (11%) were the dominate crops of 1966. The hierarchy changed to cotton (51%), wheat (20%), barley (14%), and alfalfa (6%) in 1974.

The total increase in acreage came from wheat and cotton. Wheat acreage increased 6-fold, while cotton acreage increased 56%.

Consumptive use of water increased only 41% between 1966 and 1974. This is different than Pima County where water use increased more than acreage. This is due to water being diverted away from alfalfa.

Comparison of Water Cost as a Percent of Gross-Net Return and Cropping Patterns

Figure 3.7 and Table 3.3 display energy costs for water as a percent of gross net return of a crop. Although energy rates increased over the decade, this variable cost as a percent of gross return actually decreased. This is because the gross return for a crop increased at a greater rate than energy costs.

Maricopa County. Maricopa County energy costs for water as a percent of gross net returns decreased an average of 60%. Energy costs decreased from 19% to 7% of the gross net return for cotton. Costs for wheat declined 66% or from 35% to 12% of the gross net return. Except for safflower, where costs decreased 70%, cotton and wheat had the largest decreases.

Pima County. Pima County had a 19% decrease in the variable cost of water. The largest decreases occurring for wheat and hay.

Pinal County. Pinal County had an average decrease of 38%. Wheat, sorghum and safflower having the largest decreases. Costs for wheat declined 32%, sorghum 50%, and safflower 65%.

Summarizing, Maricopa County had the greatest decrease in energy costs for water as a percent of gross return for a crop. Pinal County had the second greatest decrease, while Pima had the least decrease in energy cost.

Summary of Historical Events

All three counties experienced increases in total irrigated agricultural acreage. Pinal had the greatest increase of 46%. Pima had an increase of 15% and Maricopa an increase of 8%. All of this increase came from expanded wheat and cotton acreage except in Pima County where alfalfa and vegetables added slightly to the increase.

Energy rates for water as a percent of gross return for a crop were least in Maricopa County, greatest in Pima County. From this observation it appears that urban expansion played a major role in curtailing agricultural production in Maricopa County and not the variable cost of water.

Results of Violating Economic Assumptions

Of the four economic assumptions listed previously, all were violated. This has resulted in considerable deviations from the projected response of irrigated agriculture to increased depths to water.

No Change in Relative Prices

Because crop values rose at much greater rates than the energy costs of water, variable costs for water actually decreased as a percent of gross net value. The price of water is less of a limiting factor of production than projected. The increased acreage which has occurred in the three counties supports this observation.

No Change in National Agricultural Policies

Although this assumption has been violated, its effect on Arizona agriculture is difficult to assess. Cotton allotments and price supports have changed throughout the decade (Firch, 1973). Nationally, cotton production was high in 1962 through 1965. The Secretary of Agriculture by authority of the Agricultural Act of 1965 provided strong incentives to reduce cotton acreage in 1966 and 1967. There was a drop in national cotton production in 1967. Due to a speculative market, acreages increased in 1968, 1969, and 1970. The Agricultural Act of 1970 increased cotton acreage allotments. Since 1970 cotton prices have risen sharply due to excess demand in the non-U.S. market. Nationally, cotton production has risen over the last decade, but declined slowly over the last 25 years.

National policy concerning the export of wheat may have had some effect in Arizona. However, a change in technology was more important in the increase of wheat acreages.

No Change in Tastes and Preferences

Farmers are decreasing acreages of sugar beets, safflower, and barley while increasing acres of wheat. Sorghum acreage has also decreased as cotton acreage increased.*

The switch to wheat is a major shift of preference. Until certain technological changes occurred wheat was a marginal crop in Arizona. The change in preference was due to violation of the following assumption.

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*Sugar beets, safflower, barley, and wheat have similar planting and harvest times. Also, sorghum and cotton have similar planting times.

No Change in Technology

Development of stiff-strawed, high-yielding wheat from Mexico and the Northwest violated this assumption. As of 1973, wheat acreage had increased 10-fold and per acre yield increased by greater than 50% in Arizona (Dennis and Day, 1973). The result is that wheat is now a dominant crop in Arizona along with cotton. Wheat had been projected to drop out of agricultural production.

Summary

Violation of the assumptions of Kelso et al. (1973) has reduced the validity of their projections for planning purposes. The impact that this has on the previously discussed water management strategies is discussed in the following chapter.

Kelso et al. (1973) predicted a 14% decline in total agricultural acreage in Maricopa County between 1966 and 1975. There was actually an 8% increase in acreage with a 10% increase in water use.

Pima County was predicted to remain at 1966 acreage and water use levels in 1975. Acreage actually increased by 15% and water use by 17%.

Pinal County was predicted to have a 4% decline in total acreage and a 6% decline in water use. Acreage actually increased by 46% and water use by 41%.

Cotton and sugar beet acreages were predicted to remain constant while alfalfa, barley, wheat, sorghum, and safflower acreages would decrease. Actually, cotton and wheat substantially increased in acreage while all other crops declined.

CHAPTER IV

CONCLUSIONS AND DISCUSSION

Emerging Arizona water policies address problems associated with aquifer overdrafts. The basic policy contemplated by the state is to reduce overdrafting situations through comprehensive management of Arizona's water resources. This policy, if enacted, would entail physical management, such as the Central Arizona Project, to increase renewable supplies. Demand management, entailing economic or legal strategies, would be used to reduce water use.

Most of Arizona's proposed demand management strategies would be directed at reducing the agricultural sector's water use according to the Arizona Water Commission (1975). At this time the Water Commission does not specify what type of demand management strategies would be relied upon to accomplish a reduction in water use.

Kelso et al. (1973), however, conclude that the agricultural sector's water use can be reduced by increasing the variable price for water. The conclusions of Kelso et al. (1973) are drawn from sophisticated economic projections. However, as indicated in Chapter III of this thesis, changing the variable price of water does not influence agriculturalists' water use.

Conclusions

Kelso et al. (1973) indicate that variable water prices play a major role in agriculturists' water use decisions since water use is dependent on the cost of water. If this is true, then water use can be managed by controlling water price. The relationship between price and use indicates that governmental intervention using taxes or other price controls would predictably influence water use. Kelso et al. (1973) also indicate that as costs of water increase due to increasing pumping costs (as the depth to ground water increases) agricultural production and water use will decline.

These conclusions are only valid if water cost is the primary variable affecting water use. As shown in Chapter III, water use is dependent on the output prices of farm products. Furthermore, the output prices of farm products is dependant on: the relative prices of farm outputs compared with the cost of inputs required for production; national agricultural policies; changing tastes and preferences of consumers and producers; and changing technology. The variable price for water is not necessarily the primary input variable controlling output and therefore water use.

The information in Chapter III shows that even though energy rates for water have increased, gross returns from crops have increased even faster. The effect of an increase in water prices has been very small on water use.

The relationship between water use and the variable price of water, as indicated by the projections of Kelso et al. (1973), is not valid. Variable water prices are unreliable as decision variables in comprehensive planning and management since the price of water may not be the primary input price controlling agricultural output.

Planning decisions based on the projections of Kelso et al. (1973) may be in error. Reliance on these projections may lead planners to favor unreliable demand management strategies which use water pricing to control water use.

Comparing short term fluctuations with long term projections may not appear justified. But the data does indicate the extreme variation possible between actual and projected events when only one parameter is used to predict a complex resource use. Planning decisions based on such projections may carry a high risk if there is a high social and economic cost at issue.

Discussion

Projections of a resource use are necessary for effective management. The role of projections in resource management and allocation decisions may indicate what methods should be used in making the projections.

The Role of Projections in Water Management and Planning

Planners must rely on projections to evaluate the effects of alternative management strategies on future events (James and Lee, 1971). Water use projections try to establish the relationship between the resource use and the social, economic, and technological factors which influence the use of the resource. Therefore, the projections must also include the forecasts of those factors controlling water use.

Projections are most useful when they are integrated with decision-making and management methods available for the allocation of water supply (Domokos, Weber, and Duckstein, 1976). The forecaster should attempt to delineate and predict those factors which can be managed by the various institutions involved with water management.

Forecasting water use based only on water price changes does not include the social, economic or technological factors which also control water use. If these factors change over time the projections will necessarily be in error. Even if pricing techniques could be proven an effective part of a demand management strategy, there are no institutional means to control agricultural ground water prices in Arizona. Forecasting based on the relationship between price and use would not be useful for management since water pricing techniques could not be implemented unless there is a change in Arizona's water law.

Factors Controlling Water Use

A general overview of the social, economic and technological factors which do control water use would include: population and economic growth, private market forces, property-right laws and regulations, public service and delivery facilities, and government policies (Delleur, Miller, and Potter, 1976). These same factors also control the use of other natural resources, notably land and energy resources. Furthermore, the use of other natural resources, especially land, has a direct effect on water use.

Two examples can be cited to illustrate the effect of land use on water use. The first example is given by Miller and Gill (1976). By encouraging proper land management practices such as soil conservation, proper cropping patterns, less intensive crop rotation and structural measures, control of water pollution from non-point sources can be realized. It is not feasible to directly control non-point discharges, but it is feasible to control land use practices.

The second example relates directly to water supply/demand problems. Phoenix, Arizona was faced with the need to exten water services to outlying areas of the city which were being developed, though large tracts of undeveloped land existed within the boundaries of existing water service facilities. By encouraging development of the land within the boundaries of the service area, Phoenix reduced the need to extend their water services (Delleur et al., 1976).

Effective water use forecasting must, therefore, not only include an integration of the social, economic, and technological factors, but it must also include the forecasts of other resource use patterns which affect water use.

Suggested Water Use Forecasting Method

Many authors have analyzed Arizona's water supply/demand problems and offer legal and economic strategies to improve the allocation of Arizona's limited supply among the competing demands of increasing urban, agricultural and industrial sectors. The Arizona government, however, lacks the institutions and laws to implement these strategies (Clark, 1974; Chalmers, 1974; Null, 1974). Furthermore, the political climate in Arizona will probably preclude any significant legislation dealing with water allocation in the near future (Arizona Daily Star, Feb. 18, 1973, and May 4, 1976b).

Arizona state and local governments do have, however, various zoning and subdivision regulations to control land use practices. The state has a certain amount of control over state-leased land, and local governments have control over land development practices within their jurisdiction (Delleur et al., 1976). The institutional mechanisms for planning and allocating land resources are present, politically acceptable, and in use. The institutional mechanisms to allocate land resources are not fully comprehensive, but they are better than the mechanisms present to allocate water resources.

Methods for predicting land use tend to integrate the social, economic and technological factors affecting land use (Weiss, 1968). Also, many studies relate land use patterns with water use patterns (Delleur et al., 1976). Water use projections derived from land use forecasts would reflect integration of the social, economic, and technological factors which determine land use patterns and are related to water use. Water resource allocation decisions could then be implemented through the institutional mechanisms controlling land use development.

Regulation of land use for agricultural purposes would be restricted to state-owned land, and land incorporated into the city limits of the urban centers. This would, however, allow limited management of Arizona's agricultural water demand.

Summary of Conclusions and Discussion

The projections of Kelso et al. (1973) are not useful for water allocation strategies since they are based primarily on the effect of price on water use. Water use is determined by a number of social, economic, and technological factors, and price is not necessarily the primary factor. These projections, also, do not indicate feasible management strategies for the allocation of water since Arizona lacks the institutional mechanism to implement direct water management policies.

This author suggests that since: methods for land use projections integrate social, economic, and technological factors of land resource use; definite relationships exist between land use and water use patterns; and mechanisms for land use control are available at this time, then water use forecasts could be derived from land use projections. Although it is beyond the scope of this thesis to pursue this suggestion, it is an area in which further research is needed.

APPENDIX A

TABLE OF CROPPING ACREAGES AND CONSUMPTIVE USE ESTIMATES

Table A.1 Crop Estimates in Acres for Maricopa County. -- Source: Arizona Crop and Livestock Reporting Service (1972, 1974).

Crop	Year								
	1966	1967	1968	1969	1970	1971	1972	1973	1974
Cotton	95,700	92,600	113,400	116,900	99,500	99,170	110,300	106,600	166,100
Barley	66,000	79,000	92,000	72,000	77,000	64,000	60,000	60,000	50,000
Wheat	9,500	13,500	12,500	24,500	51,700	56,500	69,000	84,000	74,000
Corn	5,600	6,000	5,800	6,000	7,200	7,000	7,700	7,000	5,800
Sorghum	57,500	67,100	59,400	50,500	44,300	43,600	33,600	30,000	32,000
Alfalfa Hay	98,100	97,700	100,000	87,000	94,800	94,000	100,000	100,000	95,000
Other Hay	7,400	8,500	10,200	9,900	10,400	10,700	12,100	12,000	11,900
Safflower	34,800	79,500	7,000	16,850	8,100	12,750	17,100	11,900	7,700
Sugar Beets	13,116	6,860	10,290	16,620	14,070	7,690	7,370	8,050	4,670
Vegetables & Melons	49,115	44,450	39,160	39,025	34,035	30,195	31,030	31,240	25,410
Totals	436,831	495,210	449,750	439,295	441,105	425,605	448,200	450,790	472,580

Table A.2 Consumptive Use of Water by Crops in Maricopa County (in Acre-Feet). -- Source: Arizona Crop and Livestock Reporting Service (1972, 1974).

Crop	Year								
	1966	1967	1968	1969	1970	1971	1972	1973	1974
Cotton	334,950	324,100	396,900	409,150	348,250	347,095	386,050	373,100	581,350
Barley	138,600	164,583	191,667	150,000	160,416	133,333	125,000	125,000	104,167
Wheat	19,950	28,125	26,042	51,041	107,708	117,708	143,750	175,000	154,167
Corn	8,960	9,500	9,183	9,500	11,400	11,083	12,192	11,083	9,183
Sorghum	120,750	139,792	123,750	105,208	92,292	90,833	70,000	62,500	66,667
Alfalfa	608,220	602,483	616,667	536,500	584,600	579,667	616,667	616,667	585,833
Other Hay	35,520	40,375	48,450	47,025	50,825	57,475	57,000	56,525	56,525
Safflower	132,240	302,100	26,600	64,030	30,780	48,450	64,980	45,220	29,260
Sugar Beets	47,217	24,696	37,044	59,832	50,652	28,656	26,532	28,980	16,812
Vegetables & Melons	59,610	56,257	50,560	53,777	46,526	42,555	42,137	45,276	36,995
Totals	1,474,017	1,692,011	1,526,863	1,486,063	1,483,449	1,456,855	1,544,308	1,539,351	1,640,959

Table A.3 Maricopa County Crop Values per Acre, Water Cost per Acre,[1] Water Cost/Value in Percent.[2,3]

Crop		Year								
		1966	1967	1968	1969	1970	1971	1972	1973	1974
Cotton	Gross Crop Value/Acre ($)	202	270	310	227	214	228	330	506	629
	Water Cost/Acre ($)	39	39	39	39	39	39	42	42	45
	Water Cost/Value x 100%	19	14	13	17	18	14	13	8	7
Barley	Gross Crop Value/Acre ($)	85	93	80	90	89	101	99	156	222
	Water Cost/Acre ($)	23	23	23	23	23	23	25	25	27
	Water Cost/Value x 100%	27	25	29	26	26	23	25	16	12
Wheat	Gross Crop Value/Acre ($)	66	82	71	98	96	120	115	187	220
	Water Cost/Acre ($)	23	23	23	23	23	23	25	25	27
	Water Cost/Value x 100%	35	28	32	23	24	19	22	13	12
Sorghum	Gross Crop Value/Acre ($)	77	89	85	78	80	80	112	173	238
	Water Cost/Acre ($)	23	23	23	23	23	23	25	25	27
	Water Cost/Value x 100%	30	26	27	29	29	29	22	14	11
All Hay	Gross Crop Value/Acre ($)	131	157	128	143	190	186	204	270	365
	Water Cost/Acre ($)	66	66	66	66	66	66	73	73	77
	Water Cost/Value x 100%	50	42	41	46	25	25	26	30	21
Safflower	Gross Crop Value/Acre ($)	94	113	99	82	122	129	140	157	372
	Water Cost/Acre ($)	39	39	39	39	39	39	42	42	45
	Water Cost/Value x 100%	41	35	39	48	32	30	30	27	12
Sugar Beets	Gross Crop Value/Acre ($)	-	204	278	195	186	333	315	419	-
	Water Cost/Acre ($)	-	39	39	39	39	39	42	42	-
	Water Cost/Value x 100%	-	14	14	20	21	12	13	10	1

1. Energy cost only (electricity).
2. 475 ft lift.
3. Water consumption adjusted upward reflecting a 72% efficiency.

Table A.4 Crop Estimates in Acres for Pima County. -- Source: Arizona Crop and Livestock Reporting Service (1972, 1974).

Crop	Year								
	1966	1967	1968	1969	1970	1971	1972	1973	1974
Cotton	16,900	16,300	18,900	17,400	16,200	15,040	16,150	16,400	22,200
Barley	8,800	12,000	10,000	11,000	11,500	10,000	9,300	8,500	6,000
Wheat	250	400	650	1,000	2,700	6,000	7,000	7,500	9,100
Corn	600	300	300	700	500	300	250	550	600
Sorghum	13,400	18,400	16,000	15,400	16,200	13,500	9,200	9,000	8,500
Alfalfa	1,300	1,800	2,000	1,900	2,100	2,500	2,000	2,000	2,200
Other Hay	1,400	800	400	400	400	400	400	500	500
Sugar Beets	200	0	200	1,910	220	0	0	0	0
Vegetables & Melons	1,920	1,320	1,810	2,000	2,745	2,920	3,820	3,780	2,530
Totals	44,770	51,320	50,260	51,710	52,565	50,660	48,120	48,230	51,630

Table A.5 Consumptive Use of Water by Crops in Pima County (in Acre-Feet). -- Source: Arizona Crop and Livestock Reporting Service (1972, 1974).

Crop	Year								
	1966	1967	1968	1969	1970	1971	1972	1973	1974
Cotton	59,150	57,050	66,150	60,900	56,700	52,640	56,525	57,400	77,700
Barley	18,480	25,200	21,000	23,100	24,150	21,000	19,530	17,850	12,600
Wheat	525	840	1,365	2,100	5,670	12,600	14,700	15,750	19,110
Corn	1,260	480	480	1,120	800	480	400	880	960
Sorghum	28,140	38,640	33,600	32,340	34,020	28,350	19,320	18,900	17,850
Alfalfa	8,060	11,160	12,400	11,780	13,020	15,500	12,400	12,400	13,640
Other Hay	6,720	3,840	1,920	1,920	1,920	1,920	1,920	2,400	2,400
Sugar Beets	720	0	720	6,876	792	0	0	0	0
Vegetables & Melons	1,344	1,001	2,433	1,400	1,922	2,044	2,674	2,646	1,771
Totals	124,399	138,211	140,068	141,536	138,994	134,534	127,469	128,226	146,031

Table A.6 Pima County Crop Values per Acre, Water Cost per Acre,[1] Water Cost/Value in Percent.[2,3]

Crop		Year 1966	1967	1968	1969	1970	1971	1972	1973	1974
Cotton	Gross Crop Value/Acre ($)	186	242	217	201	176	223	250	447	538
	Water Cost/Acre ($)	35	57	60	62	62	68	70	77	95
	Water Cost/Value x 100%	19	24	28	31	35	30	28	17	18
Barley	Gross Crop Value/Acre ($)	62	89	88	74	87	106	91	139	205
	Water Cost/Acre ($)	21	35	36	37	37	41	42	46	57
	Water Cost/Value x 100%	34	40	41	50	42	39	46	33	28
Wheat	Gross Crop Value/Acre ($)	50	73	61	89	96	114	105	156	192
	Water Cost/Acre ($)	21	35	36	37	37	41	42	46	57
	Water Cost/Value x 100%	42	48	59	41	38	36	40	29	30
Sorghum	Gross Crop Value/Acre ($)	86	103	83	95	91	82	112	176	260
	Water Cost/Acre ($)	21	35	36	37	37	41	42	46	57
	Water Cost/Value x 100%	24	34	43	39	41	50	38	26	22
All Hay	Gross Crop Value/Acre ($)	71	126	97	136	159	122	190	180	306
	Water Cost/Acre ($)	59	100	103	106	106	115	119	130	162
	Water Cost/Value x 100%	81	79	106	78	67	94	63	72	53

1. Energy cost only (electricity).
2. 350 ft lift.
3. Water consumption adjusted upward reflecting a 72% efficiency.

Table A.7 Crop Estimates in Acres for Pinal County. -- Source: Arizona Crop and Livestock Reporting Service (1972, 1974).

Crop	Year								
	1966	1967	1968	1969	1970	1971	1972	1973	1974
Cotton	90,900	87,800	101,800	107,200	95,600	101,300	110,300	115,300	141,950
Barley	30,000	52,000	47,800	45,000	43,000	42,000	42,000	47,000	38,000
Wheat	7,800	12,500	13,800	13,800	37,100	44,500	41,000	43,000	56,000
Corn	400	300	300	900	600	350	200	0	0
Sorghum	31,200	40,000	35,900	25,300	20,000	19,000	14,400	12,000	14,000
Alfalfa	20,600	21,000	18,200	17,000	18,000	17,000	18,000	18,700	17,000
Other Hay	2,900	2,500	2,400	2,300	2,500	2,500	2,900	2,000	1,900
Safflower	0	1,500	0	3,250	2,400	3,750	6,100	10,200	6,800
Sugar Beets	2,700	3,400	2,700	3,700	4,040	2,990	1,500	1,500	1,520
Vegetables & Melons	5,425	7,810	9,940	4,560	4,245	5,410	4,170	4,950	3,090
Totals	191,925	228,810	232,840	223,010	227,485	238,800	240,570	254,650	280,260

Table A.8 Consumptive Use of Water by Crops in Pinal County (in Acre-Feet). -- Source: Arizona Crop and Livestock Reporting Service (1972, 1974).

Crop	Year								
	1966	1967	1968	1969	1970	1971	1972	1973	1974
Cotton	318,150	307,300	356,300	375,200	334,600	354,500	386,050	403,550	496,825
Barley	63,000	109,200	100,380	94,500	90,300	88,200	88,200	98,700	79,800
Wheat	16,380	26,250	28,980	28,980	77,910	93,450	86,100	90,300	117,600
Corn	640	480	480	1,400	960	560	320	0	0
Sorghum	65,520	84,000	75,390	53,130	42,000	39,900	30,240	25,200	29,400
Alfalfa	127,720	130,200	112,840	105,400	111,600	105,400	111,600	115,940	105,400
Other Hay	13,920	12,000	11,520	11,040	12,000	12,000	13,920	9,600	9,120
Safflower	0	5,700	0	12,350	9,120	14,250	23,180	38,760	25,840
Sugar Beets	9,720	12,240	9,720	13,320	14,544	10,764	5,400	5,400	5,472
Vegetables & Melons	4,617	7,339	8,805	5,846	4,532	6,301	3,239	4,530	2,675
Totals	619,667	694,709	704,415	701,206	697,566	725,325	748,249	791,980	872,132

Table A.9 Pinal County Crop Values per Acre, Water Cost per Acre,[1] Water Cost/Value in Percent.[2,3]

Crop		Year								
		1966	1967	1968	1969	1970	1971	1972	1973	1974
Cotton	Gross Crop Value/Acre ($)	245	298	291	228	231	269	308	481	585
	Water Cost/Acre ($)	25	26	26	26	25	25	26	35	42
	Water Cost/Value x 100%	10	9	9	11	11	9	8	7	7
Barley	Gross Crop Value/Acre ($)	85	92	77	86	93	94	90	131	156
	Water Cost/Acre ($)	16	16	16	15	15	15	16	21	25
	Water Cost/Value x 100%	19	17	21	17	16	16	18	16	16
Wheat	Gross Crop Value/Acre ($)	65	76	62	82	96	111	107	179	198
	Water Cost/Acre ($)	16	16	16	15	15	15	16	21	25
	Water Cost/Value x 100%	19	21	26	18	16	14	15	12	13
Corn	Gross Crop Value/Acre ($)	101	89	104	103	117	92	127	-	-
	Water Cost/Acre ($)	10	10	10	10	10	10	11	14	17
	Water Cost/Value x 100%	10	11	10	10	9	11	9	-	-
Sorghum	Gross Crop Value/Acre ($)	88	97	68	94	78	84	101	162	292
	Water Cost/Acre ($)	16	16	16	15	15	15	16	21	25
	Water Cost/Value x 100%	18	16	24	16	19	18	16	13	9
All Hay	Gross Crop Value/Acre ($)	121	148	114	125	146	153	152	206	294
	Water Cost/Acre ($)	43	44	44	43	43	43	44	60	71
	Water Cost/Value x 100%	36	30	38	34	29	28	29	29	24
Safflower	Gross Crop Value/Acre ($)	-	76	-	97	107	147	119	133	349
	Water Cost/Acre ($)	25	26	26	26	25	25	26	35	42
	Water Cost/Value x 100%	-	34	-	27	23	17	22	26	12

1. Energy cost only (electricity).
2. 390 ft lift.
3. Water consumption adjusted upward reflecting a 72% efficiency.

APPENDIX B

MAPS OF STUDY AREAS

Key to Maps

County and Figures	Abbreviation of Area	Description	Map No.
Maricopa County Figures B.1 and B.2	MAR	Maricopa Water Conservation District #1	17
	AD	Adaman Mutual Water Co.	17
	LMP	Litchfield Park, Marinette and Peoria Pump Areas	16
	TON	Tonapah	8
	HAR	Harquahala Valley	9
	AG	Aguila	7
	RB	Rainbow Valley	14
	QC	Queen Creek	18
Pima County Figures B.1 and B.3	A	Sahuarita-Continental	24
	B	Marana	25
	C	Avra Valley	25
Pinal County Figures B.1 and B.2	CG	Casa Grande	21
	CO	Coolidge	21
	EL	Eloy	22
	MAR	Maricopa	20
	ST	Stanfield	20
	QC	Queen Creek	19

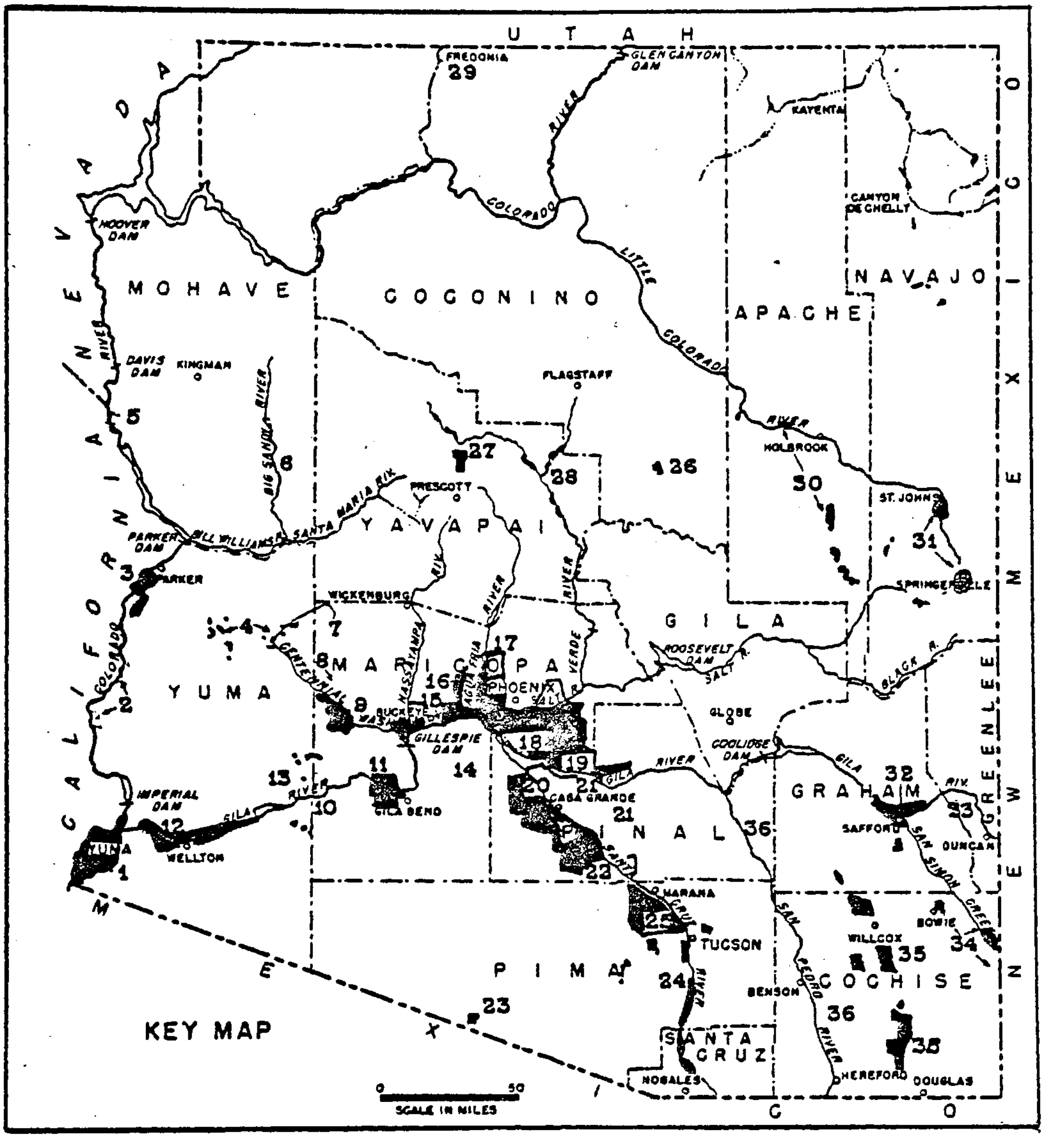

Figure B.1 Map of Arizona. -- Numbered areas are irrigated crop lands. See Figures B.2 and B.3 for expanded areas of Maricopa, Pima, and Pinal Counties. Source: University of Arizona College of Agriculture (1963).

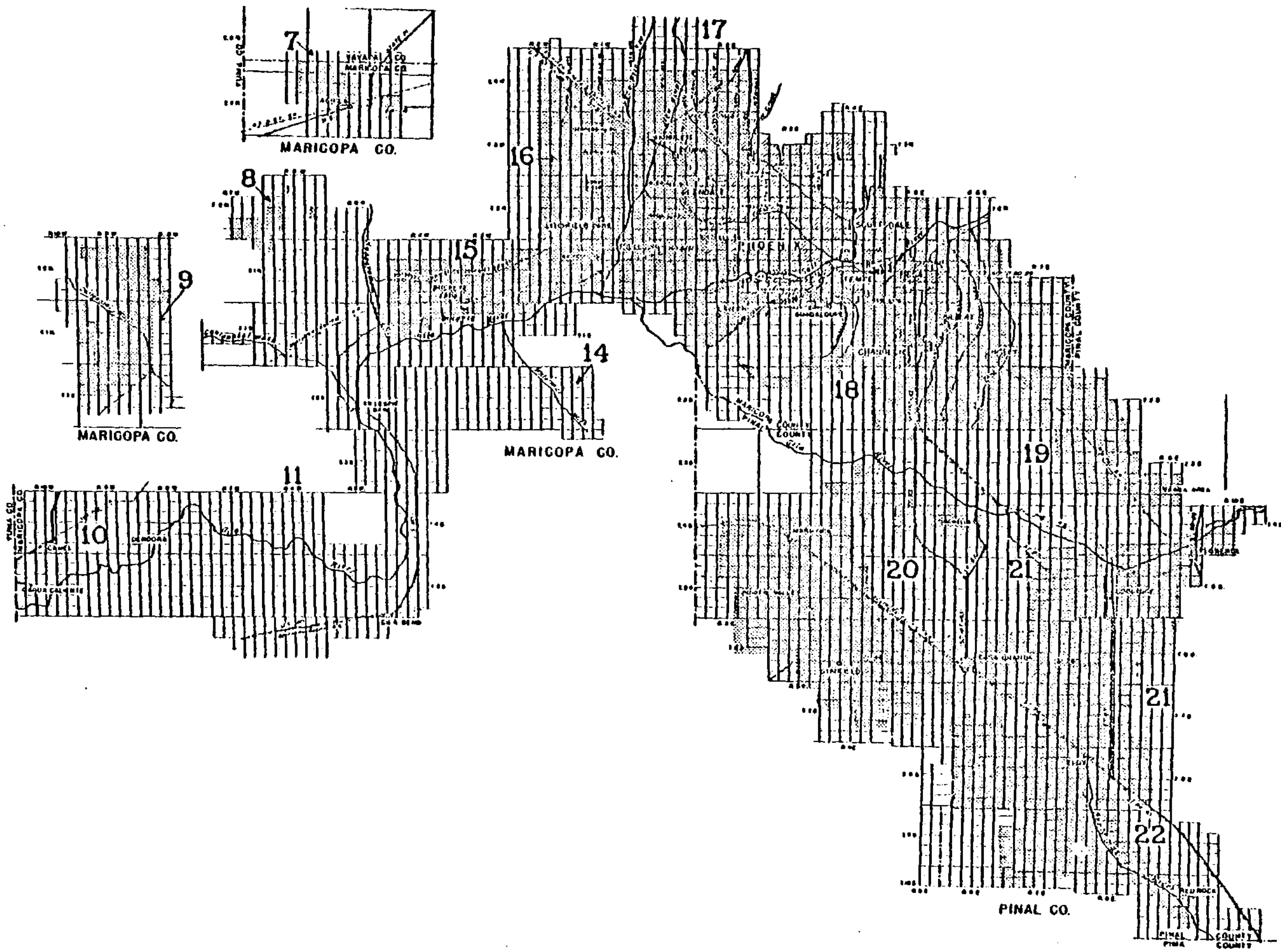

Figure B.2 Expanded Map of Maricopa and Pinal Counties Showing Irrigated Areas. -- Source: University of Arizona College of Agriculture (1963).

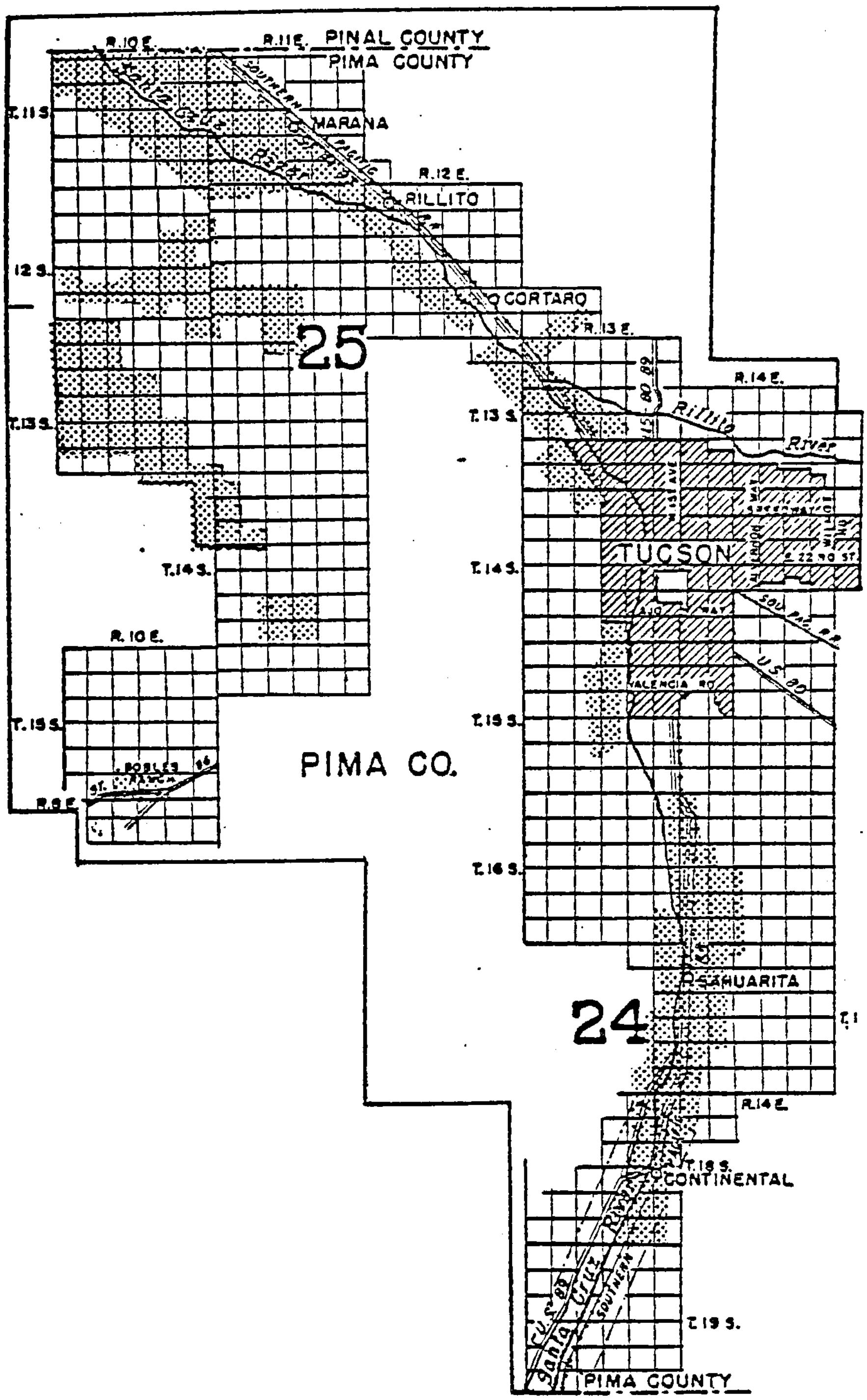

Figure B.3 Expanded Map of Eastern Pima County Showing Irrigated Crop Land. -- Source: University of Arizona College of Agriculture (1963).

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