EVALUATION OF GEOTHERMAL ENERGY IN ARIZONA

Arizona Geothermal Planning/Commercialization Team

Quarterly Topical Progress Report
July 1, 1980 - September 30, 1980

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Work performed under Contract No. DE-FC03-80RA50076
U. S. Department of Energy
San Francisco Office
Region IX

Subcontract 115-80 with
University of Arizona
Tucson, AZ 85721

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1.0 EXECUTIVE SUMMARY

1.1 Introduction

Dwindling oil supplies and dependence on foreign oil have encouraged a more intensive review of alternative energy resources. Geothermal energy reserves are abundant in the western U.S. and may be able to supplement this country's energy supply. Consequently, planning efforts have been directed toward estimating the potential of geothermal energy utilization in Arizona, and for providing information necessary for its prospective commercialization.

In the past, there has been a lack of both awareness and development of geothermal energy in Arizona. Investigation and planning could provide a base from which interested developers of geothermal energy can operate in the future. This project will clearly benefit Arizona and the U.S. as a whole in that an important step will have been taken toward developing an alternative energy form in the state.

The main emphasis for this project is to produce plans and provide information for geothermal energy commercialization. The technical approach for achieving this goal is to characterize geothermal resources and possible users. Further, evaluations of geothermal applications have been conducted where specific proven or potential geothermal resources correspond with specific applications. In the past, these have been referred to as Site-Specific Development Plans; however, the label, evaluation of geothermal applications, more accurately portrays the nature of the work done by the Arizona Geothermal Commercialization Team. Additionally, a program of direct interaction with business and community leaders has been undertaken. Several approaches have been taken, including the publication of a monthly newsletter, to increase awareness of geothermal resources and uses, and to open channels for further communication.

1.2 Introduction to Project

The Department of Energy (DOE) through its San Francisco Operations Office has delegated responsibilities for the commercialization of geothermal energy in Arizona to the Arizona Solar Energy Commission (ASEC) via a cooperative agreement. The ASEC assumed authority for monitoring the progress of the project through its director James Warnock and its associate director Frank Mancini. The ASEC in turn subcontracted the planning activities to the University of Arizona.

The Arizona Geothermal Commercialization Team consisted of two key personnel, three support personnel and additional temporary personnel. Key personnel are: 1) Frank Mancini, PhD, Project Administration. Dr. Mancini's responsibilities included monitoring the progress of the project and serving as liaison between the Arizona Geothermal Commercialization Team and the DOE; 2) Don H. White, PhD, Team Leader. Dr. White's responsibilities involved coordinating and monitoring all the data produced by workers on the project, suggesting and analyzing ADPs, suggesting and analyzing geothermal applications, and editing all reports written for this project. Support personnel are: 1) Larry Goldstone, Project Coordinator. His responsibilities consisted of coordinating all the workers on the project, technical analysis of the ADPs and evaluation and preparation of geothermal applications; 2) Greta Jensen, Group Leader. Her responsibilities included analysis of energy developments and economics in Arizona, and preparation of ADPs; 3) Lani Malysa, Group Leader. Her responsibilities included analysis of institutional and environmental procedures. There were a number of additional temporary personnel involved in this project. Their tasks are listed in the organization chart of the Arizona Geothermal Commercialization Team (Figure 1-1).

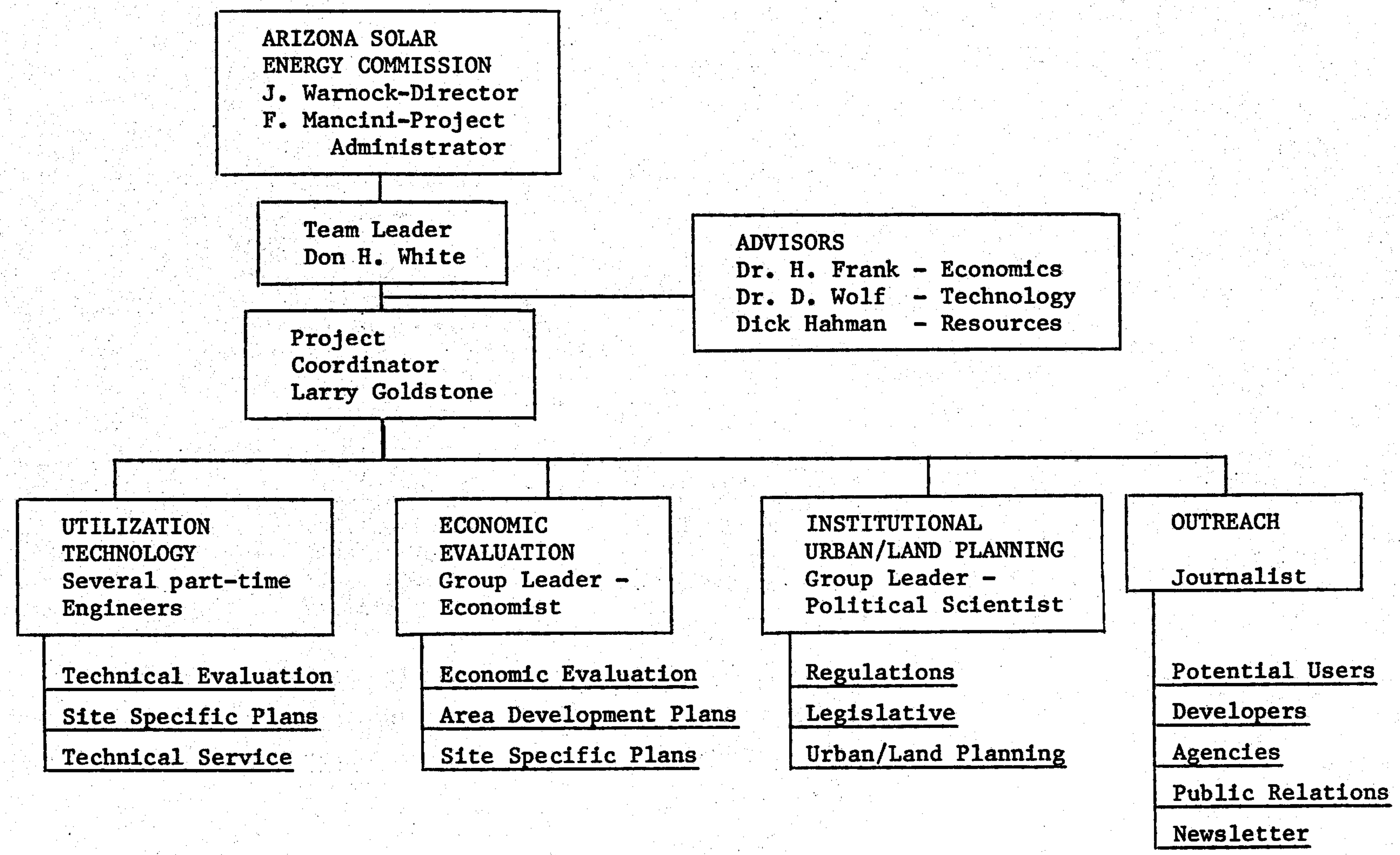


Figure 1-1: Organizational Chart
Arizona Geothermal Commercialization Team

The year 1980 is the third year for the Arizona Geothermal Commercialization Team's involvement in planning for geothermal commercialization within the State of Arizona. At the outset of 1980, Arizona was moved from Region X to Region IX jurisdiction of DOE. During the first year of the project, an appraisal of potential geothermal resources and uses was undertaken. Efforts were directed toward a survey of the geology of the state, the identification of potential resources, and twenty-two possible applications of geothermal energy specifically suited for Arizona. In the second year, the Arizona Team took the planning phase one step further. Nine geothermal applications were considered in detail, four regions of the state were studied as Area Development Plans, an institutional analysis was completed and an outreach program was initiated. The present year's work represents a continuation of work not yet completed during past years as well as some new tasks.

1.3 Objectives

The overall objectives of the Arizona Geothermal Commercialization Team have been to produce geothermal development plans to be used by the private sector and to provide a source of information for interested parties in the state. These objectives were met through a balanced planning and outreach program encompassing seven specific tasks. Each task played a significant role in providing assistance to potential geothermal developers and are defined as follows:

1) The formulation of Area Development Plans involved the compilation and analysis of detailed energy and economic data for three areas in the state. The result of these studies are a determination of potential market penetration of geothermal energy in each of the areas investigated. Also, potential developers were identified from the residential, commercial, industrial

and agricultural sectors.

2) The evaluation of geothermal applications, or Site Specific Development Analyses, involved preliminary engineering and economic analysis for selected applications for geothermal energy in Arizona, looking particularly at resource locations and given uses. Such analyses provided technical assistance to possible private and public developers of the resource.

3) The evaluation of geothermal resources provided information on Arizona geothermal resource locations and characteristics. Results of this task included reporting reservoir temperatures and reporting on leasing and exploration activities within the state.

4) In certain instances, more complete engineering and economic analyses were performed as deemed appropriate based on the results of task 2. Such studies resulted in detailed technical research for promising geothermal applications.

5) A program of technical assistance was also provided during the year. This program involved limited technical assistance to the public and private sectors in Arizona who were interested in commercial geothermal energy applications.

6) Growth pattern impacts were also studied to provide a better understanding of the role of geothermal energy in a fast growing state such as Arizona. Effects of population and economic growth patterns were evaluated to determine the impact on the potential commercialization of geothermal energy.

7) An outreach program for the purpose of providing information was continued during the year, principally by the publication of a monthly newsletter.

1.4 Area Development Plans

During 1979 the 14 counties of the state were organized into seven regional areas for purposes of planning the future use of geothermal energy. Work during 1979 was concentrated in the Southern portion of Arizona, especially within Maricopa and Pima Counties where the majority of the state's population resides. Figure 1-2 shows the divisions within Arizona for planning purposes. With respect to Arizona's seven planning areas, four were analyzed during 1979.

Priorities

- I) Maricopa
- II) Pima
- III) Graham/Greenlee
- IV) Pinal
- V) Yuma
- VI) Cochise/Santa Cruz
- VII) Northern Counties (1,3,4,8,9,13)

County Names

1. Apache
2. Cochise
3. Coconino
4. Gila
5. Graham
6. Greenlee
7. Maricopa
8. Mohave
9. Navajo
10. Pima
11. Pinal
12. Santa Cruz
13. Yavapai
14. Yuma

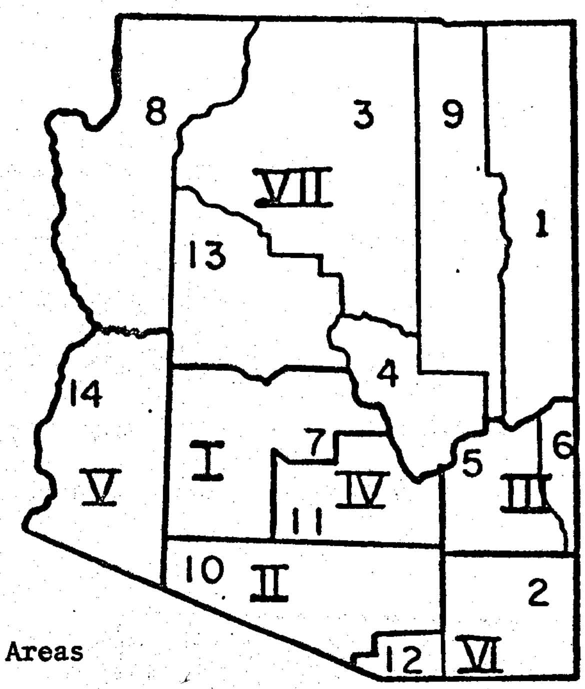


Figure 1-2: Geothermal Planning Areas

During 1980, the remaining three areas of the state were analyzed and the information for the previously completed four areas was updated. Detailed information was gathered on population and population growth, land status, water availability, industry and industrial growth, various economic indicators, energy use patterns, and energy prices. Results of this work will be input to New Mexico Energy Institute (NMEI) for modeling geothermal energy on line between 1980 and 2020.

1.5 Evaluation of Geothermal Applications

Based on the recommendation of the preliminary study of 1978 and recent developments in the state, evaluations were completed for ten geothermal applications (previously called site specific development analyses). It is important to note that none of these applications are under actual development at this time. The technical, financial, environmental and institutional aspects of each were studied.

1.5.1 Space Cooling and Heating

The heating aspects of this task have been completed. Therefore, during 1980, attention was devoted to applications of absorption chillers and heat pumps to potential users in the state.

1.5.2 Geothermal Power Plants

The State of Arizona is experiencing a fast growth in population. The populace has more than doubled in members in the last twenty years, totalling 2.63 million in 1979. The population in the year 2000 has been projected to be 4.28 million. With this constant increase in population, a need for an increase in electricity production becomes inevitable. According to a study conducted under the direction of the U.S. Department of Commerce the net generating capacity available to Arizona from power plants was about 7,699 Megawatts (MW) in 1976; while the net generating capacity that will be needed in the year 2000 is 19,375 MW. Thus more plants generating power will be needed. Utilities in Arizona are aware of this increased demand for electricity and are planning to increase their future production capacity by building new power plants. Most of these new plants will be coal-fired, the rest will be nuclear power plants. These power plants might face strict environmental and safety regulations that could cause electricity prices to rise in a few cases, and may hinder the development of some of these power plants. Consequently, in order to meet the future demand for electricity, it becomes of paramount importance to utilize the available energy resources in the state.

Geological studies have shown that some geothermal prospects in Arizona are likely to have fluid temperatures above 150°C and might be suitable for use in power production. Most work on this application was completed during 1979 and a minimum of new work was completed in 1980. This information was to be input to NMEI in order to obtain a cost estimate on a geothermal power plant.

1.5.3 Geothermal-Assisted Copper Dump Leaching

Arizona is the largest copper-producing state in the nation and this industry is expected to grow in the future due to the large copper reserves in the state. Currently there are about fourteen operating mining locations in the state. Preliminary work on this application was begun in 1979. Work completed during 1980 consisted of efforts to visit copper mines in Arizona and to refine cost studies. Future interactions hopefully will lead to a commercial geothermal project.

1.5.4 In-Situ Leaching of Uranium, Zinc and Copper

During 1979, the Arizona Geothermal Team evaluated the feasibility of the integration of geothermal resources with the *in-situ* leaching of uranium (first priority) and copper (second priority). *In-situ* leaching utilizes the existing sulfuric acid capacity and existing commercial technology of chelating agents in liquid-liquid extraction to recover these valuable metals from very impure solutions. Work on this application consisted of efforts to define the geological mining criteria necessary for each type of ore. Also, a study of chelating agents was undertaken.

1.5.5 Geothermal Steam Turbine Pumping

Arizona's agriculture is based on irrigation. Most of that irrigation water is underground water that must be pumped to the surface for use. Thus, a substantial amount of natural gas and electricity is used to power these pumps. In the future, geothermal energy might be used in some agricultural areas to power the pumps. During 1980, pumping requirements and land area involved was evaluated for the irrigated areas of Arizona.

1.5.6 Direct Thermal Use for Food Processing

Arizona has a few food processing plants mainly in the Phoenix and Tucson areas, but the potential for growth in this industry is believed to be high. This industry is a good potential user of moderate-temperature geothermal resources. Work for 1980 on this application consisted of assessing current and future food processing trends, crops likely to be grown in Arizona, and temperature requirements for processing local crops.

1.5.7 Geothermal Energy Utilization in Modern Cattle Feedlots

The cattle feedlot business is an important segment of the Arizona economy. Most of Arizona's feedlots are moving from the Phoenix area to the agricultural belt extending from Casa Grande to Yuma. Modern technology is beginning to impact upon the cattle feedlot business, especially due to the pressures of rising grain and energy costs. There is a fundamentally sound basis for expecting future (and existing) feedlots to become larger, more integrated business operations. Essentially all of the energy requirements of the new developments in cattle feedlot operations are low-temperature in nature. Thus, geothermal energy may prove important in future cattle feedlots.

Recent work on this application included identifying the existing feedlot and alfalfa operations in Arizona. Assessments of energy and temperature requirements on these existing operations was also completed. In addition, the integration of an alcohol plant (for gasohol purposes) and a cattle feedlot were investigated in detail.

1.5.8 Geothermal-Assisted Coal Power Plants

There are a few coal-fired power plants under construction in Arizona, e.g., in the areas of Springerville and Willcox. More units will be constructed in the next ten years in these and other areas in the state. Geothermal brine may be used primarily to pre-heat the make-up water and then coal is used to convert this water to process steam. This idea has been studied by the City of Burbank's Public Service Department to be applied in the City of Burbank in California. The evaluation of a similar application in Arizona may be advantageous. 1980 work on this application consisted of summarizing the City of Burbank study of a hybrid geothermal/coal-fired power plant and applying it to future power plants in Arizona.

1.5.9 Satellite Urban Development

Under this application, work was done on planning for the development and growth of a new or existing community based on geothermal energy. Required population and local necessities were defined. Research conducted at Arizona State University proved useful in analyzing this application.

1.5.10 Geothermal-Assisted Aquaculture

Studies have shown that some fish grow much faster in warmer water. Similar work has also been done on shrimp. Studies have been done to determine whether geothermal water can supply the right environment to induce faster growth in fish and shrimp. 1980 work on this application consisted of reviewing current work done by E.G. & G., Idaho and the University of Arizona. Possible sites were located in Arizona based on the environmental requirements of the shrimp and other seafoods.

1.6 Continued Evaluation of Geothermal Resources

The Arizona Geothermal Commercialization Team continued to provide information on geothermal resource locations and qualities, including that on federal lands. Leasing activity was also reported. This task involved liaison with the Arizona Bureau of Geology and Mineral Technology, other state agencies and geothermal developers. Particular emphasis was placed on evaluating the geothermal resource locations and qualities in the remaining three ADP's.

1.7 Engineering and Economic Analyses

The Arizona Geothermal Commercialization Team made more complete preliminary engineering and economic analyses of specific technologies as needed for Task 2, utilizing when possible, the services of New Mexico Energy Institute, E.G. & G. Idaho, Inc. and other organizations in the western states and within the federal government. Technologies that were studied in depth included a gasohol plant and the cooling/heating of a new community.

1.8 Technical Assistance in State of Arizona

The Arizona Geothermal Commercialization Team provided a limited amount of technical assistance to the private and public sectors in the State of Arizona interested in utilizing geothermal energy. Most of the technical assistance provided involved the dissemination of information as opposed to new research in areas of inquiry. Research and technical information were provided to several engineering firms in the Tucson and Phoenix areas and also to the Agricultural Extension Service at the University of Arizona.

1.9 Impact of Various Growth Patterns Upon Geothermal Energy Development

The Arizona Geothermal Commercialization Team identified probable growth patterns of population and the resultant economy so that the future potential of geothermal energy under these scenarios can be evaluated. This information will be input to NMEI.

1.10 Outreach Program

The Arizona Geothermal Commercialization Team continued its outreach program, which involved interactions with potential users, resource developers, various agencies and other groups. Information on geothermal energy was supplied to industry, institutions, state agencies and local governments and the general public, through publications, workshops, meetings, etc. Also, a monthly publication of a newsletter distributed to cities, legislators and industry was initiated.

The following sections will detail work completed during the third quarter (July, August and September) of 1980.

2.0 AREA DEVELOPMENT PLANS

In addition to studies on the remaining two ADP's for Arizona, a completion of the Yuma County ADP was undertaken during the third quarter as new information became available.

Information on Maricopa, Pima, Pinal, Greenlee and Graham counties for the Area Development Plans continued to be updated. The following sources, among many others, have been contacted for any new publications and additional information: Office of the Governor, Office of Economic

Planning and Development, various councils of governments, community planning offices, industrial development agencies, individual developers and the Chamber of Commerce in the key communities.

2.1 Yuma County

2.1.1 Land Ownership

Figure 2-1 presents a general land ownership map for Yuma County. The majority of Yuma County is federal land. Table 2-1 shows acres owned by various sectors.

Table 2-1 Land Ownership in Yuma County

Sector	Percentage	Total Acres
Federal	81	5,176,710
Private	8	511,280
State	7	447,370
Indian	4	255,640
Total	100	6,391,000

2.1.2 Matching of Geothermal Resources to Potential Users

Results of Yuma County's Area Development Plan indicate some prospects for geothermal applications. Table 2-2 presents an estimate of industrial process heat requirements for one industry on an annual basis. A reservoir temperature of 70°C was assumed for Yuma County. Based on this

Table 2-2 Yuma County

Estimated Process Heat Energy Requirements
Assumed Reservoir Temperature: 70°C

SIC Code	Industry Description	Process Heat Temperature	Energy Use 10^{10} Btu/yr
3273	Ready Mix Cement	65°C	.004

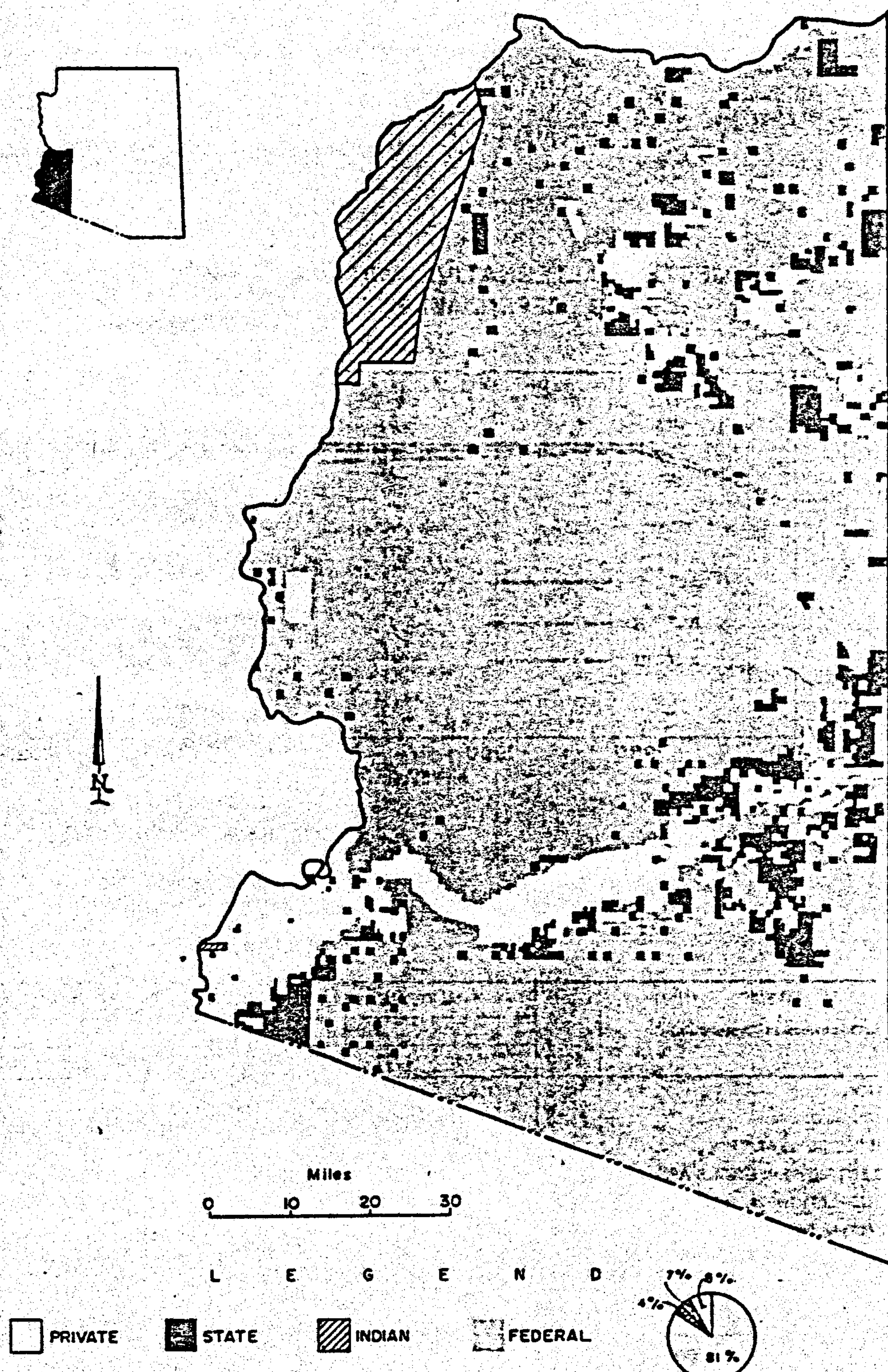


Figure 2-1: Land Ownership Yuma County

Source: Arizona Water Commission

temperature expectation, the industry presented is considered a potential user of geothermal energy. It should be noted that industrial process heat requirements do not include energy consumed for space cooling or heating.

From work performed in conjunction with the New Mexico Energy Institute, Figures 2-2 and 2-3 model geothermal energy on line as a function of time over the next forty years. Two cases are shown. The first, Figure 2-2, presents energy on line assuming a city owned utility developed the resource. The second case, Figure 2-3, presents energy on line assuming a private developer developed the potential resource. The difference results from differing costs of capital. One important assumption should be noted: it is assumed for modeling purposes that geothermal energy comes on line when the price of other energy alternatives rises above a computed cost per MMBTU for geothermal energy. In other words, it is assumed that industry will use the lowest cost energy available.

Results from Figures 2-2 and 2-3 summarize as follows. Under private development in Yuma County, geothermal energy would come on line by 1993 and grow steadily until 2020. Under city utility development, geothermal energy would be cost competitive by 1989. Thus, city utility development results in faster development in an earlier time frame. Table 2-3 reports energy on line in terms of barrels of oil replaced per year.

Table 2-3 Barrels of Oil Replaced by Geothermal Energy Per Year

Process Heat Market

Yuma County

	1985	1990	2000	2020
Private Developers	0	0	53,393	212,500
City Utility	0	9196	132,142	226,785

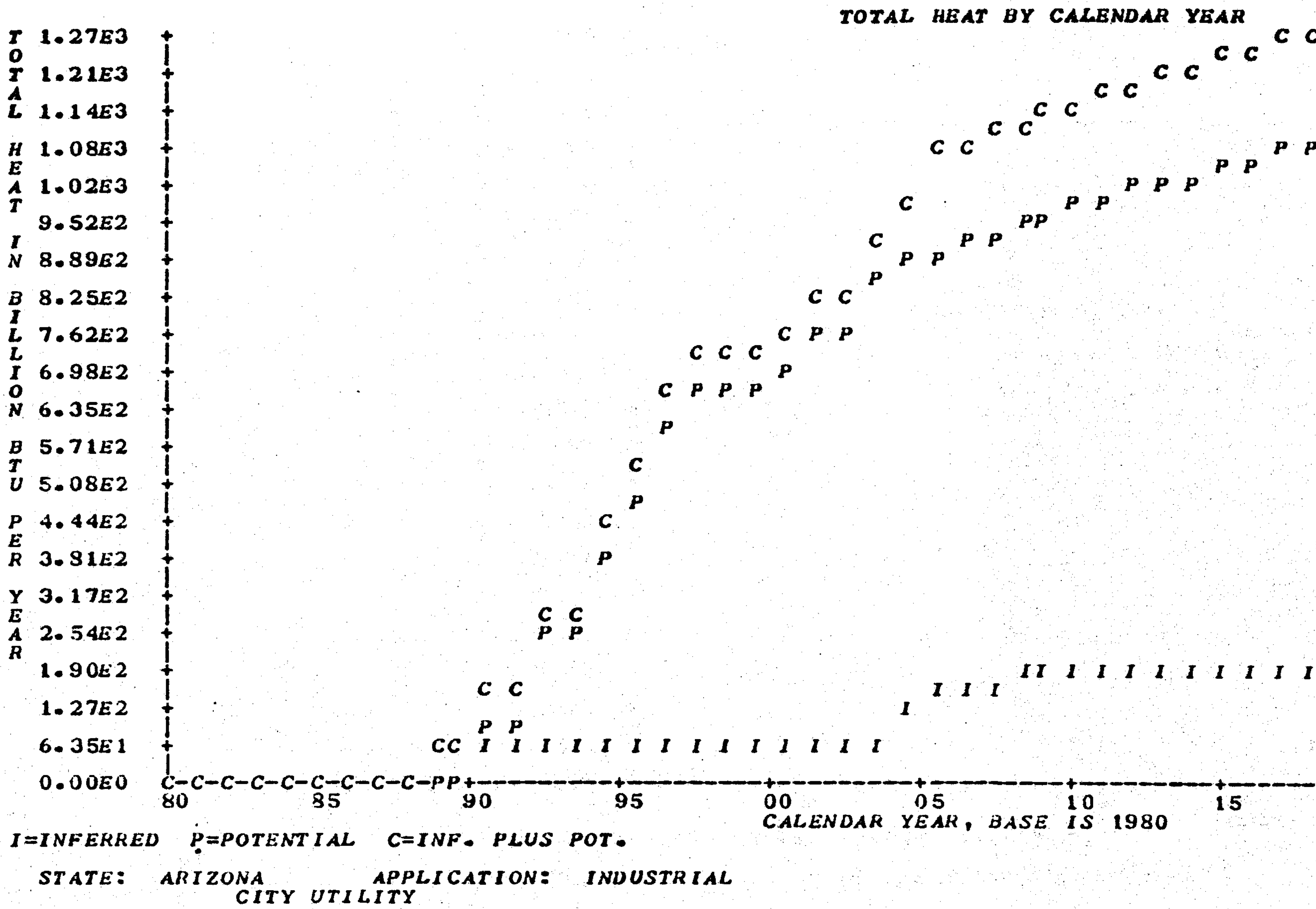


Figure 2-2: Projected Geothermal Heat On Line by Year Under City Development
Source: New Mexico Energy Institute

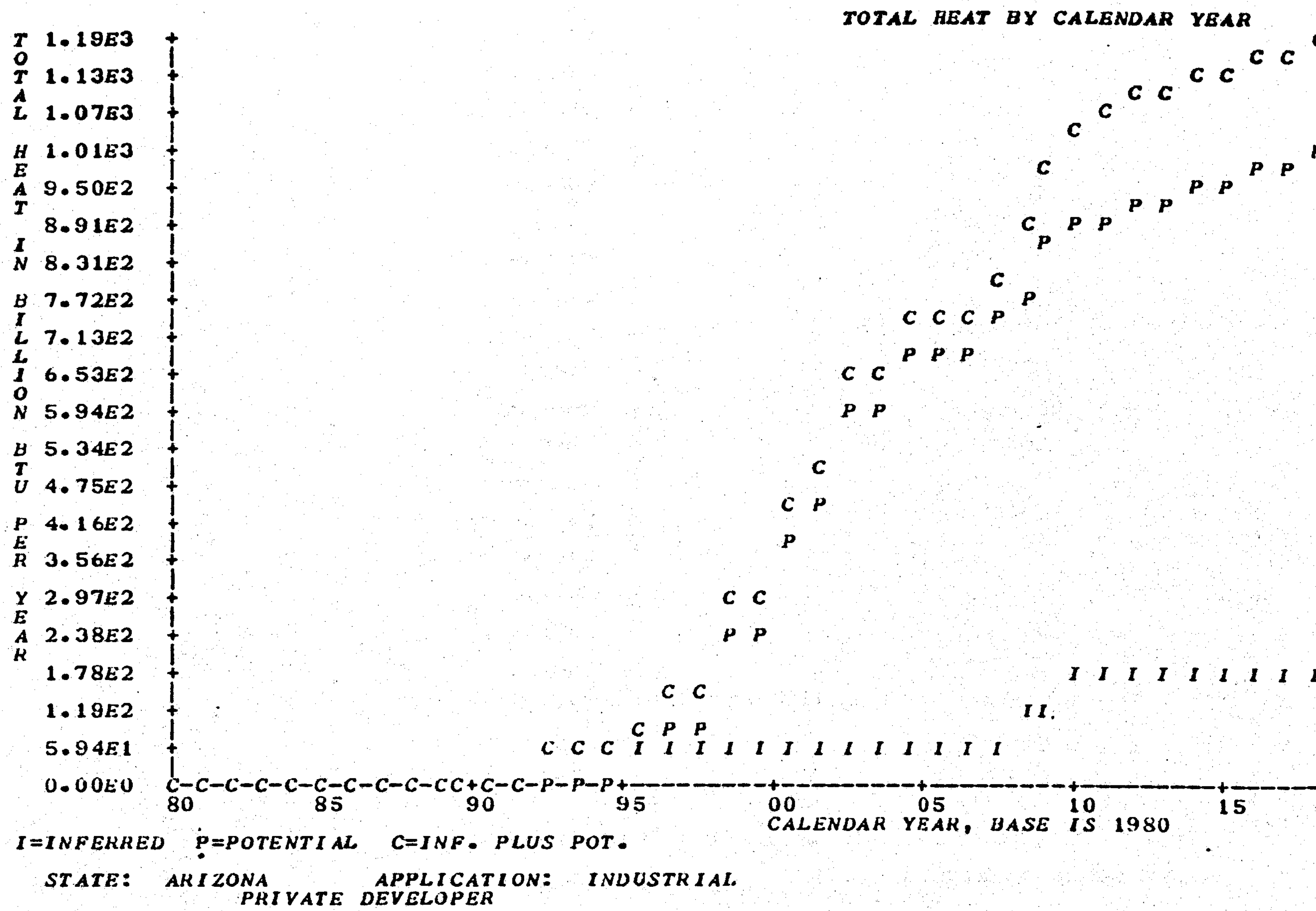


Figure 2-3: Projected Geothermal Heat On Line Under Private Development
Source: New Mexico Energy Institute

It is apparent that geothermal energy's contribution in the process heat market is significant in barrels of oil saved by 2020.

Modeling comparable to the above results was also performed for the residential and commercial sectors. However, the scope of work was confined to space heating energy requirements. It is believed that space heating in Yuma County is limited to only a few winter months and would not justify the establishment of district heating systems. Thus, results from the residential and commercial sectors have been omitted until a system including space heating and space cooling can be modeled.

Agribusiness and agricultural industries were also identified in Yuma County. Most agricultural processing is concentrated in citrus crops along with raising livestock. Future expansion of agricultural processing in Yuma County would have significant benefits for local residents and farmers. Identifying a low cost energy source which would be available and suitable for agricutural and livestock processing and irrigation could stimulate a local industry.

2.2 Cochise/Santa Cruz Counties

2.2.1 Economy

The 1979 estimated population for Cochise and Santa Cruz Counties combined is 101,879. The total land area of the two counties is 7,502 square miles which results in a population density of 13.6 persons per square mile. The ethnic breakdown of the population is 52 percent White, 40 percent Hispanic, 2 percent Negro, .2 percent Indian and 5.8 percent other.

Historically, the population of Cochise County has grown at an annual rate of 3.0 percent per year. Future projections show a steady continued growth; however, growth is expected to be centered principally to the south and west of the city of Willcox. The population of Santa Cruz County has traditionally experienced slow growth; however, from 1968 to 1978 there was a 38.4 percent increase in population. Over 50 percent of the population is centered in Nogales. Population projection to 2020 are presented in Figures 2-4 and 2-5.

The major towns are listed in Table 2-4 along with projected populations to 2000.

Table 2-4: Major Cities in Cochise and Santa Cruz Counties

Cochise	1979	2000
Sierra Vista	25,969	37,487
Douglas	13,342	19,160
Bisbee	10,119	14,155
Benson	4,333	6,153
Willcox	3,487	5,343
Santa Cruz	**1979**	**2000**
Santa Cruz	19,635	32,950
Nogales	14,646	26,502
Patagonia	1,009	1,850

The fastest growing city in Cochise County is Willcox, located on a major transcontinental highway in the center of the southeast Arizona agricultural area. The city presently sustains its economy by trade and services for farmers, ranchers and travelers. However, the Willcox area

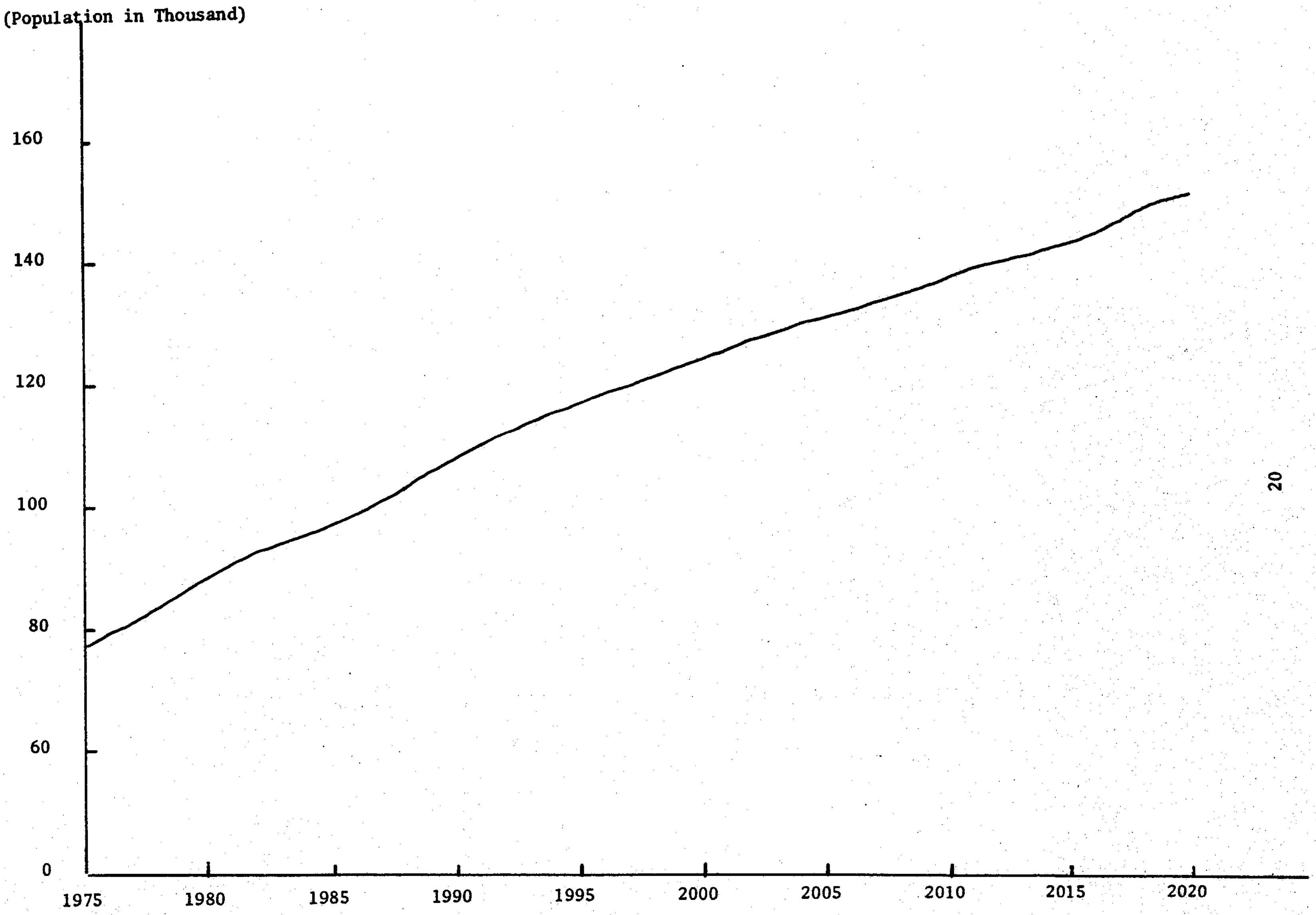


Figure 2-4: Population Projections for Cochise County
Source: Arizona Department of Economic Security, Population Statistics Unit, May 31, 1979

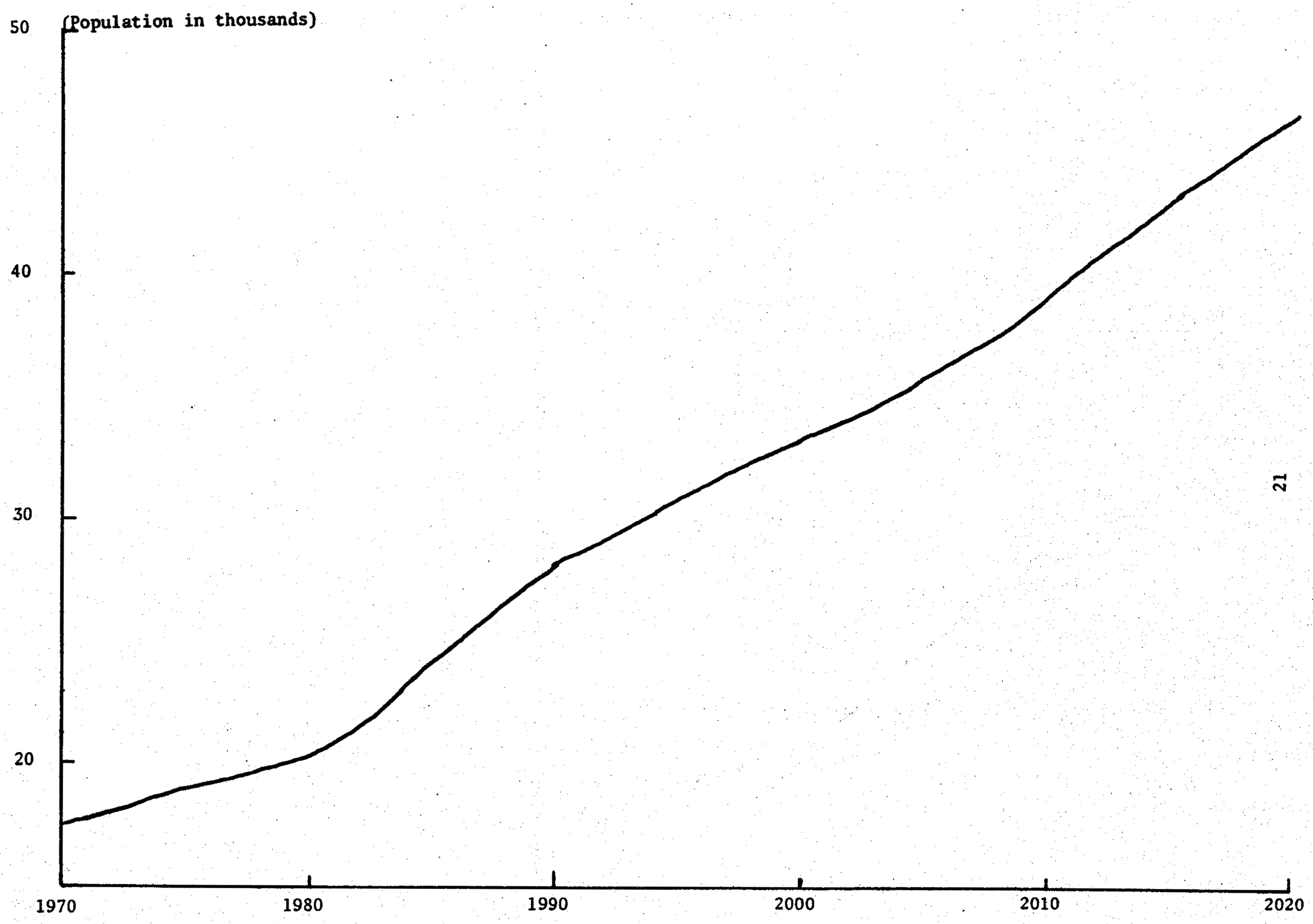


Figure 2-5: Population Projections for Santa Cruz County
Source: Technical Advisory Committee (DES)

has shown increasing diversification.

Future growth is anticipated in Willcox in both agriculture and agribusiness. Plans for a gasohol plant are presently being considered. The plant is expected to be operating by early 1981, directly employing 30 people. In addition a pork-kill plant is in the planning stages and is anticipated to directly employ ten people.

The agricultural sector in Cochise County continues to be of major importance. The county is the primary producer of feed grain in the state accounting for 43 percent of Arizona's grain sorghum and 90 percent of its corn production. In addition, the Willcox area produces 31 percent of the state's hogs and 17 percent of its range cattle. Crop receipts amounted to $61.5 million in 1977 with livestock receipts amounting to $35.4 million, for total agricultural receipts of almost $100 million.

Presently, agriculture accounts for only 4 percent of total employment in Cochise County and is not projected to increase. The trade and services sectors are expected to absorb most of the increasing population within the area. Currently accounting for 20 percent of total employment, by 2000 this figure is expected to rise to 26 percent.

In Santa Cruz County, Nogales, although not the fastest growing city in the county, is the most important in terms of trade. Nogales lies on the U.S./Mexican border and is expected to grow rapidly as trade between Mexico and the United States increases.

Santa Cruz County's economy is based on tourism and international trade. Wholesale and retail trade are the most important employment sectors accounting for almost 50 percent of total employment in the county.

Manufacturing and construction are not significant in either county. Specifically, construction is expected to decline at a .9 percent annual rate and manufacturing to grow just slightly through the year 2000. No significant changes are expected regarding agricultural employment over the next 20 years. See Figure 2-6 for current employment levels and projections to 2000.

Other economic indicators in both counties indicate positive growth trends. Personal per capita income projections to 2000 are presented in Figure 2-7 for Cochise and Santa Cruz Counties. Annual growth rates are 2.9 percent and 3.0 percent respectively. These income figures represent a slower growth rate than is common in the populous counties of Pima and Maricopa. Wages in both Santa Cruz and Cochise Counties are also typically lower than in the more industrialized counties such as Pima and Maricopa.

Between 1968 and 1978 the value of retail sales has steadily grown in both counties. In Cochise County retail sales have increased 209 percent and similarly a 153-percent increase in Santa Cruz County. Bank deposits in Cochise County have increased 189 percent over the ten-year period and 354 percent over ten years in Santa Cruz County.

In conclusion, Cochise and Santa Cruz Counties have typically been slow-growth counties in Arizona. This is evidenced in both population and various gauges of economic welfare.

2.2.2 Land Ownership

Figures 2-8 and 2-9 show general land ownership maps for Cochise and Santa Cruz Counties. Table 2-5 gives acreage breakdowns for each ownership class.

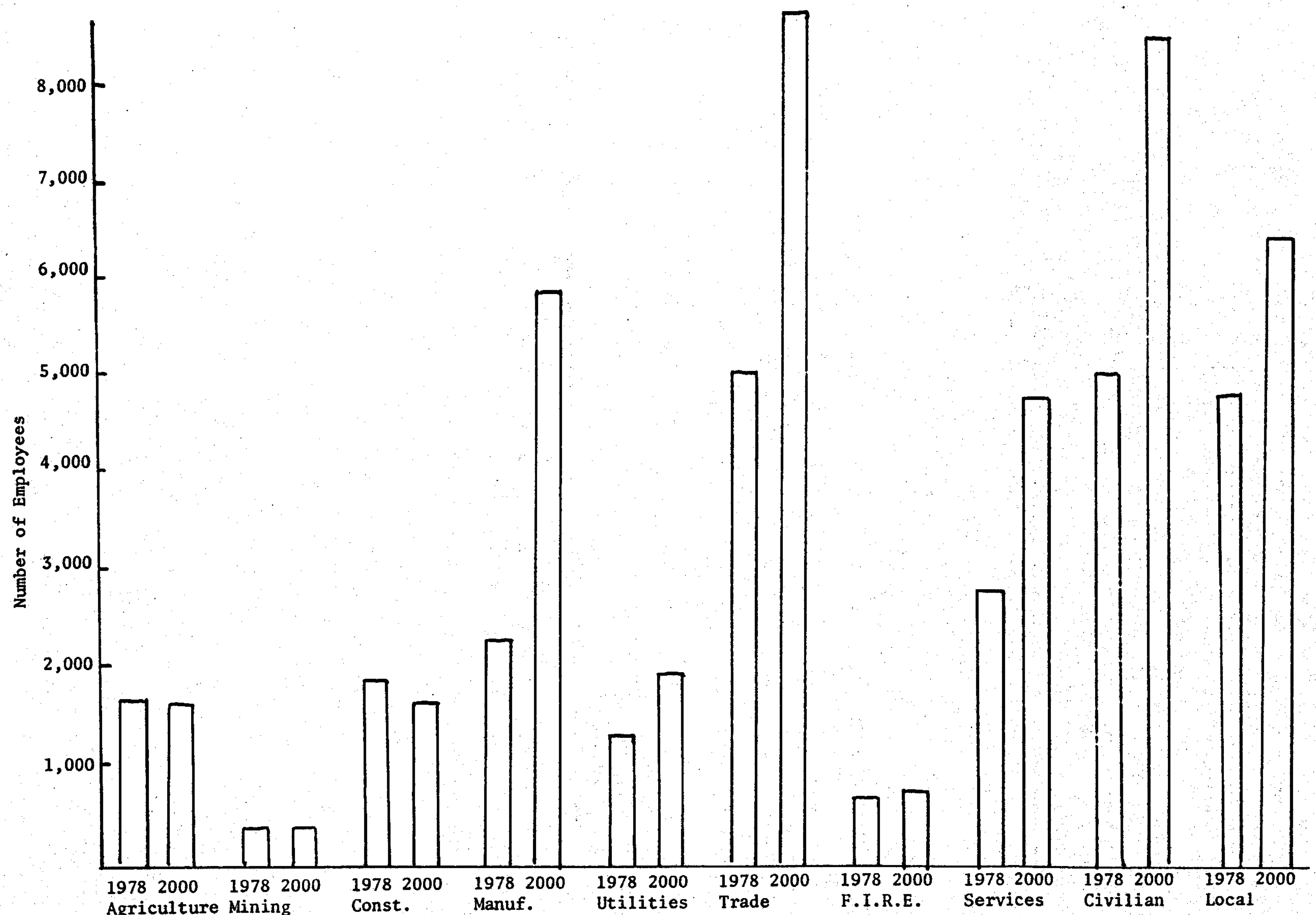


Figure 2-6: Employment Projections for Cochise/Santa Cruz Counties
Source: Department of Economic Security

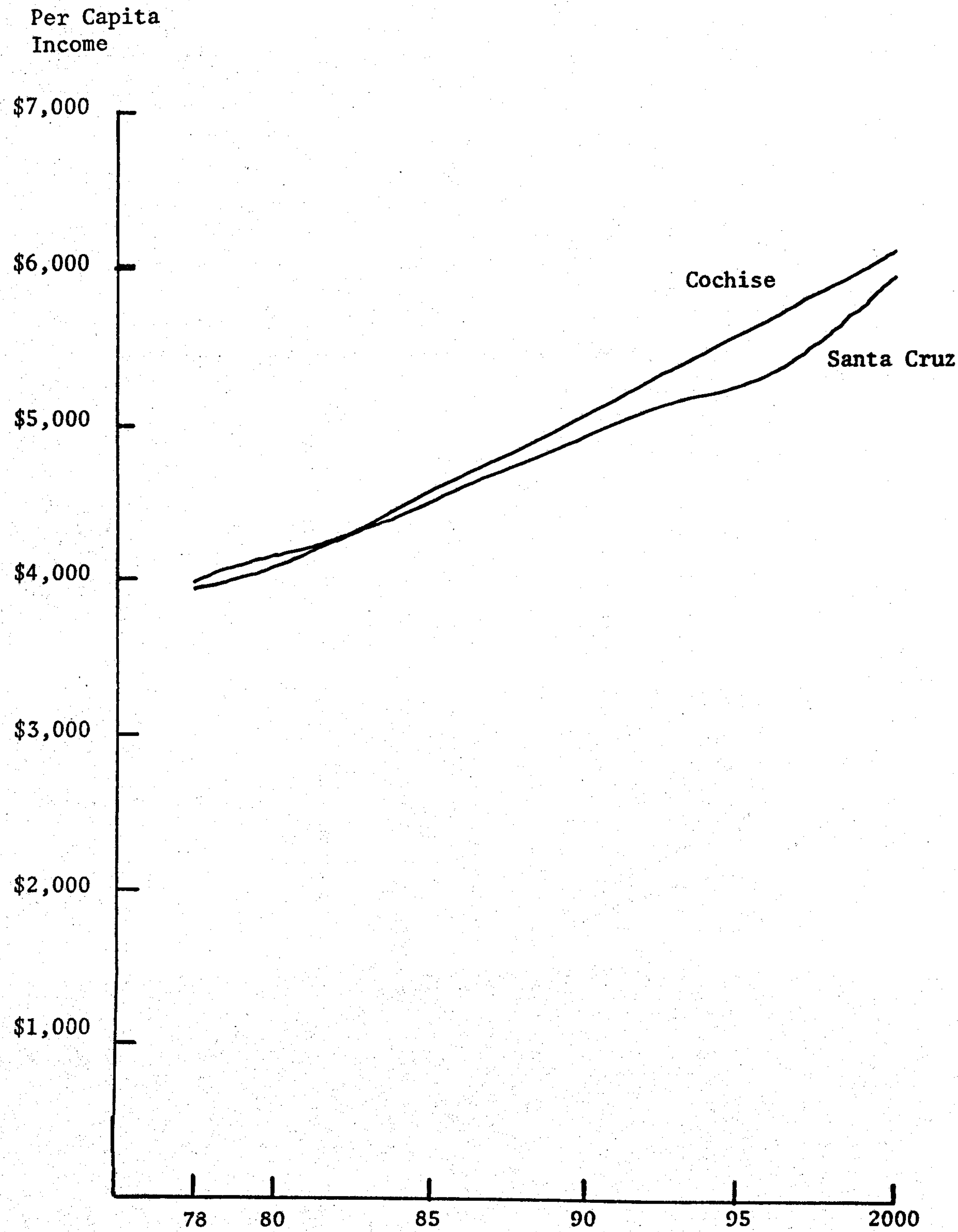


Figure 2-7: Personal Per Capita Increase Projections for Income Cochise/Santa Cruz Counties (1972 dollars)

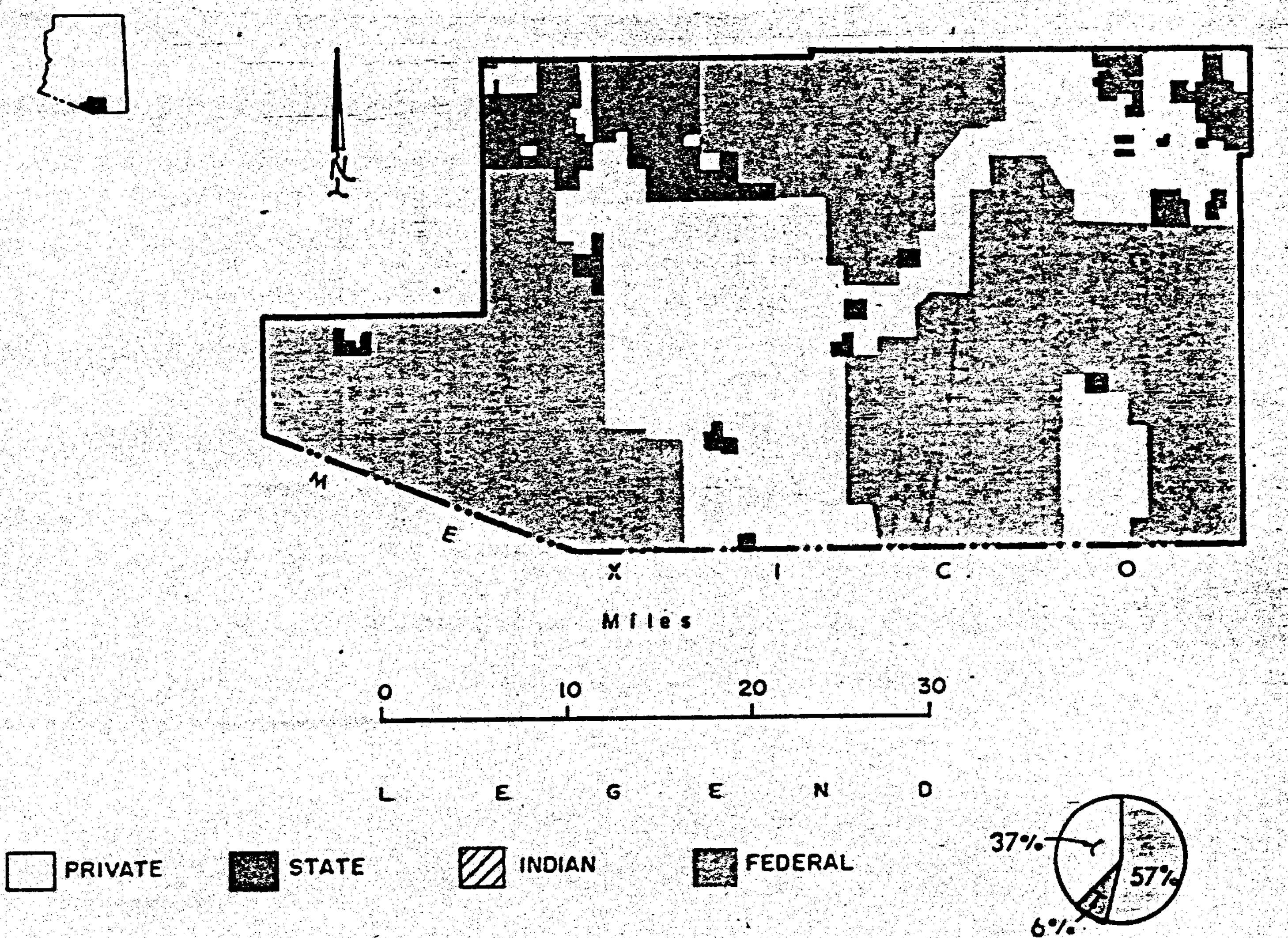


Figure 2-8: Land Ownership Santa Cruz County
Source: Arizona Water Commission (1977)

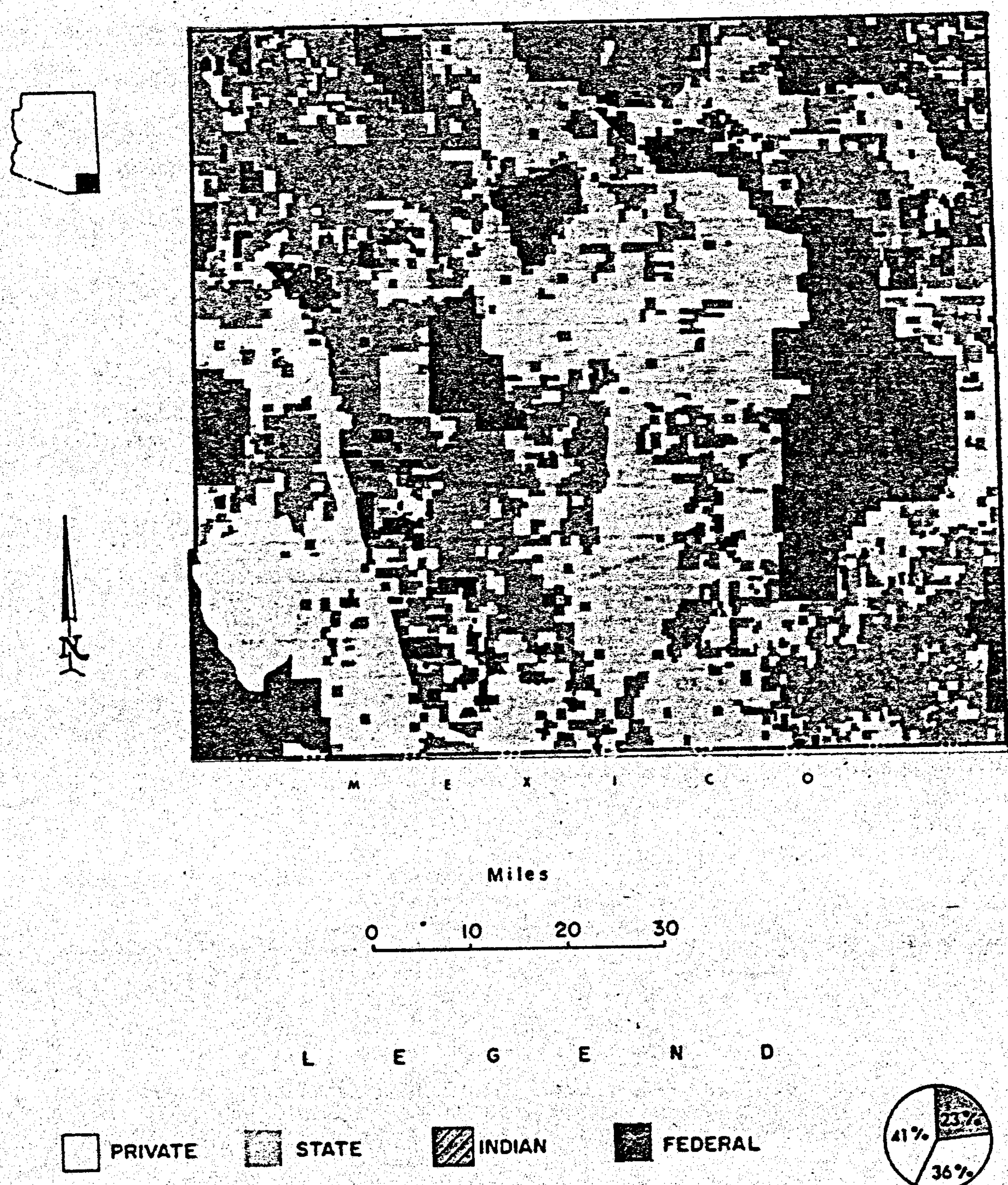


Figure 2-9: Land Ownership Cochise County.
Source: Arizona Water Commission (1977)

Table 2-5: Land Ownership in Cochise/Santa Cruz Counties

	Cochise %	Total Acres	Santa Cruz %	Total Acres
Federal	23	92,092	57	454,290
State	36	1,441,440	6	47,820
Indian	0	--	0	--
Private	41	1,641,640	37	294,890
Total	100	4,004,00	100	797,000

2.2.3 Energy Use

Sulpher Springs Valley Cooperative, Inc., serves electricity to Cochise County. Figure 2-10 shows 1979 monthly sales patterns for four of the largest users in the area.

Residential consumers show a peak demand in the winter months of January and February and low demand for natural gas in May when it is not used for heating purposes. This suggests two major factors: (1) There are more furnaces used in the area than there are evaporative coolers. Furnaces consume a substantial amount more electricity than swamp coolers. (2) Most of the residential dwellings are equipped with electric heaters, as the climate in Cochise County in the winter is relatively cold, heat is needed in the county in the winter.

Large and small commercial users show an increase in demand in July, after which the demand begins to decline. This is due to the use of electrically-generated space cooling in the summer months.

Gas sales for Cochise County are divided between several utility companies. The Town of Benson, Willcox City Government and Arizona Public Service Co. are among those who serve the county. Figure 2-11 presents

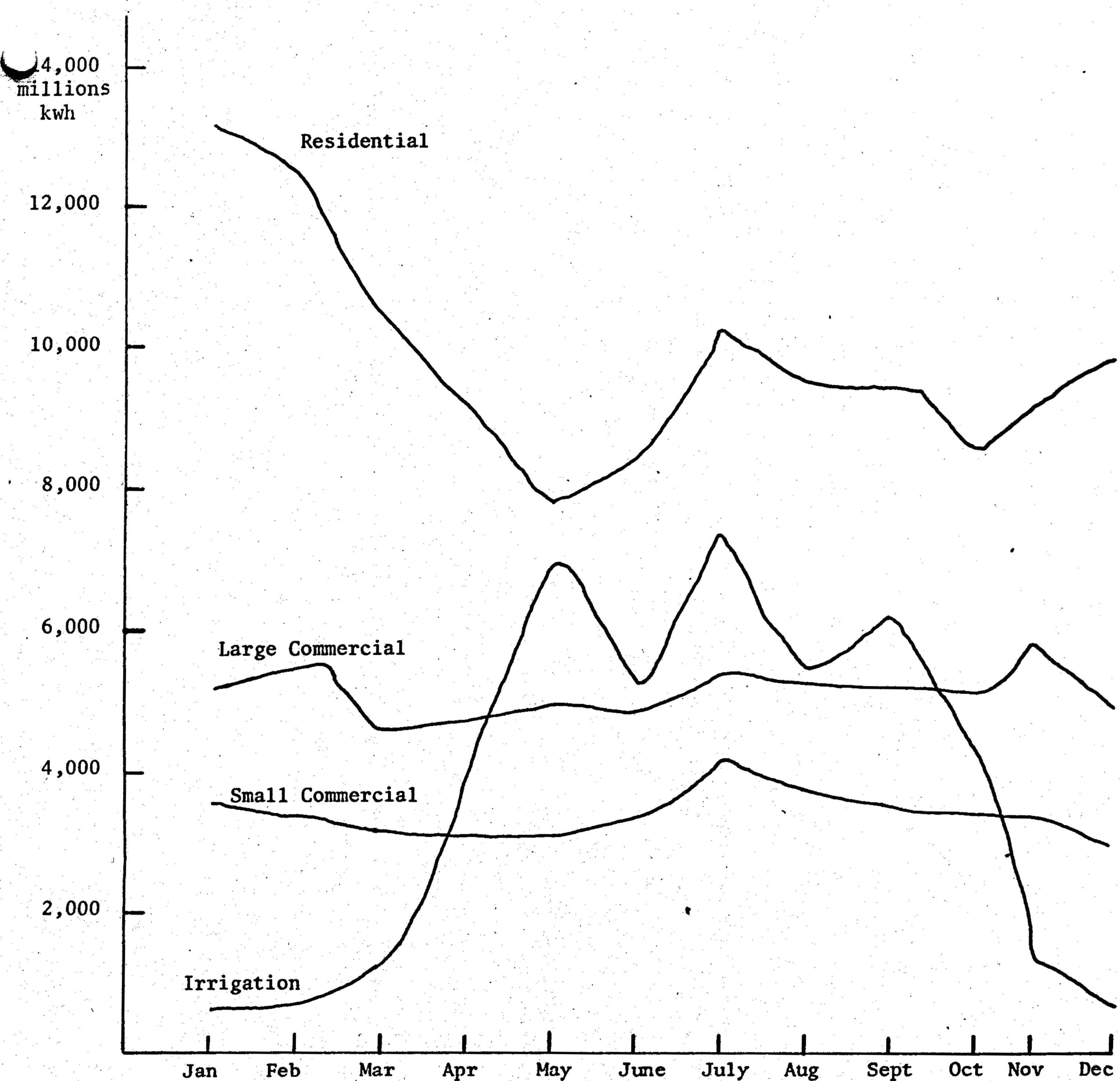


Figure 2-10: 1979 Electricity Sales for Sulpher Springs Valley Coöp., Inc. in Cochise County

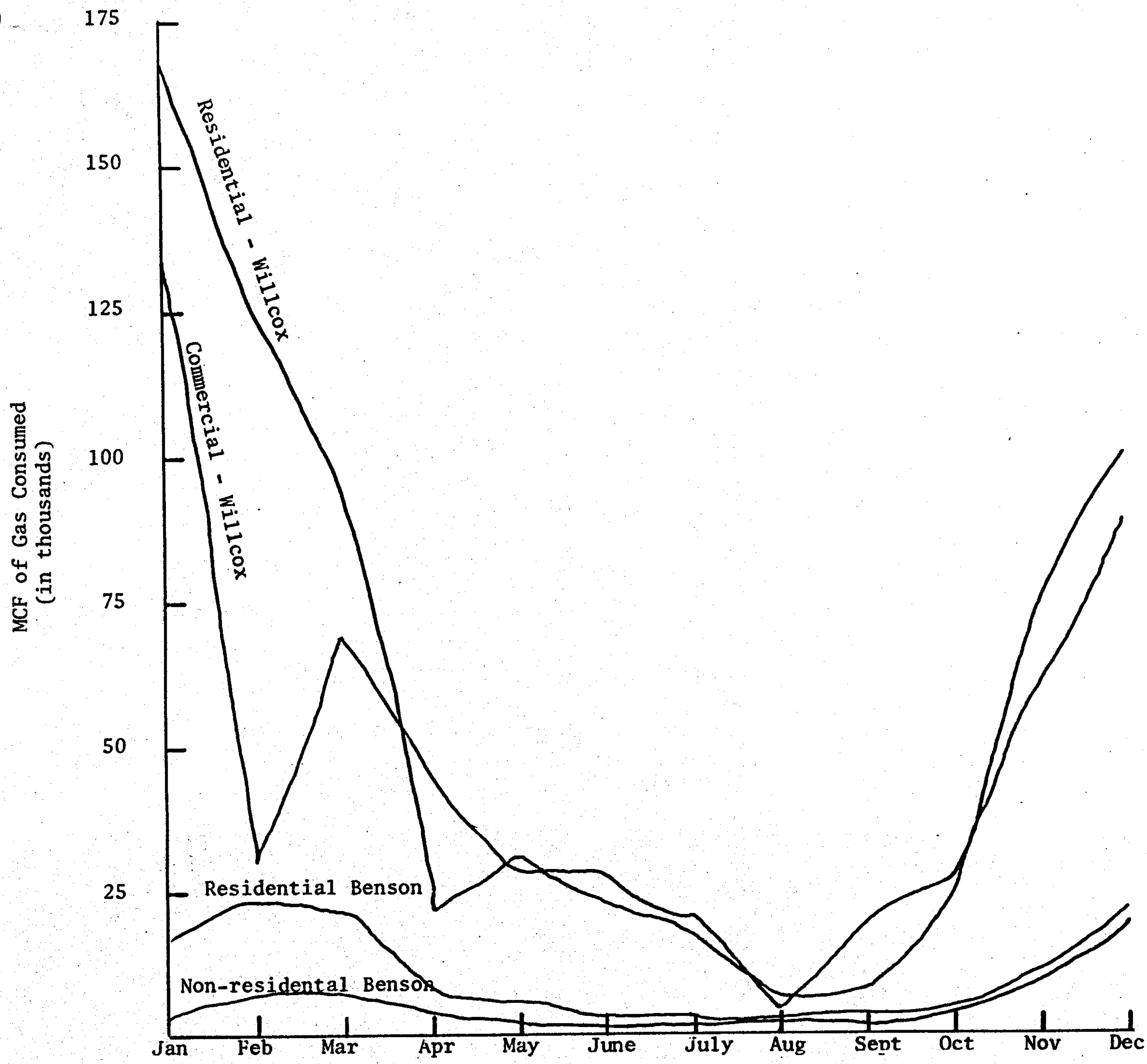


Figure 2-11: Estimated Natural Gas Sales by Month, 1979. For Town of Benson, Willcox City Government, Cochise County

the Town of Benson and Willcox City Government gas sales. Both utility companies show sales at a peak during the winter months, and declining usage during the summer months. Data is not yet available from Arizona Public Service Co.

Natural gas in Cochise County is used year-round to heat hot water for buildings in all of the user classes.

Santa Cruz County electricity consumption is shown in Figure 2-12. This figure presents the consumption pattern shown by Citizens Utility Company in 1979, the only data received to date. The pattern shown is one typical of electricity usage in Arizona; high consumption in the summer months when space cooling is necessary and relatively low consumption in the winter months. It should also be noted that the residential sector is the largest consumer along with the commercial class. The industrial sector in Santa Cruz County is relatively small.

2.2.4 Water

The projected water use in Cochise County, a predominantly agricultural and copper mining county, is substantially large.

The forecasted urban water use in Cochise County is generally small in comparison with total use and the availability of dependable supplies. No problems are foreseen, therefore, in satisfying the urban water needs of this county.

However, the primarly trade-oriented Santa Cruz County shows substantial future urban water use. The high and medium projected urban deficiencies are expected to be in excess of 50 percent of the available dependable supply and projected withdrawals associated with these projections exceed

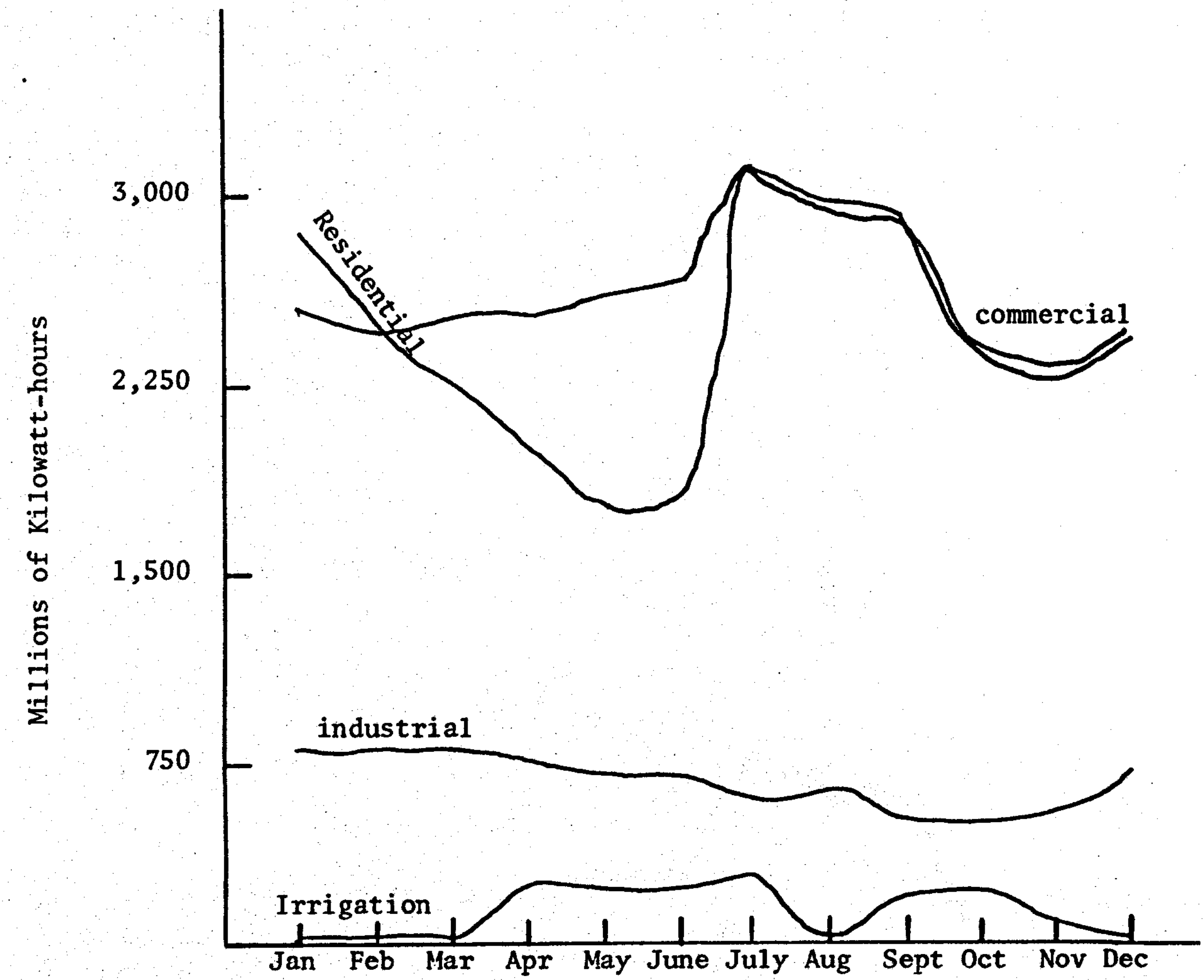


Figure 2-12: 1979 Electricity Sales for Citizens Utilities Co. in Santa Cruz County

dependable supplies. The need for higher quality water for municipalities will create a deficiency in the county as a total return of wastewater to the municipal supply is not possible.

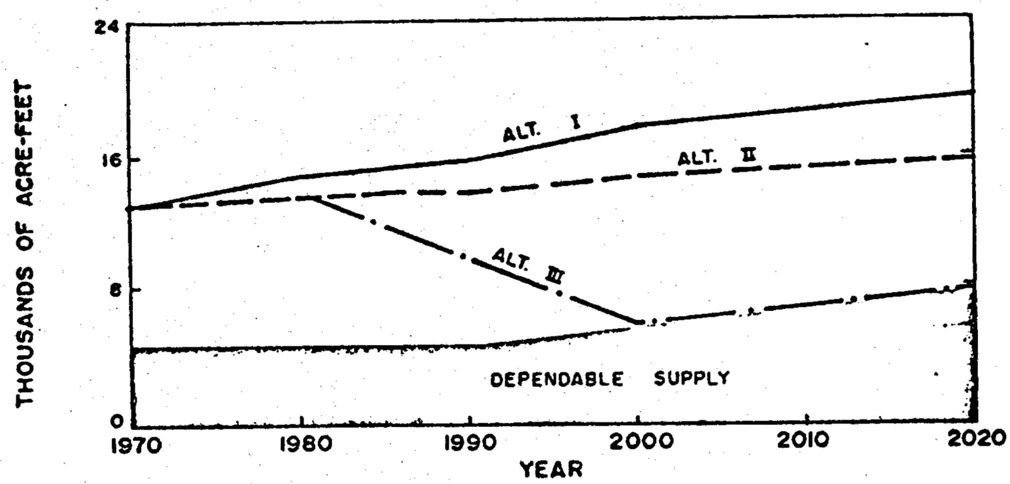
Copper mining is a major contributor to the economy of Cochise County, so a significant increase in water use associated with mining is predicted. Santa Cruz County has no such large user.

The criteria used to develop study projections for agricultural production result in large differences in future agricultural levels in Cochise County. In Santa Cruz County, agricultural production levels and water use remain essentially the same for the high and medium projections and reduce to almost zero for the low projections. There is no projected water use for steam electric power generation in Santa Cruz County. The irrigated acreage forecast for Cochise County in alternative I are large primarily because there is more privately owned land that overlies economically exploitable groundwater than in any other area of the state. In general, both Cochise and Santa Cruz Counties are faced with water supply problems. Most of the dependable water in this area is groundwater recharge. Future projections are shown in Figures 2-13 and 2-14.

2.2.5 Matching of Geothermal Resources to Potential Users

Within both counties only one industry was found which could use 70°C geothermal water for process heat needs. Two large firms fall under the ready mix cement industry in Cochise County. In Santa Cruz County there was no match between industries and process heat requirements of less than 65°C. This could be attributed to the lack of large industry in Santa Cruz County.

PROJECTED ALTERNATIVE WATER DEPLETIONS AND DEPENDABLE SUPPLY

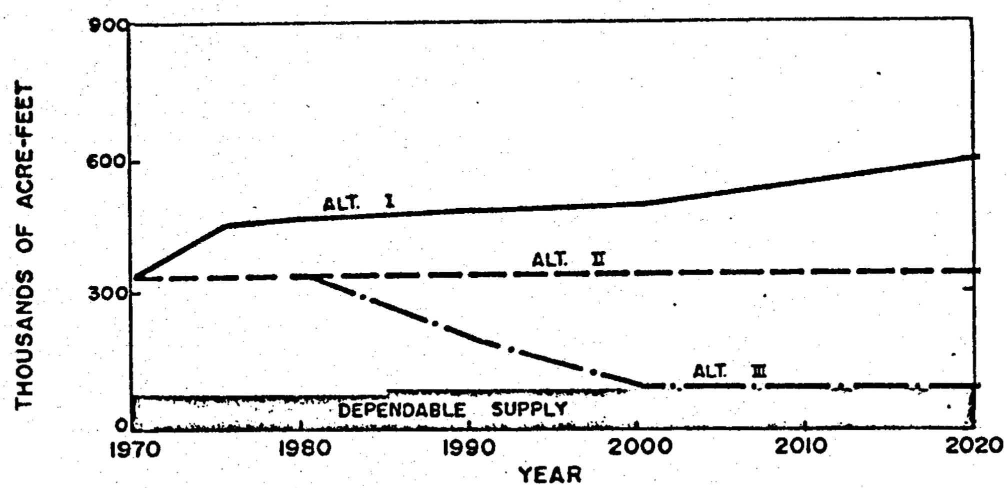


ALTERNATIVE FUTURES SUMMARY

ITEM (Quantities in Thousands)		ALTERNATIVE				FUTURES	
		I		II		III	
	1970	1990	2020	1990	2020	1990	2020
POPULATION	14.0	43.7	86.4	33.3	60.2	33.3	60.2
HARVESTED ACRES	3.0	3.3	3.5	3.0	3.0	2.0	0.5
URBAN DEPLETIONS AF/YR	1.8	3.3	6.3	2.6	4.4	2.6	4.4
STEAM ELECTRIC DEPLETIONS AF/YR	0	0	0	0	0	0	0
MINERAL DEPLETIONS AF/YR	0	1.0	2.0	1.0	2.0	1.0	2.0
AGRICULTURAL DEPL. AF/YR	11.0	11.7	11.4	10.6	9.8	7.0	1.6
TOTAL WATER DEPL. AF/YR	13	16	20	14	16	11	8
DEPENDABLE WATER AF/YR	5	5	8	5	8	5	8
SURPLUS SUPPLY (Def.)	(8)	(11)	(12)	(9)	(8)	(6)	0

Figure 2-13: Projected Future Water Availability and Use.
Santa Cruz County
Source: Arizona Water Commission (1977)

PROJECTED ALTERNATIVE WATER DEPLETIONS AND DEPENDABLE SUPPLY



ALTERNATIVE FUTURES SUMMARY

ITEM (Quantities in Thousands)	1970	ALTERNATIVE I 1990	I 2020	II 1990	II 2020	FUTURES III 1990	III 2020
POPULATION	61.9	121.0	212.0	121.0	194.0	121.0	194.0
HARVESTED ACRES	118.0	172.0	213.0	118.0	118.0	88.0	7.2
URBAN DEPLETIONS AF/YR	8.9	13.6	22.0	13.6	20.2	13.6	20.2
STEAM ELECTRIC DEPLETIONS AF/YR	1.1	5.1	33.2	4.4	16.8	4.4	16.8
MINERAL DEPLETIONS AF/YR	8.0	25.0	55.0	14.0	43.0	14.0	43.0
AGRICULTURAL DEPL. AF/YR	335.0	455.0	506.0	313.0	280.0	180.0	17.0
TOTAL WATER DEPL. AF/YR	353	499	616	345	360	212	97
DEPENDABLE WATER AF/YR	85	97	97	97	97	97	97
SURPLUS SUPPLY (Def.)	(268)	(402)	(519)	(248)	(263)	(115)	0

Figure 2-14: Projected Future Water Availability and Use. Cochise County
Source: Arizona Water Commission (1977)

From work performed in conjunction with the New Mexico Energy Institute, Figures 2-15 and 2-16 model geothermal energy on line as a function of time over the next forty years. Figure 2-15 presents energy on line assuming a city-owned utility developed the potential resource. As has been shown in other counties, development by city-owned utility occurs faster than under private development. The difference between the two cases is attributed to differing costs of capital. One underlying assumption should be noted. It is assumed for modeling purposes that geothermal energy comes on line when the price of other energy alteratives rise above a computed cost per MMBTU for geothermal energy. In other words, it is assumed that industry will use the lowest cost energy which is available.

Results from Figures 2-15 and 2-16 summarize as follows. Under private development, geothermal energy would come on line in 1984 and climb rapidly until 2005. Similarly, under a city-owned utility, geothermal energy would come on line by 1984 and climb rapidly until 2006. Thus, city development occurs comparatively faster than private development. Table 2-6 reports the results of the modeling in summary form in terms of barrels of oil.

Table 2-6: Barrels of Oil Replaced by Geothermal Energy per Year. Process Heat Market
Cochise and Santa Cruz Counties

	1985	1990	2000	2020
Private Developer	1,216,071	2,696,428	3,250,000	3,785,714
City Utility	2,553,571	2,839,286	3,303,571	3,803,571

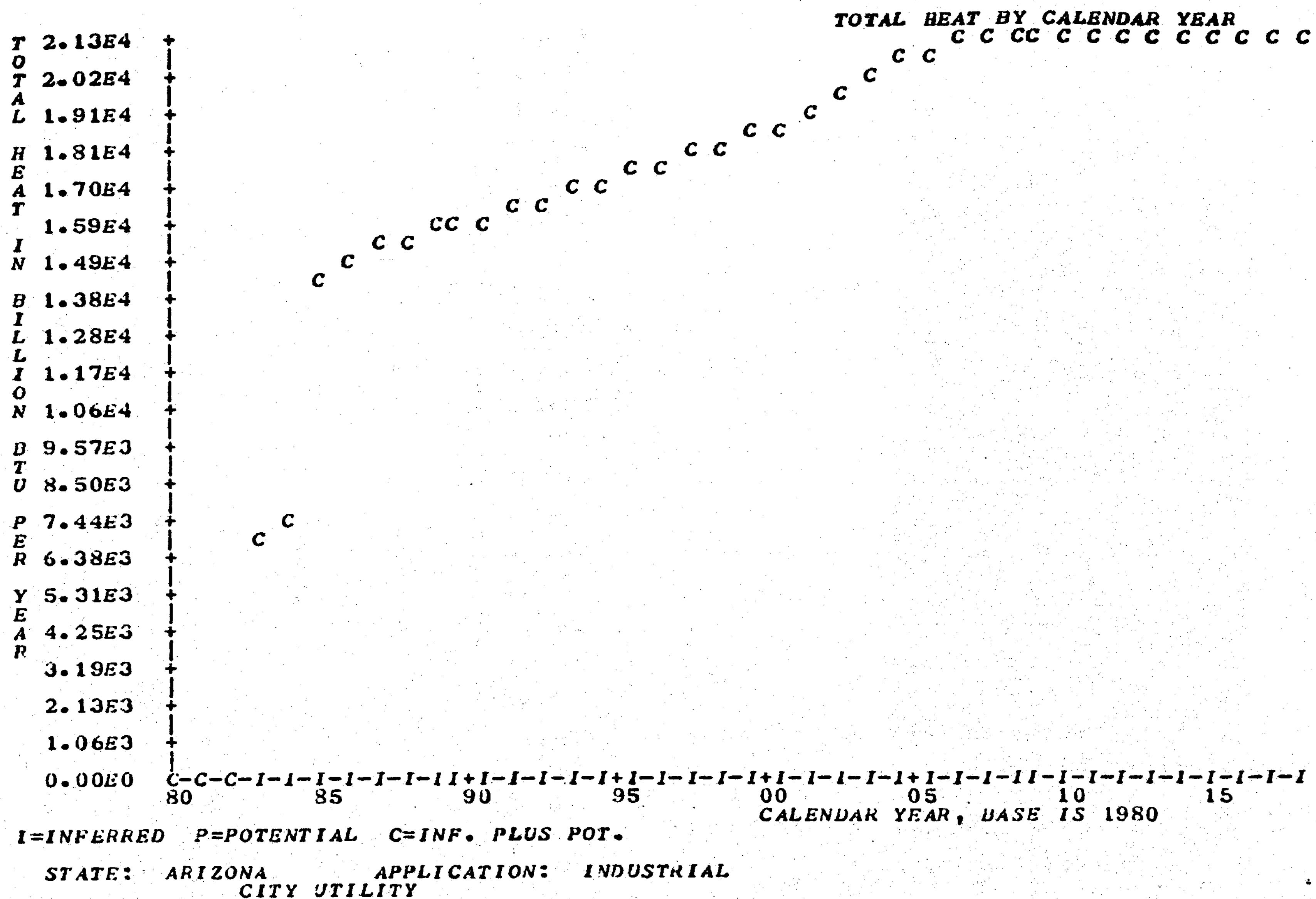


Figure 2-15: Projected Industrial Geothermal Heat On Line Under City Development. Cochise and Santa Cruz Counties.

Source: New Mexico Energy Institute

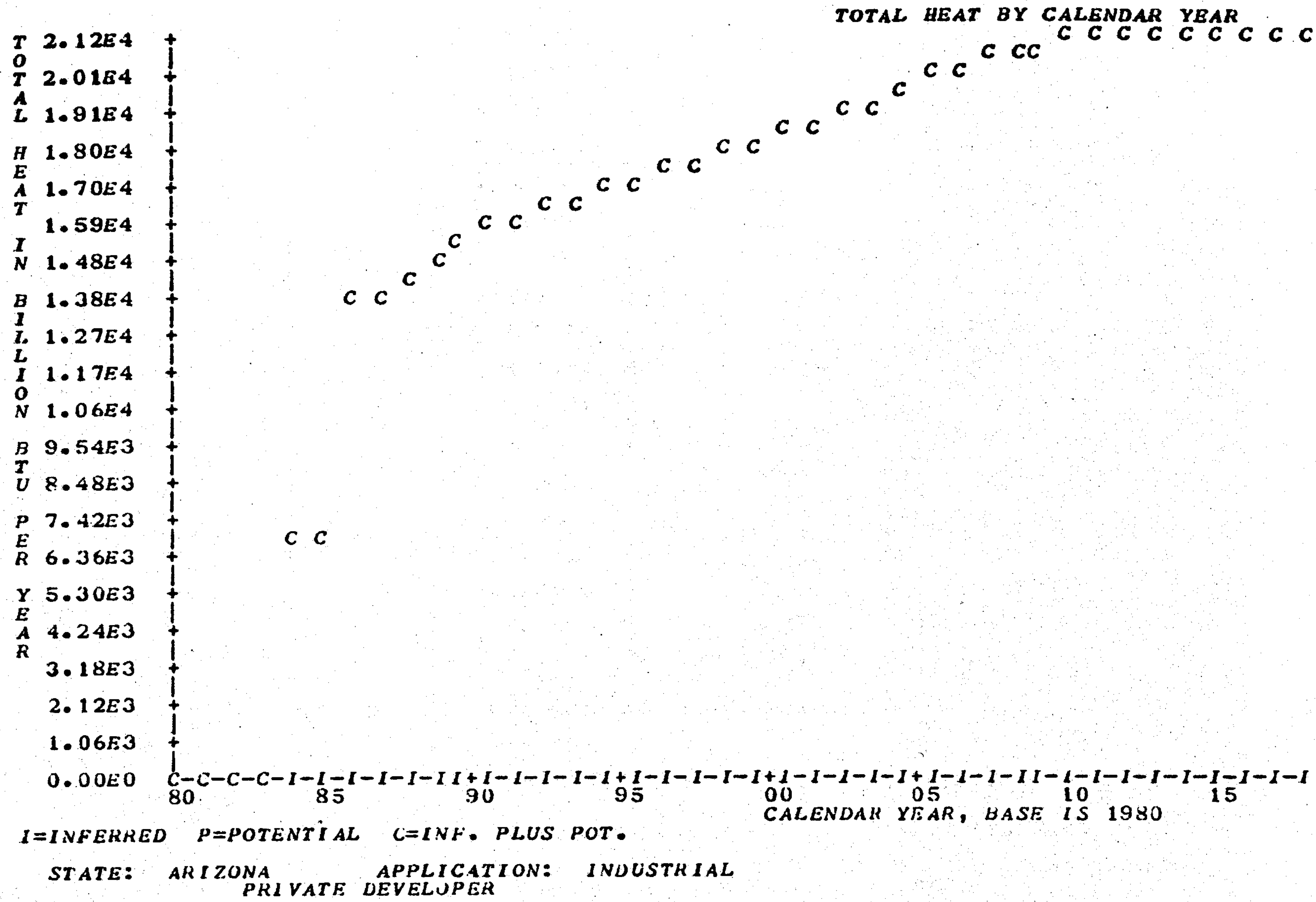


Figure 2-16: Projected Industrial Geothermal Heat On Line Under Private Development.
Cochise and Santa Cruz Counties.
Source: New Mexico Energy Institute

Similar modeling was performed for the residential and commercial space heating markets; however, it is believed that space heating, without a capability for space cooling, is not economically justifiable. Future work will include both space heating and cooling.

Agribusiness and agricultural industry in particular were identified in Cochise County and agriculture remains the base of local economic activity. Most agricultural processing is concentrated in corn and sorghum; however, livestock is also important to the Cochise County economy. Currently many of the agricultural products are exported to California for processing. Identifying a low-cost energy source that would be available and suitable for agricultural and livestock processing could stimulate a local industry.

The economy of Santa Cruz County is based on tourism and international trade, and there is a lack of industry. Thus, no match between industries and process heat requirements of less than the assessed reservoir temperature of 65°C were found. The potential for the use of geothermal energy in Santa Cruz County is being investigated.

2.3 Northern Counties

2.3.1 Economy

The 1979 estimated population for the Northern Arizona Counties was 351,000 people. These counties include: Apache, Coconino, Gila, Mohave, Navajo and Yavapai. The total land area of the counties is 65,709 square miles which results in a population density of 5.3 persons per square mile. The ethnic breakdowns of the population is 55% white, 28% Indian, 11% Hispanic and 1% Black.

Since 1970 the northern counties have experienced an annual population growth rate of 5.8%. Table 2-7 shows the annual population growth for each of the counties from 1970 to 1978.

Table 2-7: Annual Population Growth for the Northern Counties 1970-1978

Cities	Annual Growth Rate
Mohave	9.8%
Yavapai	7.7%
Apache	6.5%
Coconino	4.1%
Navajo	4.0%
Gila	2.5%

The source of this growth for these years is principally attributed to net migration. These figures are tabulated in Table 2-8.

Table 2-8: Sources of Population Growth for the Northern Arizona Counties 1970-1978

Counties	National Increase	Net Migration
Apache	28%	24%
Coconino	16%	17%
Mohave	5%	73%
Navajo	17%	15%
Yavapai	0%	62%

Figures for Gila County are not available.

Population projections for the combined counties are indicated in Figures 2-17 showing a steady growth for the next forty years.

The largest city in Northern Arizona is Flagstaff. This city is rapidly becoming the manufacturing center for Northern Arizona due in part to the excellent transportation facilities.

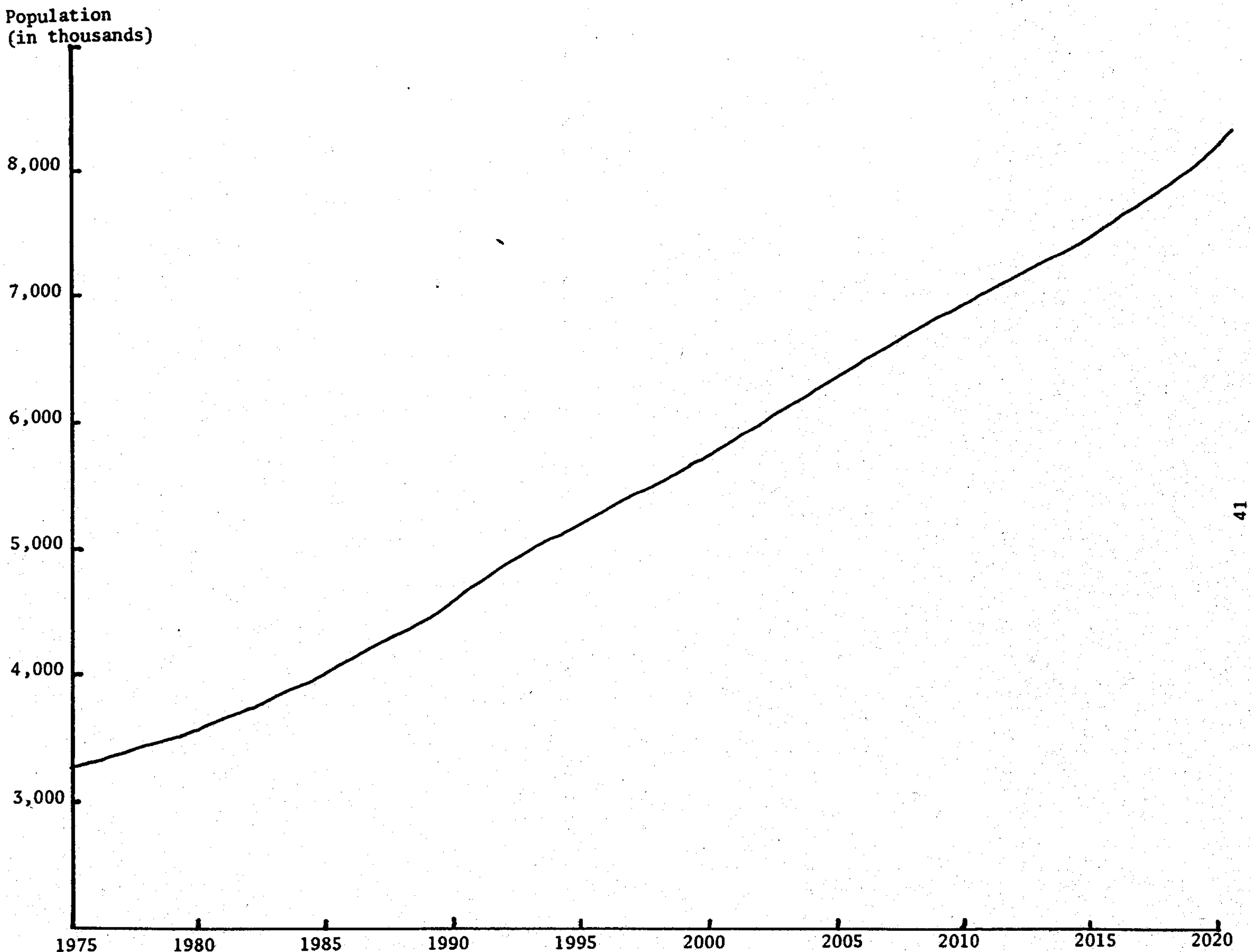


Figure 2-17: Population Projection for Northern Arizona Counties to 2020
Source: Technical Advisory Committee (DES)

Presently, manufacturing is the primary employment sector in the northern counties, but as shown in Figures 2-18 and 2-19 it is projected that the service sector will account for a large percentage of total employment in 2000. The service sector is expected to grow at 4 percent per year for the next twenty years along with light industry growth, in particular, in the area of retail sales.

The Department of Economic Security estimates that total employment in the northern counties will rise 1.8 percent per year to 2000.

In addition, several other economic indicators show positive growth in Northern Arizona. Figure 2-20 presents projections of personal per capita income for the northern counties to 2,000. Annual growth rates are shown in Table 2-9.

Table 2-9: Annual Personal Per Capita Income Growth to 2000

County	% Annual Per Capita Income Growth
Apache	1.4
Coconino	1.7
Gila	2.0
Mohave	1.7
Navajo	1.3
Yavapai	1.8

These income figures represent a slower rate of growth than is common in the more populous counties of Pima and Maricopa. Also, the types of employment found in these two counties tend to have a lower wage scale than the more industrialized counties.

Between 1968 and 1978 the value of retail sales steadily increased in both counties. Table 2-10 indicates the percentage increase in retail

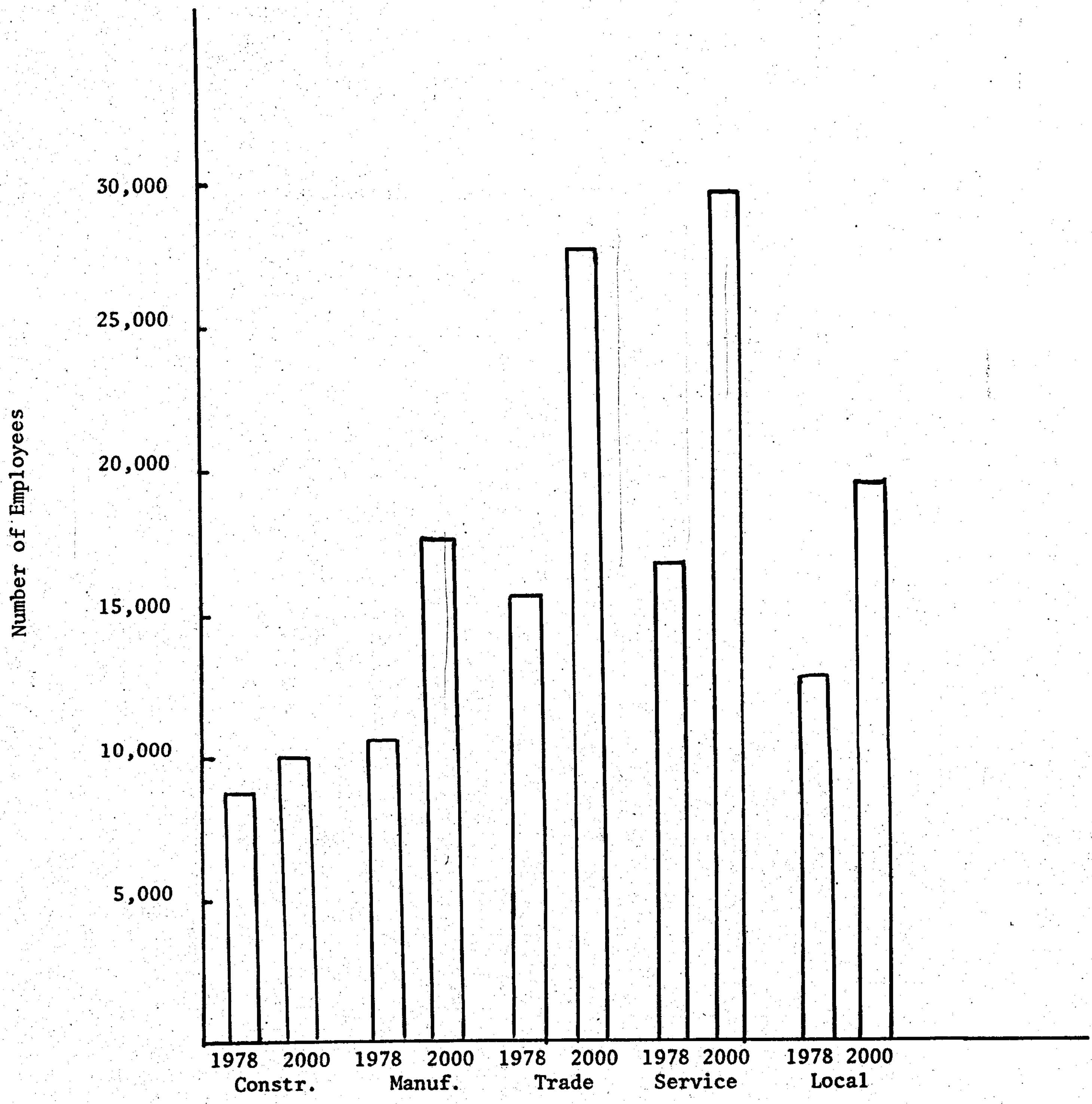


Figure 2-18: Major Employment Sector Projections in the Northern Counties
Source: Department of Economic Security

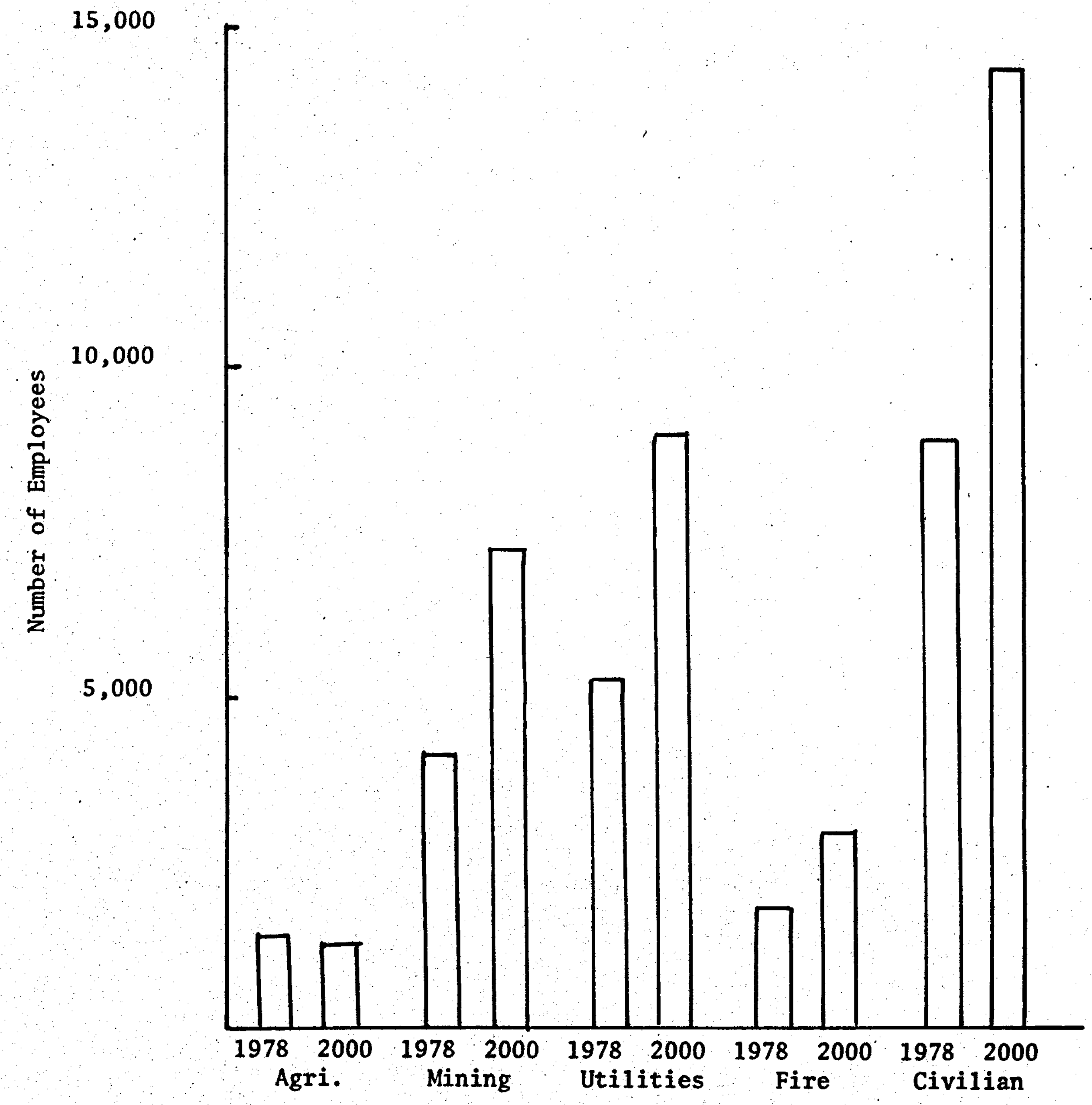


Figure 2-19: Other Employment Sectors Projections in the Northern Counties
Source: Department of Economic Security

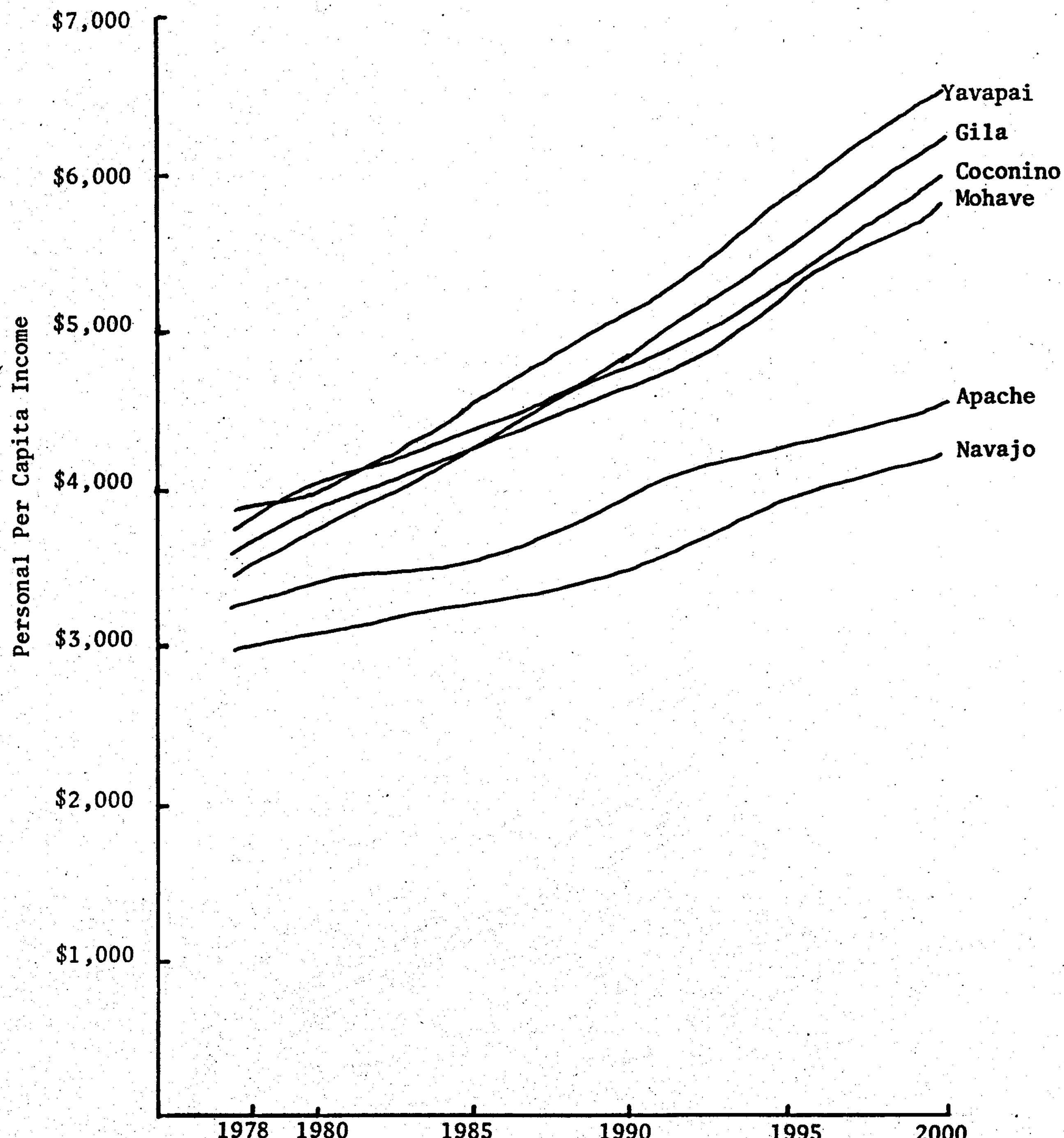


Figure: 2-20: Personal Per Capita Income Projections for the Northern Counties (1972 Dollars).
Source: Department of Economic Security

sales and bank deposits over the ten year period.

Table 2-10: Retail Sales in the Northern Counties

Counties	% Increase in Retail Sales 1968 - 1978	% Increase in Bank Deposits 1968 - 1978
Apache	242.1	231.5
Coconino	231.4	239.3
Gila	195.7	152.1
Mohave	363.4	413.0
Navajo	360.1	270.9
Yavapai	300.2	212.2

In summary, Northern Arizona counties have historically been slower growth counties in Arizona. However, this trend is changing as Northern Arizona encourages light industry in an attempt to diversify its economy away from a principally rural base. The abundance of warm springs and wells is still under investigation. However, the sparse population and lack of industrial base has resulted in few potential developers of geothermal energy.

2.3.2 Land Ownership

Figures 2-21, 2-22, 2-23, 2-24, 2-25, and 2-26 show general land ownership maps for Apache, Coconino, Gila, Mohave, Navajo and Yavapai Counties. Table 2-11 gives acreage breakdowns for each ownership class.

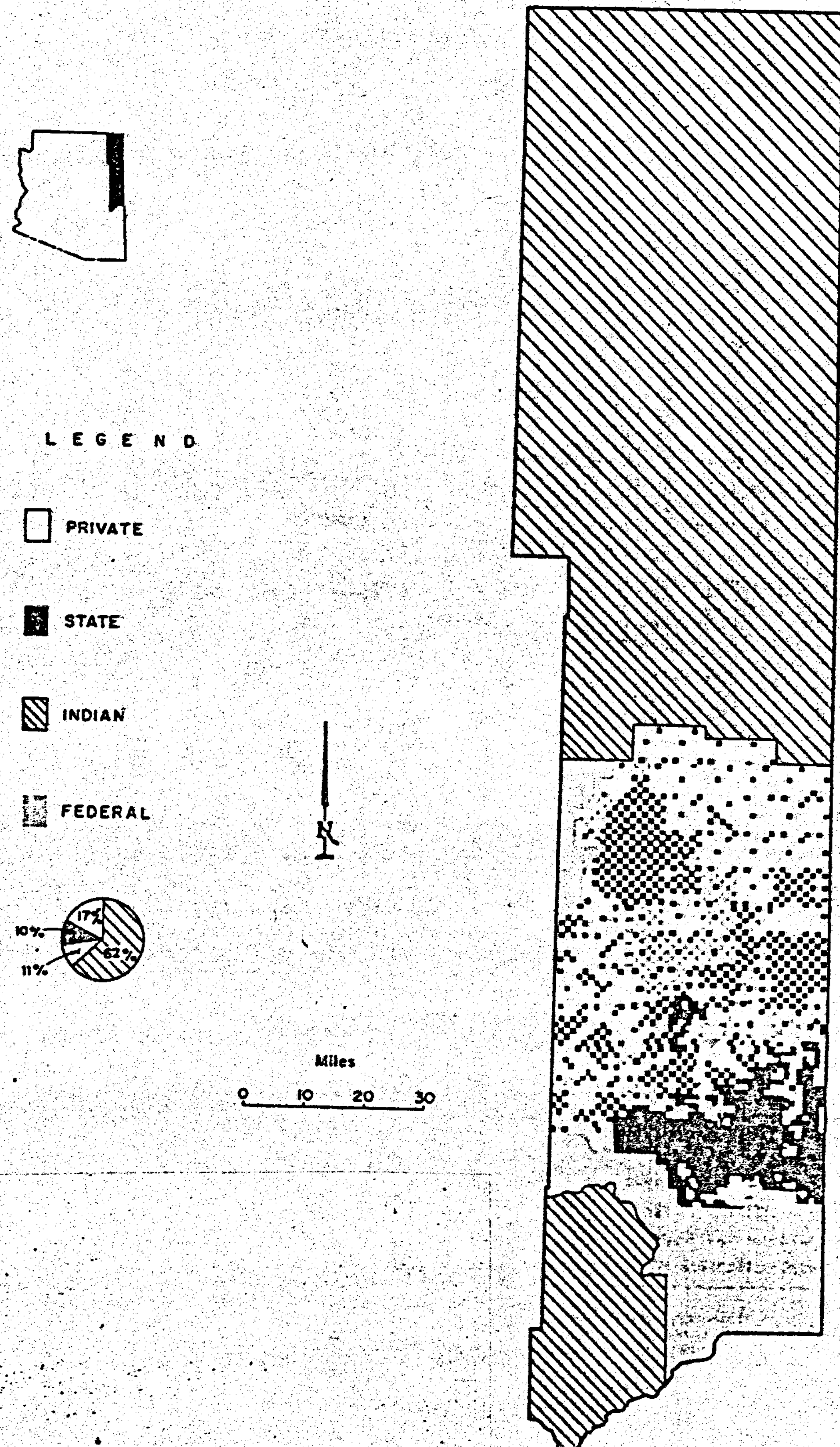


Figure 2-21: Land Ownership - Apache County.
Source: Arizona Water Commission (1977)

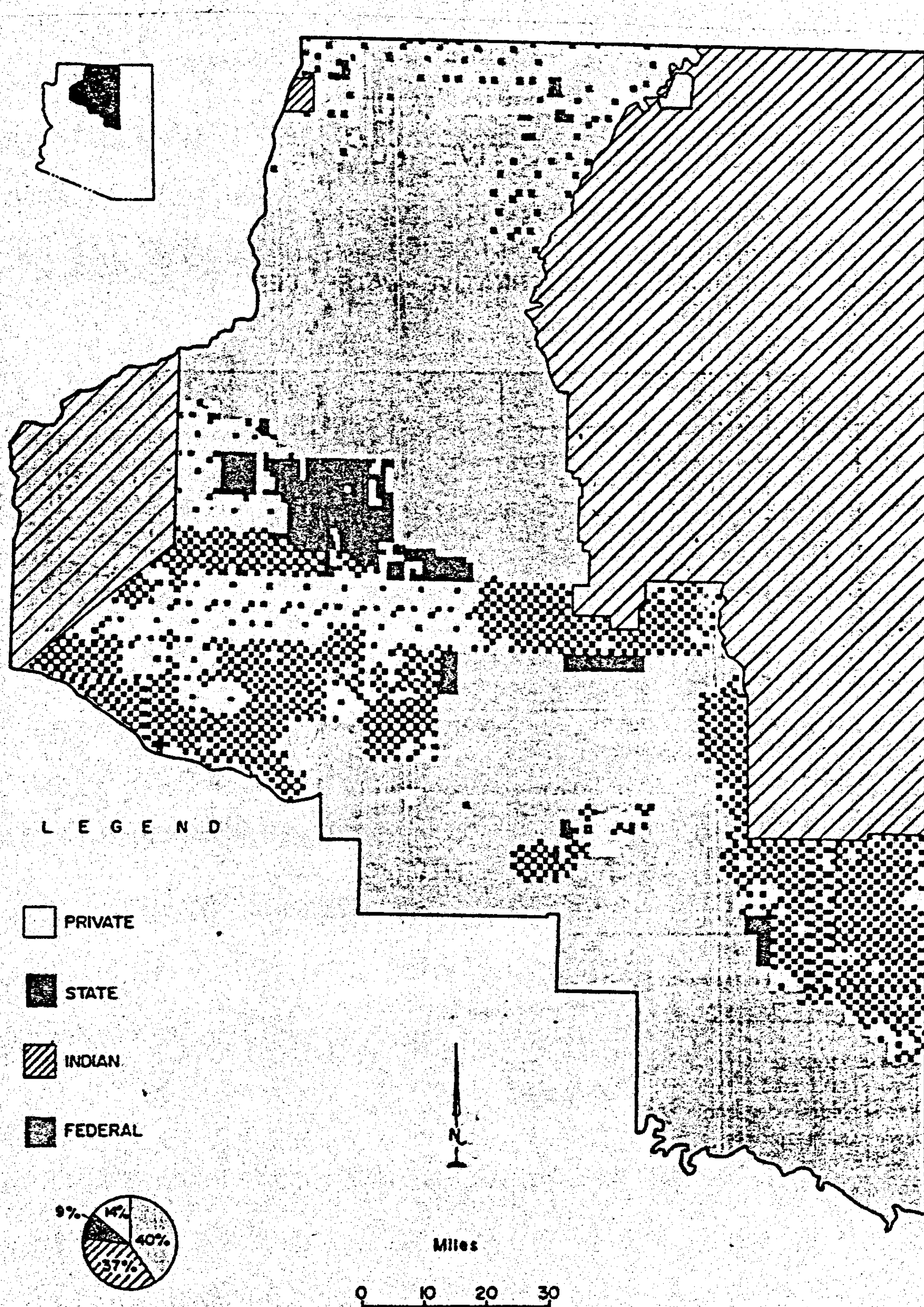


Figure 2-22: Land Ownership - Coconino County
Source: Arizona Water Commission (1977)

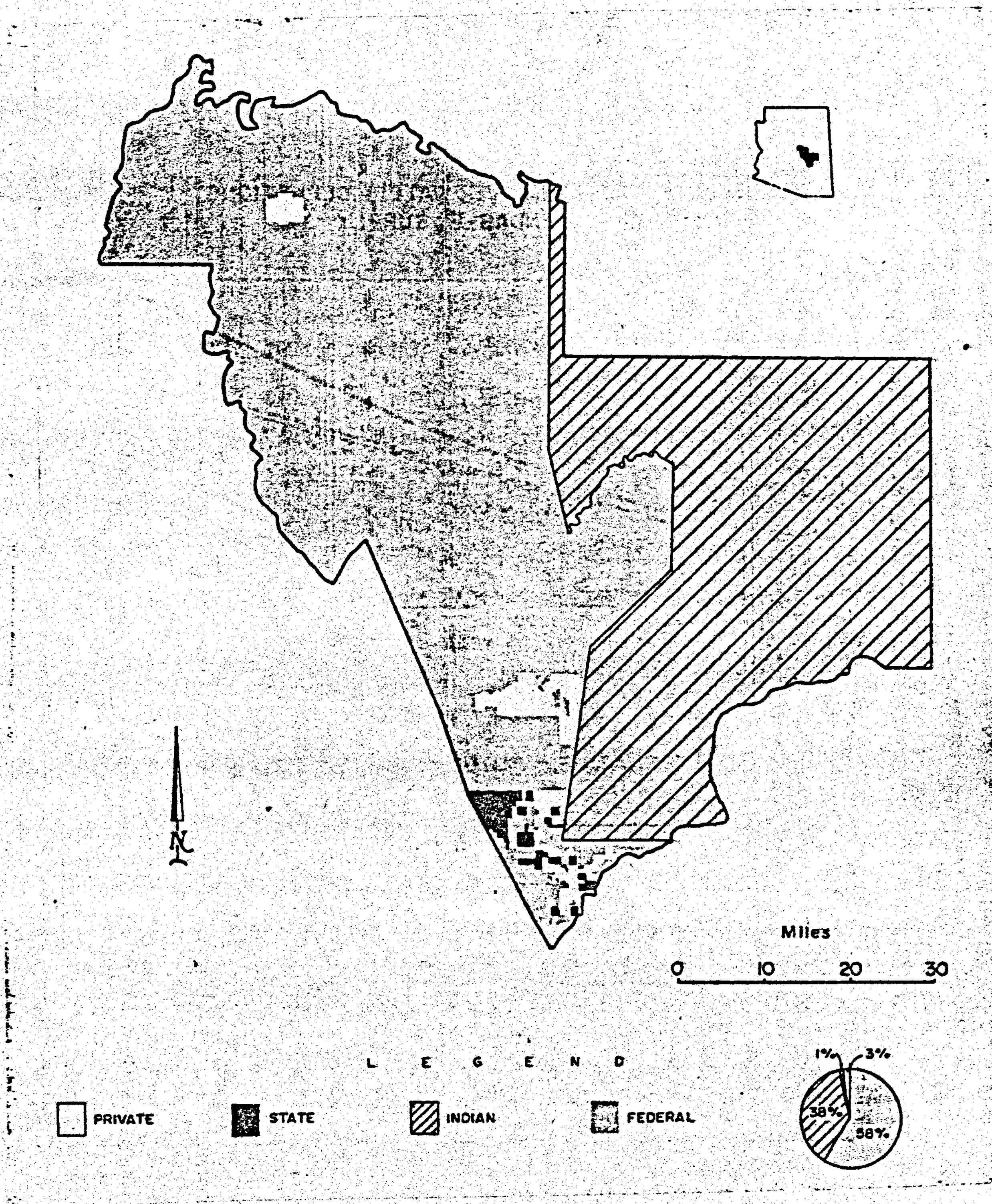


Figure 2-23: Land Ownership - Gila County
Source: Arizona Water Commission (1977)

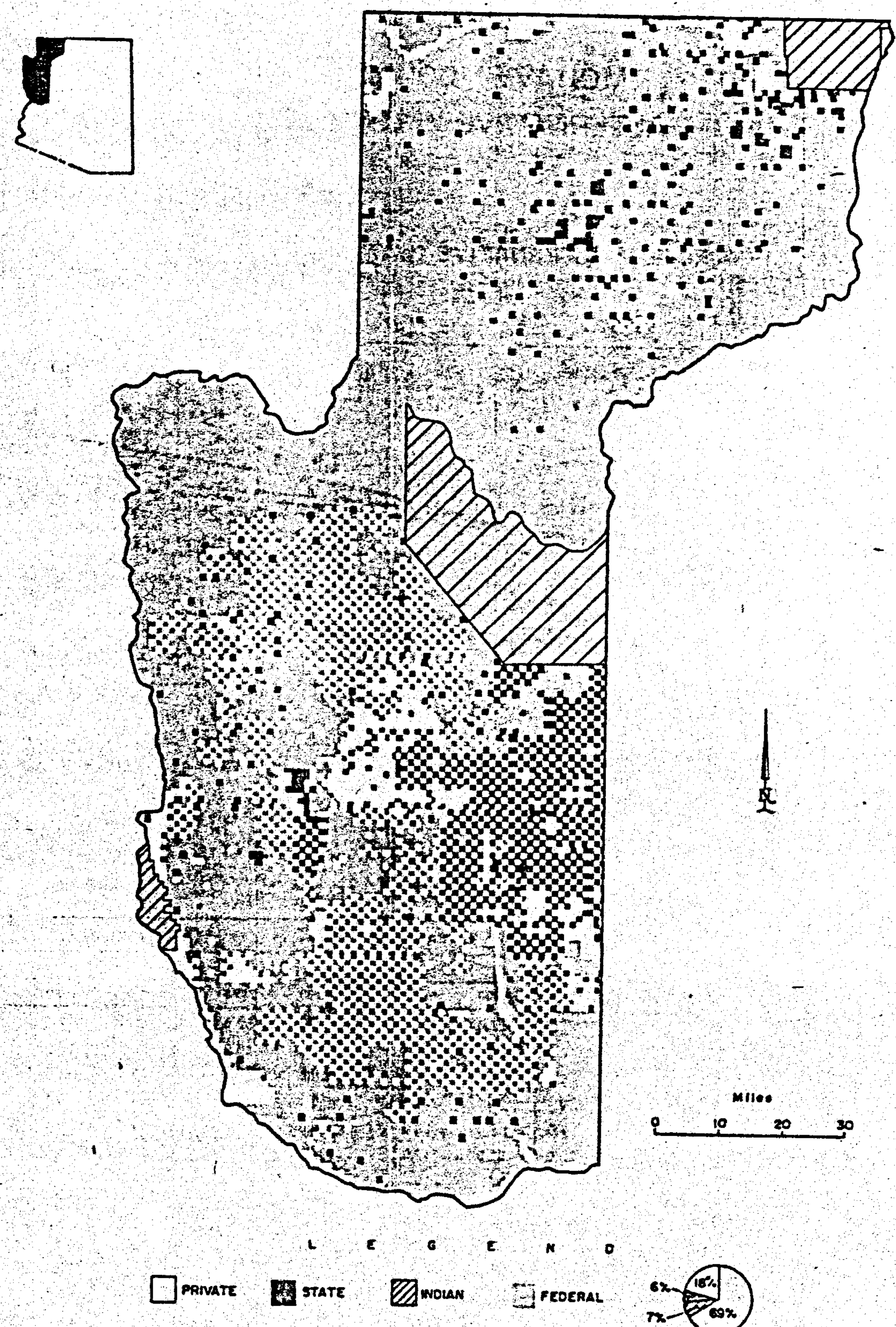


Figure 2-24: Land Ownership - Mohave County
Source: Arizona Water Commission (1977)

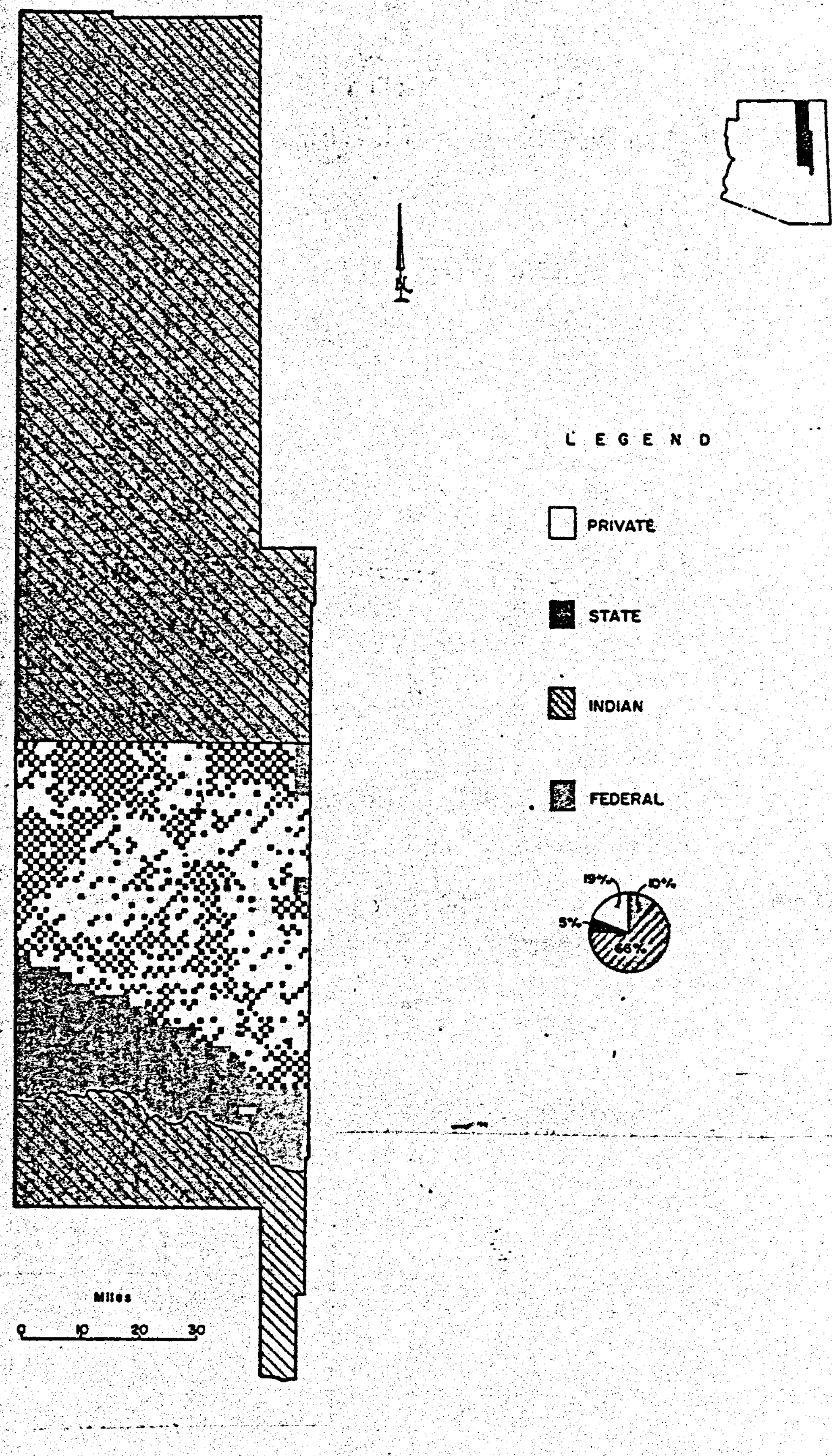


Figure 2-25: Land Ownership - Navajo County
Source: Arizona Water Commission (1977)

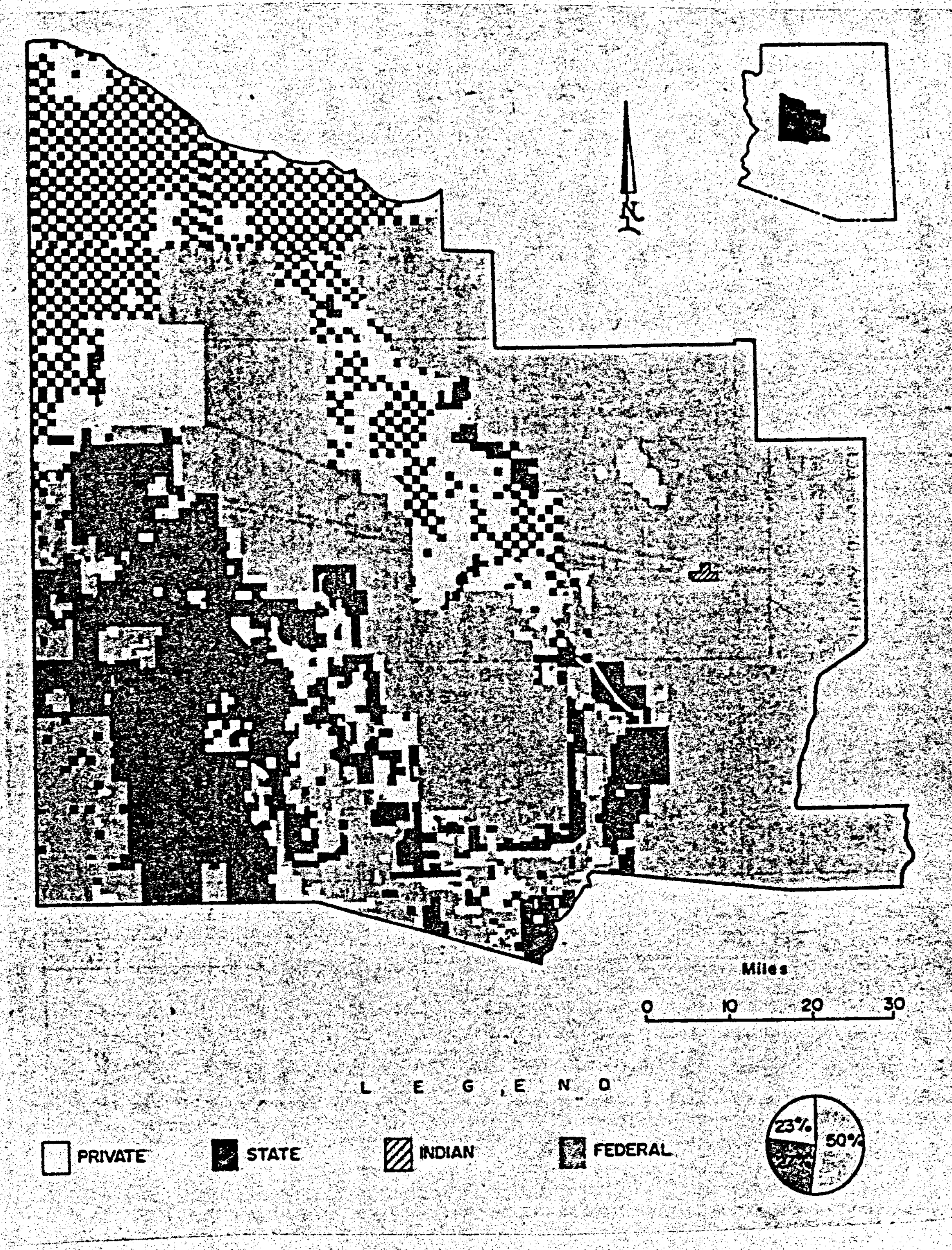


Figure 2-26: Land Ownership - Yavapai County
Source: Arizona Water Commission (1977)

Table 2-11: Land Ownership in Apache, Coconino, Gila, Mohave, Navajo, and Yavapai Counties

	Apache %	Total Acres	Coconino %	Total Acres
Federal	11	786,610	40	4,754,800
State	10	715,100	9	1,069,830
Indian	62	4,443,620	37	4,398,190
Private	17	1,215,670	14	1,664,180
Total	100	7,151,000	100	11,887,000
	Gila %	**Total Acres**	**Mohave %**	**Total Acres**
Federal	58	1,763,200	69	5,855,340
State	1	30,400	6	509,160
Indian	38	1,155,200	7	594,020
Private	3	91,200	18	1,527,480
Total	100	3,040,000	100	8,486,000
	Navajo %	**Total Acres**	**Yavapai %**	**Total Acres**
Federal	10	634,300	50	2,589,500
State	5	317,150	27	1,398,330
Indian	66	4,186,380	0	--
Private	19	1,205,170	23	1,191,170
Total	100	6,343,000	100	5,179,000

2.3.3 Energy Use

The largest utility company serving Northern Arizona is Arizona Public Service Company, which provides electricity to the area. Southern Union Gas serves Prescott, Kingman and Flagstaff; Navapache Electric Corporation serves both Navajo and Apache County; and Mohave Electric Cooperative, Inc. provides electricity to Mohave County. These and several small utility companies have been contacted, requesting data on monthly sales for 1979. The information received to date is from Southern Union Gas Company for the three largest cities in Northern Arizona.

Natural gas sales for the four user classes, presented in Figures 2-27, 2-28, 2-29, show peak demand in the winter months. Residential users are clearly the largest consumers in the winter months due to the use of natural gas for heating. In the summer months, demand decreases as people turn to electricity-generated cooling units to cool their homes, causing a decline in natural gas consumption to a low in August. This general pattern is consistent for all three cities with one exception. The industrial class of Kingman and Yavapai County consists primarily of the copper mine northwest of Kingman. Natural gas consumption at the mine increases in the summer months as the mine uses its own resources combined with natural gas to generate power.

For comparison purposes, Table 2-12 shows the average natural gas consumption per user for 1979 for the northern counties versus the southern counties. The figures show a substantial difference between the use of natural gas in the north versus the south. The disparity can be attributed to the climatic differences. The northern counties experience cold winters whereas winters in the southern part of the state are mild. This would account for the higher natural gas consumption in the northern areas for heating purposes.

Table 2-12: Comparison of Average Consumption of Natural Gas by User Class for 1979 Per Facility. (MCF)

Northern Counties

	Residential	Commercial	Industrial
Flagstaff	134.0 MCF	758.26	42416.7
Kingman	52.0 MCF	407.45	87557.25
Prescott	106.34 MCF	442.25	17555.0

Southern Counties

	Residental	Commercial	Industrial
Southern Counties	62.9	467.7	13786.8

Source: Southern Union Gas Corporation
Southwest Gas Corporation

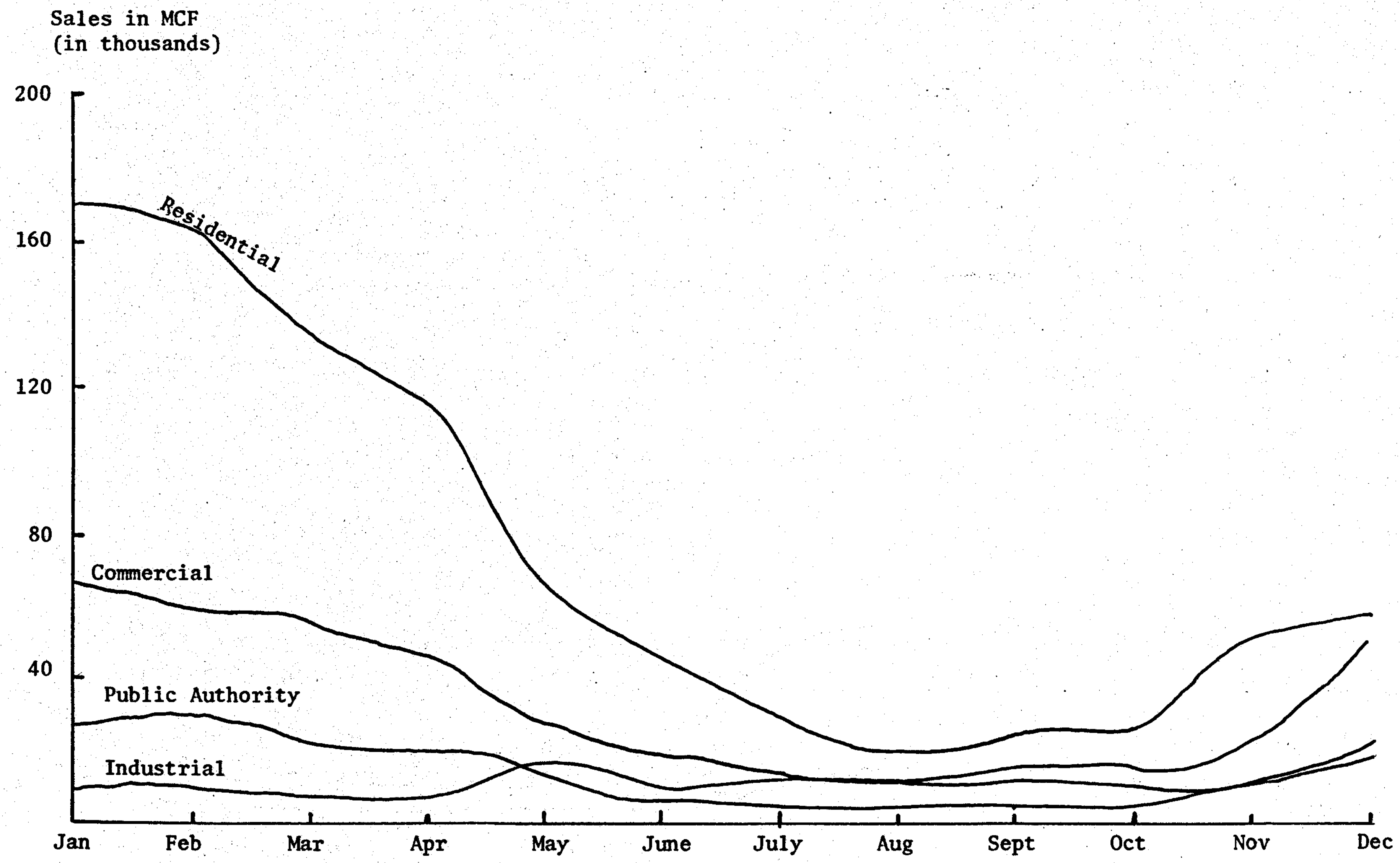


Figure 2-27: Estimated Natural Gas Sales by the Month for 1979 for Prescott, Yavapai County
Source: Southern Union Gas Company

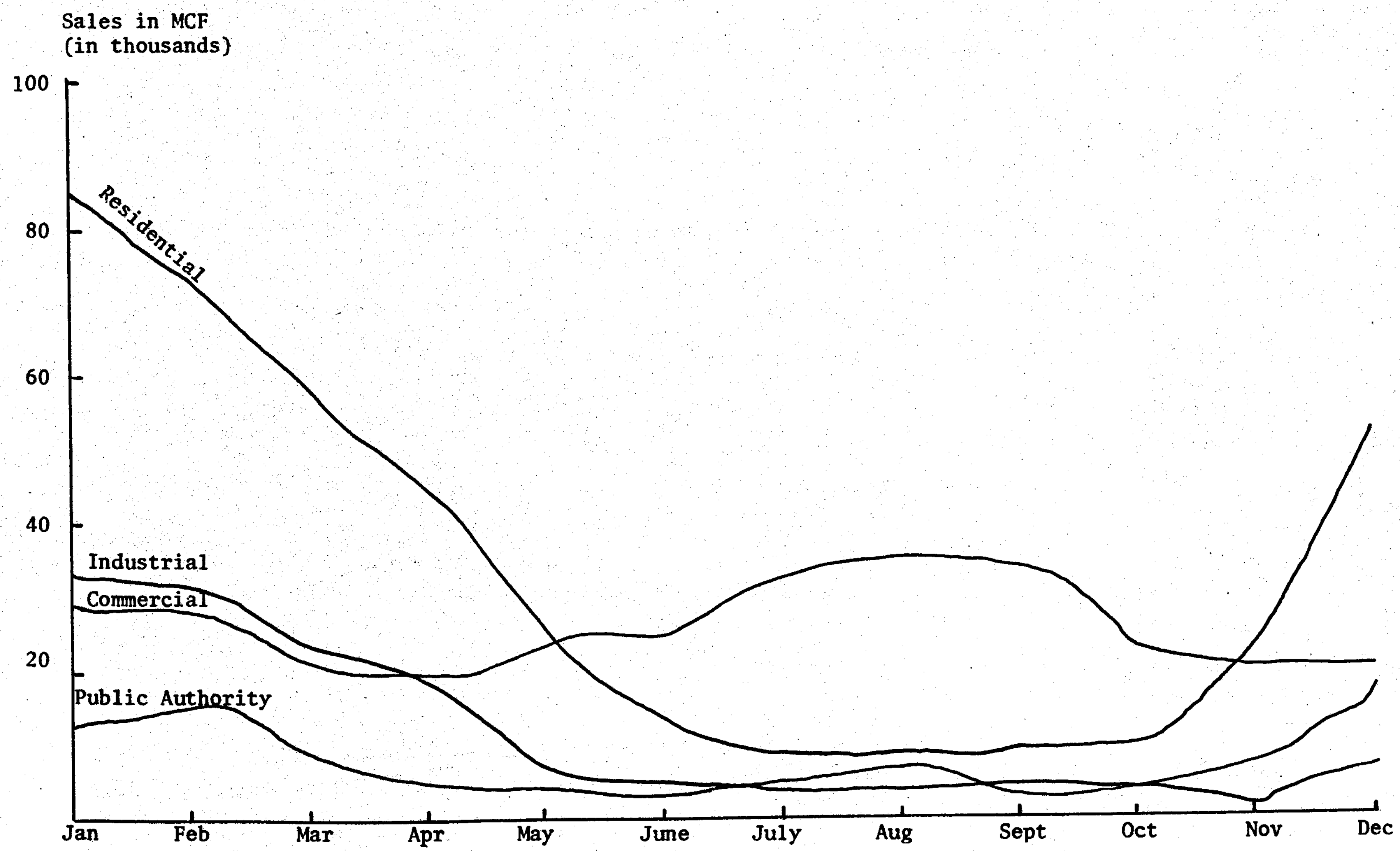


Figure 2-28: Estimated Natural Gas Sales by the Month for 1979 for Kingman, Mohave County
Source: Southern Union Gas Company

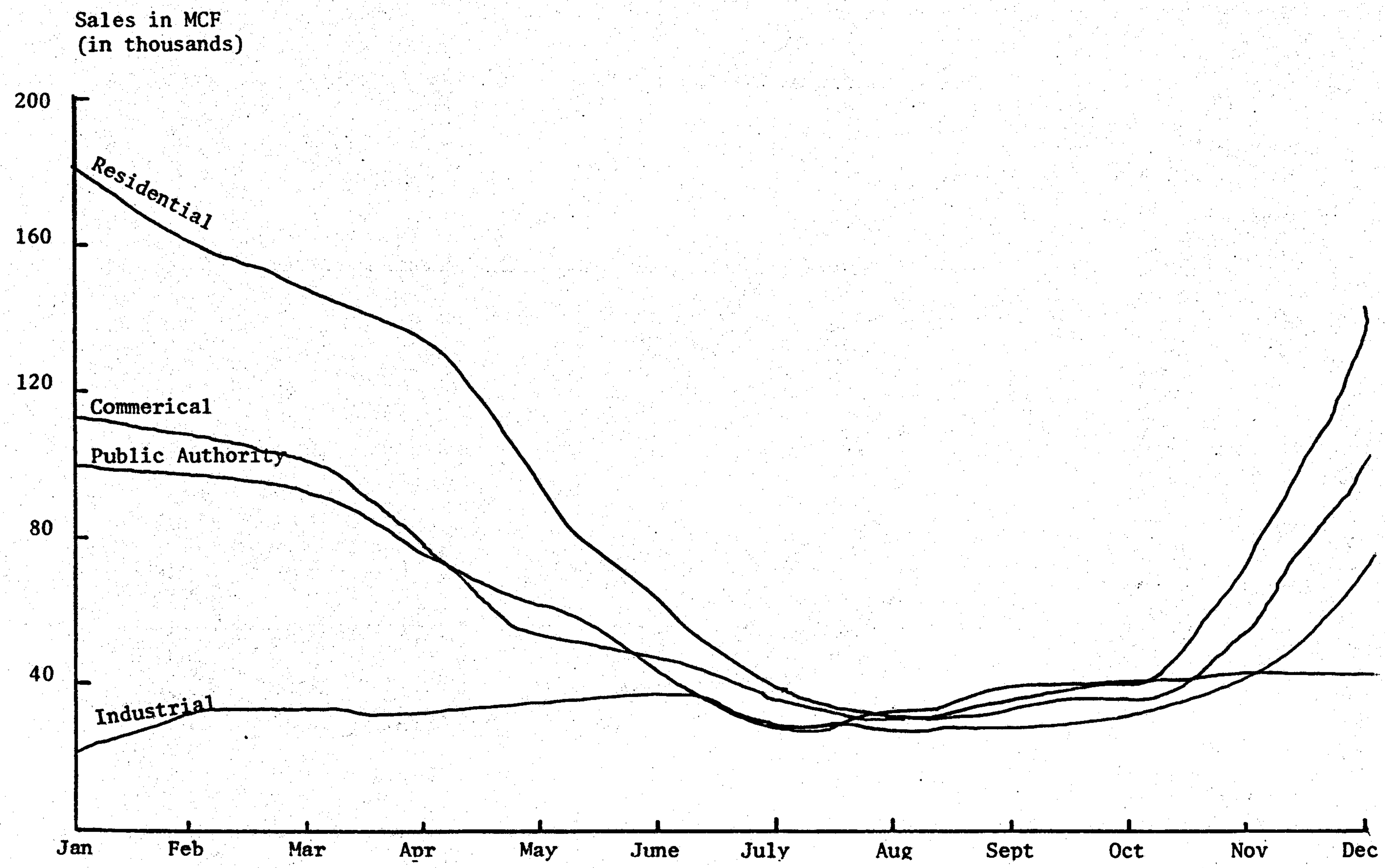


Figure 2-29: Estimated Natural Gas Sales by the Month for 1979 for Flagstaff, Coconino County
Source: Southern Union Gas Company

Figures for electricity consumption for the northern counties are not yet available.

2.3.4 Water

In general, the population of the northern counties is expected to increase substantially by 2020; however, urban water depletions in Northern Arizona are expected to increase more rapidly than population. In Apache, Coconino and Navajo counties, the current per capita rate of use is much lower than the remainder of the state. These rates are expected to show small increases.

Because of the scattered nature of most urban water use in Northern Arizona, the reuse of water is limited. Therefore, depletions represent a larger portion of withdrawals for urban use than other parts of Arizona.

Little change is expected in irrigated agricultural production and water use. The acre increase is approximately evenly divided between the counties.

Large increases are forecast to occur in the amounts of water used to cool steam electric power plants. There has been a significant increase in water use due to new power plants and the expansion of existing power plants. Additional coal-fired plants or plant expansions are anticipated and by 2020, water use will range from 68,000 to 154,000 acre-feet per year. As much as 23,000 acre-feet of this may occur in Yavapai County if the high projection of electrial generation in Arizona is realized.

Mineral production is projected to increase substantially although water used for this purpose will continue to be less than 10 percent of the statewide value. Both Yavapai and Mohave Counties anticipate major expansions of the existing copper mines.

Northern Arizona has several surface water hydrologic areas. Most of the developed area in Apache, Coconino and Navajo Counties lie in the Colorado River Drainage Basin. In Yavapai County, most urban development occurs in the Verde River Basin. In Mohave County, future dependable supplies along the Colorado River are reported as equal to projected depletions.

In all of the northern counties, the total water depletions for alternatives II and III are the same because irrigated crop land does not have to be reduced to achieve a balance between supply and use in these counties and agricultural depletions are assumed to remain constant in all future time frames for each alternative. (For specific details see Figures 2-30, 2-31, 2-32, 2-33, 2-34 and 2-35).

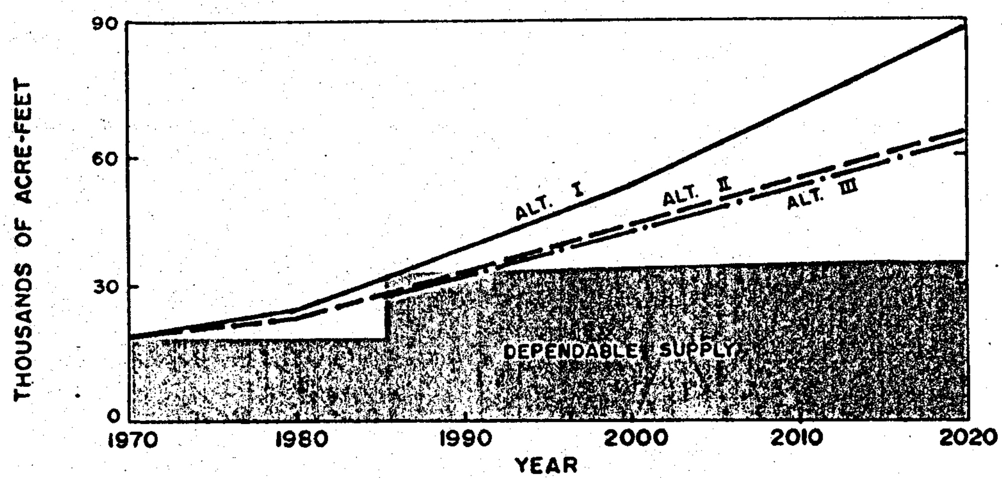
2.3.5 Matching of Geothermal Resources to Potential Users

The geothermal resources in the Northern Arizona Counties are still under investigation. Due to the relatively sparse population of these counties, few industrial matches with geothermal energy were found. The only counties in which matches were found were Apache and Mohave where inferred reservoir temperatures were 95°C and 111°C respectively.

Three firms were identified as being able to utilize process heat in these temperature ranges. They were furniture, ready-mix concrete and stone cutting.

From work performed in conjunction with the New Mexico Energy Institute, Figures 2-36 through 2-39 model geothermal energy on line as a function of time over the next forty years. The four cases shown are all

PROJECTED ALTERNATIVE WATER DEPLETIONS AND DEPENDABLE SUPPLY

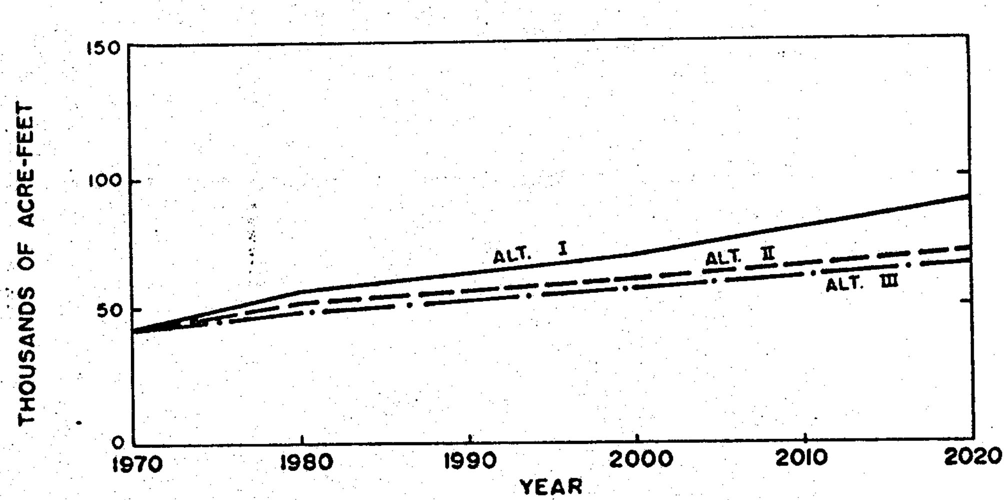


ALTERNATIVE FUTURES SUMMARY

ITEM (Quantities in Thousands)		ALTERNATIVE				FUTURES	
		I		II		III	
	1970	1990	2020	1990	2020	1990	2020
POPULATION	29.3	53.9	65.2	40.5	56.4	40.5	56.4
HARVESTED ACRES	1.0	1.2	1.3	1.0	1.0	0.8	0
URBAN DEPLETIONS AF/YR	2.9	3.8	4.9	2.9	4.2	2.9	4.2
STEAM ELECTRIC DEPLETIONS AF/YR	0	0	0	0	0	0	0
MINERAL DEPLETIONS AF/YR	14.0	33.0	82.0	29.0	60.0	29.0	60.0
AGRICULTURAL DEPL. AF/YR	2.0	2.3	2.6	2.0	2.0	1.6	0
TOTAL WATER DEPL. AF/YR	19	39	89	34	66	33	64
DEPENDABLE WATER AF/YR	19	34	37	34	37	34	37
SURPLUS SUPPLY (Def.)	0	(5)	(52)	0	(29)	1	(27)

Figure 2-30: Projected Future Water Availability and Use in Gila County.
Source: Arizona Water Commission (1977)

PROJECTED ALTERNATIVE WATER DEPLETIONS



NOTE Dependable supply can be developed to satisfy depletions in all timeframes

ALTERNATIVE FUTURES SUMMARY

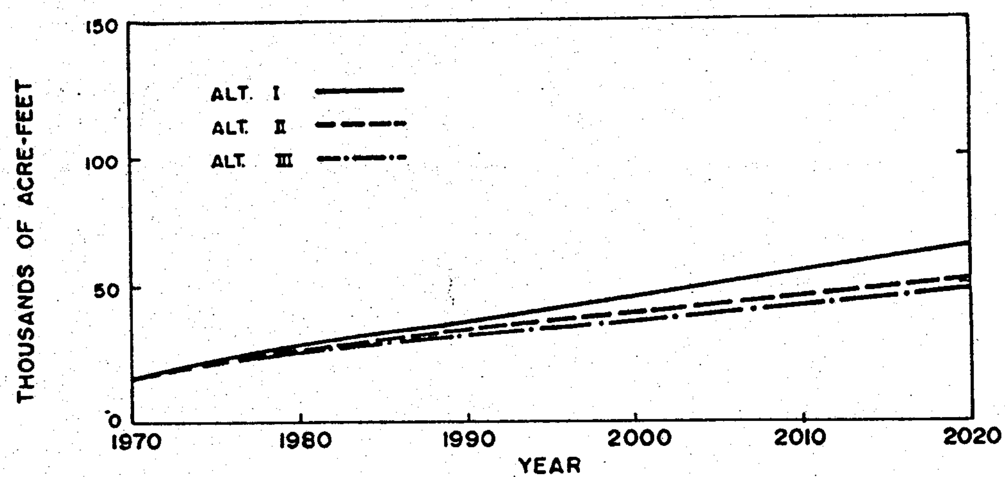
ITEM (Quantities in Thousands)		ALTERNATIVE				FUTURES	
		I		II		III	
	1970	1990	2020	1990	2020	1990	2020
POPULATION	47.6	81.2	124.0	72.1	106.0	72.1	106.0
HARVESTED ACRES	13.0	14.5	15.0	13.0	13.0	13.0	13.0
URBAN DEPLETIONS AF/YR	15.3	16.1	19.9	15.4	18.5	15.4	18.5
STEAM ELECTRIC DEPLETIONS AF/YR	3.1	13.5	36.1	11.7	22.9	11.7	22.9
MINERAL DEPLETIONS AF/YR	0	4.0	6.0	4.0	6.0	4.0	6.0
AGRICULTURAL DEPL. AF/YR	26.0	28.9	30.0	26.0	26.0	26.0	26.0
TOTAL WATER DEPL. AF/YR	44	62	92	57	73	57	73
DEPENDABLE WATER AF/YR[1]	44	62	92	57	73	57	73
SURPLUS SUPPLY (Def.)[2]	0	0	0	0	0	0	0

[1]The developable dependable supply exceeds depletions, therefore, supply and dependable supply are assumed to be in balance

[2]Deficiencies may exist in localized areas.

Figure 2-31: Projected Future Water Availability and Use in Navajo County.
Source: Arizona Water Commission (1977)

PROJECTED ALTERNATIVE WATER DEPLETIONS



NOTE: Dependable supply can be developed to satisfy depletions in all timeframes

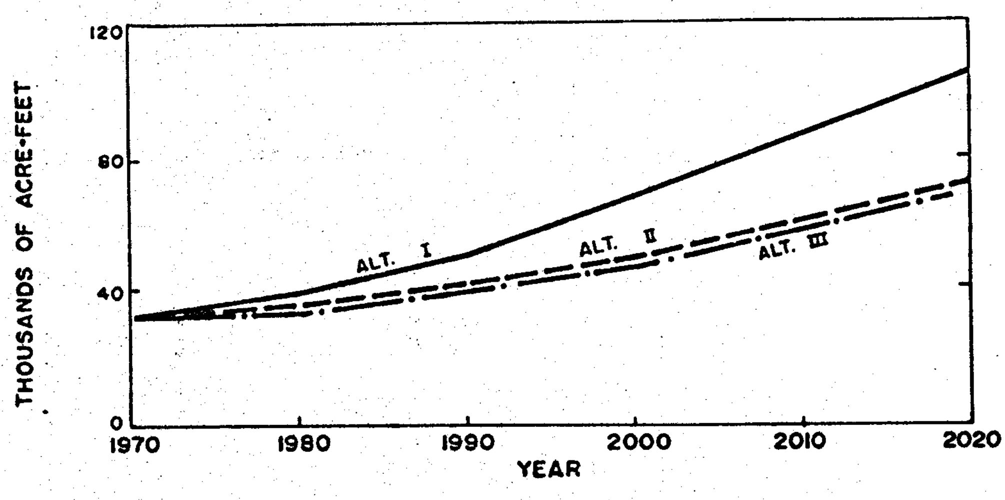
ALTERNATIVE FUTURES SUMMARY

ITEM (Quantities in Thousands)		ALTERNATIVE FUTURES					
		I		II		III	
	1970	1990	2020	1990	2020	1990	2020
POPULATION	32.3	75.7	134.0	75.4	141.0	75.4	141.0
HARVESTED ACRES	8.5	9.4	9.8	8.5	8.5	8.5	8.5
URBAN DEPLETIONS AF/YR	2.3	5.3	10.1	5.3	10.6	5.3	10.6
STEAM ELECTRIC DEPLETIONS AF/YR	0	14.7	37.3	12.8	24.0	12.8	24.0
MINERAL DEPLETIONS AF/YR	1.0	2.0	3.0	2.0	3.0	2.0	3.0
AGRICULTURAL DEPL. AF/YR	14.0	15.5	16.2	14.0	14.0	14.0	14.0
TOTAL WATER DEPL. AF/YR	17	37	67	34	52	34	52
DEPENDABLE WATER AF/YR[1]	17	37	67	34	52	34	52
SURPLUS SUPPLY (Def.)[2]	0	0	0	0	0	0	0

[1]The developable dependable supply exceeds depletions, therefore, supply and dependable supply are assumed to be in balance.
[2]Deficiencies may exist in localized areas.

Figure 2-32: Projected Future Water Availability and Use in Apache County.
Source: Arizona Water Commission (1977)

PROJECTED ALTERNATIVE WATER DEPLETIONS AND DEPENDABLE SUPPLY



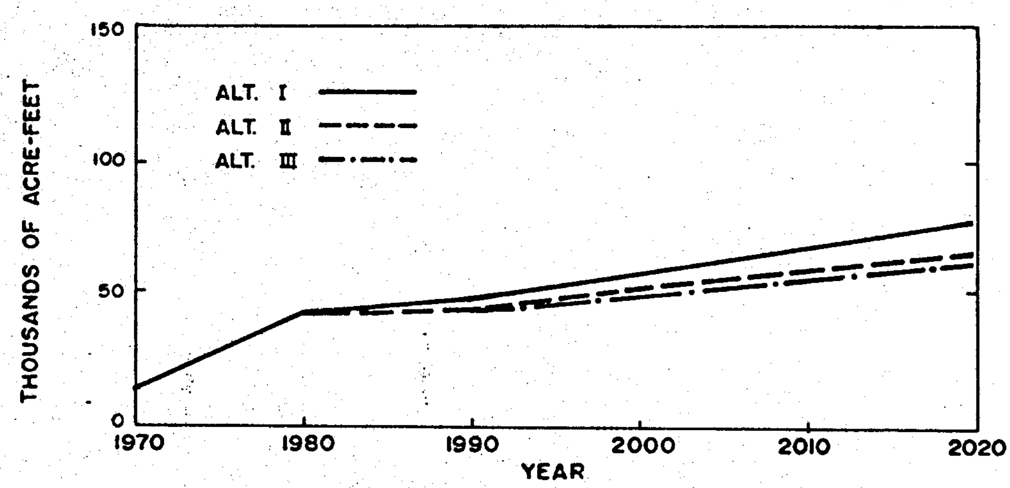
ALTERNATIVE FUTURES SUMMARY

ITEM (Quantities in Thousands)		ALTERNATIVE				FUTURES	
		I		II		III	
	1970	1990	2020	1990	2020	1990	2020
POPULATION	36.8	108.0	191.0	67.0	92.8	67.0	92.8
HARVESTED ACRES	6.0	6.7	6.9	6.0	6.0	6.0	6.0
URBAN DEPLETIONS AF/YR	4.9	8.8	15.6	5.4	7.6	5.4	7.6
STEAM ELECTRIC DEPLETIONS AF/YR	0	0	22.7	0	9.5	0	9.5
MINERAL DEPLETIONS AF/YR	5.0	20.0	48.0	17.0	38.0	17.0	38.0
AGRICULTURAL DEPL. AF/YR	24.0	24.2	22.8	21.8	19.8	22.0	20.0
TOTAL WATER DEPL. AF/YR	34	53	109	44	75	44	75
DEPENDABLE WATER AF/YR[1]	22	46	58	41	47	41	47
SURPLUS SUPPLY (Def.)	(12)	(9)	(51)	(3)	(28)	(3)	(28)

[1] In certain areas where additional water may be developed the dependable supply was set equal to depletion. Transfer from areas where a supply could be developed to deficient areas is not feasible because of geographic condition, therefore, deficiencies are unavoidable.

Figure 2-33: Projected Future Water Availability and Use in Yavapai County.
Source: Arizona Water Commission (1977)

PROJECTED ALTERNATIVE WATER DEPLETIONS



NOTE Dependable supply can be developed to satisfy depletions in all timeframes

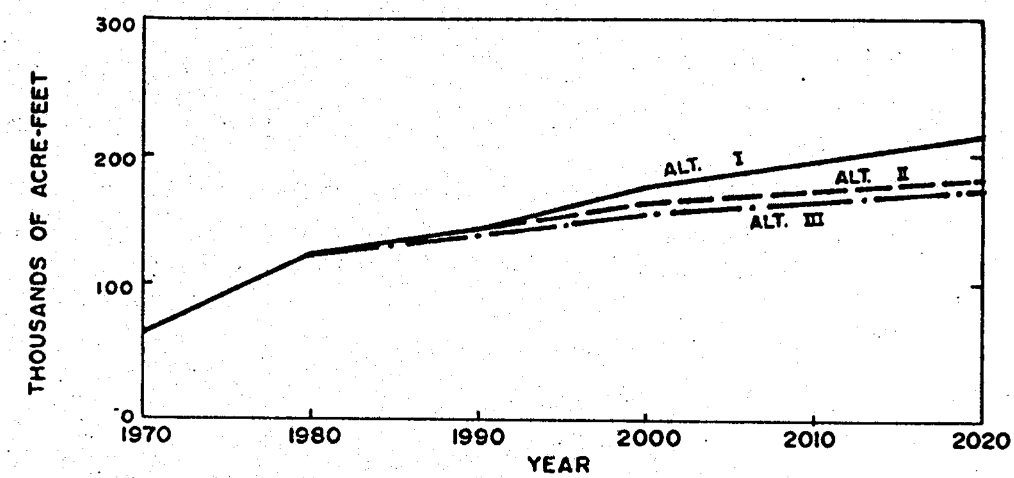
ALTERNATIVE FUTURES SUMMARY

ITEM (Quantities in Thousands)		ALTERNATIVE				FUTURES	
		I		II		III	
	1970	1990	2020	1990	2020	1990	2020
POPULATION	48.3	77.7	100.0	103.0	160.0	103.0	160.0
HARVESTED ACRES	4.5	5.0	5.2	4.5	4.5	4.5	4.5
URBAN DEPLETIONS AF/YR	5.3	6.4	8.7	8.4	13.9	8.4	13.9
STEAM ELECTRIC DEPLETIONS AF/YR	0	31.4	57.6	27.3	42.2	27.3	42.2
MINERAL DEPLETIONS AF/YR	0	1.0	2.0	1.0	2.0	1.0	2.0
AGRICULTURAL DEPL. AF/YR	9.0	9.9	10.4	9.0	9.0	9.0	9.0
TOTAL WATER DEPL. AF/YR	14	49	79	46	67	46	67
DEPENDABLE WATER AF/YR[1]	14	49	79	46	67	46	67
SURPLUS SUPPLY (Def.)[2]	0	0	0	0	0	0	0

[1]The developable dependable supply exceeds depletions, therefore, supply and dependable supply are assumed to be in balance
[2]Deficiencies may exist in localized areas.

Figure 2-34: Projected Future Water Availability and Use in Coconino County.
Source: Arizona Water Commission (1977)

PROJECTED ALTERNATIVE WATER DEPLETIONS



ALTERNATIVE FUTURES SUMMARY

ITEM (Quantities In Thousands)		ALTERNATIVE				FUTURES	
		I		II		III	
	1970	1990	2020	1990	2020	1990	2020
POPULATION	25.9	52.6	94.3	55.6	82.4	55.6	82.4
HARVESTED ACRES	8.0	24.9	31.1	24.5	30.3	23.8	28.9
URBAN DEPLETIONS AF/YR	6.7	9.0	15.7	9.5	13.9	9.5	13.9
STEAM ELECTRIC DEPLETIONS AF/YR	0	0	26.2	0	10.9	0	10.9
MINERAL DEPLETIONS AF/YR	4.0	9.0	28.0	9.0	18.0	9.0	18.0
AGRICULTURAL DEPL. AF/YR	23.0	97.0	112.0	94.7	109	92.0	104.0
TOTAL WATER DEPL. AF/YR[1]	71	152	219	150	189	148	184
DEPENDABLE WATER AF/YR[2]	67	138	187	139	169	139	169
SURPLUS SUPPLY (Def.)	(4)	(14)	(32)	(11)	(20)	(9)	(15)

[1]Includes 37,300 AF/YR for fish and wildlife depletions.

[2]Dependable supply from the Colorado River is equal to depletions. Off-river dependable supply was added to determine total county dependable supply. Deficiencies only occur from off-river uses. Dependable supply for 1970 includes uncredited return flows

Figure 2-35: Projected Future Water Availability and Use in Mohave County.
Source: Arizona Water Commission (1977)

based on the implicit assumption that geothermal energy comes on line when the price of the cheapest energy alternatives (i.e. natural gas) rises above a computed cost per million Btu for geothermal energy. Figure 2-36 presents geothermal energy on line for industrial process heat assuming only private development occurs, while Figure 2-37 presents geothermal energy on line for industrial process heat assuming a city owned utility develops the potential resource. Clearly, development by a city owned utility occurs sooner than does private development. Two reasons for this situation can be cited. First, a city typically has a lower cost of capital than does private industry and, second, city utilities require lower rates of return on invested capital.

The results of these figures suggest that under private industrial development geothermal energy would come on line by 1989 and rise rapidly to 2020 as other energy prices increase. Under city development, geothermal energy for industrial process heat would come on line by 1983 and rise rapidly to 2005.

For comparison purposes, Table 2-13 reports energy on line in terms of barrels of oil replaced per year.

Table 2-13: Barrels of Oil Replaced by Geothermal Energy Industrial Process Heat Market

	1985	1990	2000	2020
Private Developer	0	9357	165,000	350,000
City Utility	9482	87,500	276,796	378,571

Similar modeling was also performed for the residential and commercial space heating markets (both sectors are reported as residential) for the

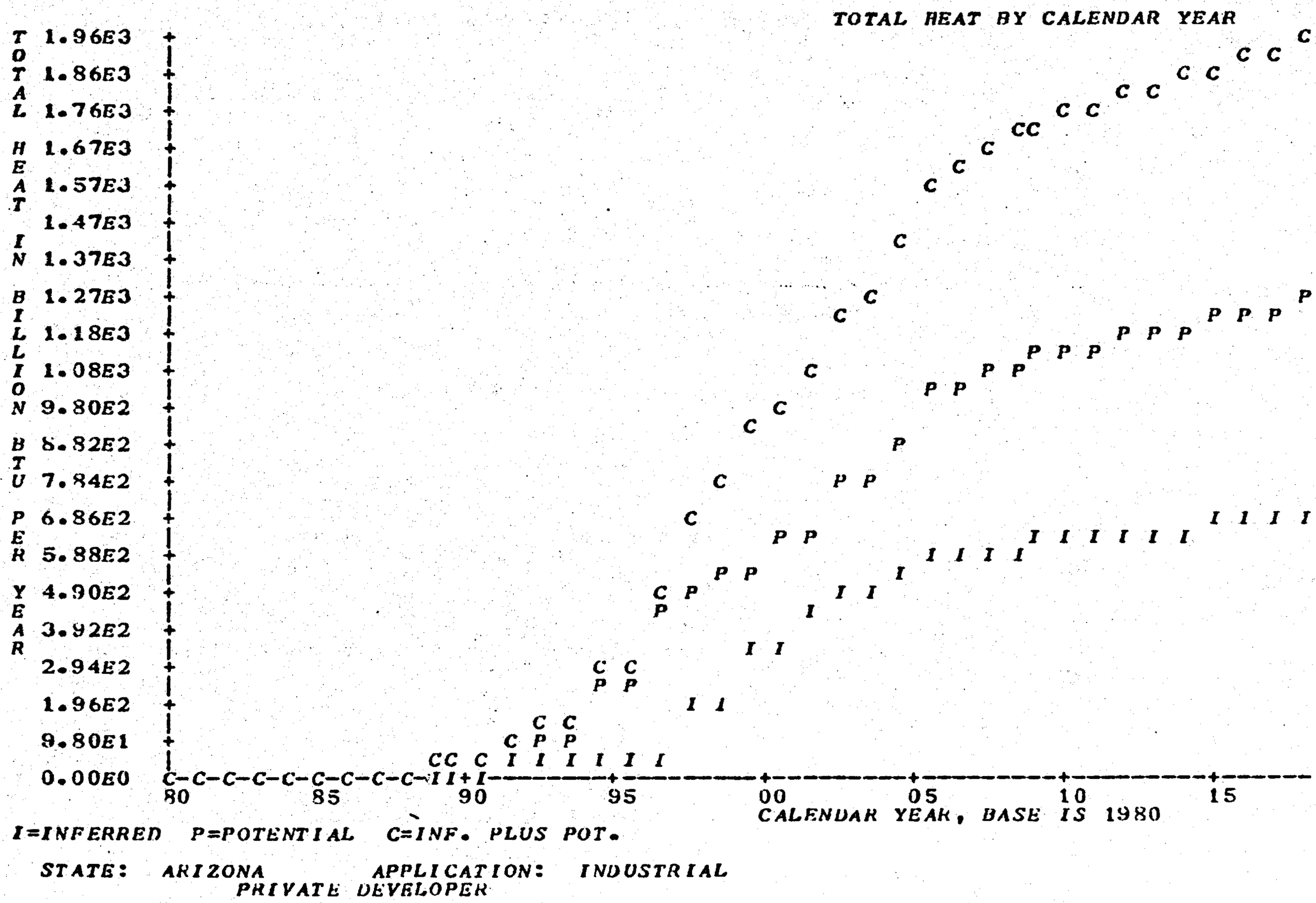


Figure 2-36: Projected Geothermal Heat On Line Under Private Development-Northern Counties
Source: New Mexico Energy Institute

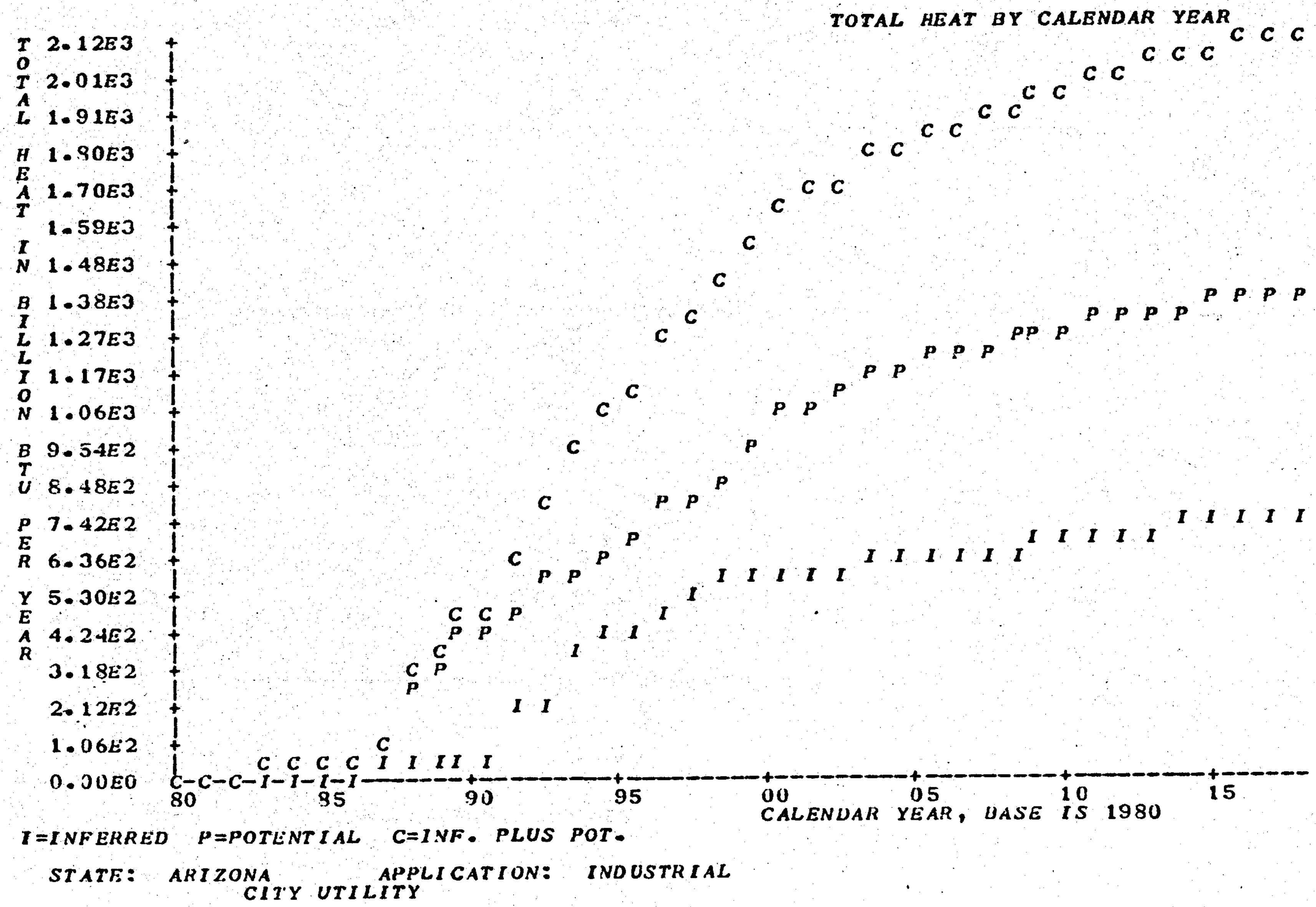


Figure 2-37: Projected Geothermal Heat On Line by Year Under City Development-Northern Counties
Source: New Mexico Energy Institute

northern counties. Climatic conditions in Northern Arizona justify inclusion of these results.

Figures 2-38 and 2-39 show total geothermal energy on line as a function of time for the residential and commercial space heating markets and the industrial process heat market. Once again results confirm that development by a city utility is faster than development by the private sector. Under city utility development, geothermal energy resources become the cheapest energy alternative beginning in 1983 whereas private development would not be expected to occur until 1989. Results are presented in Table 2-14 in terms of barrels of oil replaced per year.

Table 2-14: Barrels of Oil Replaced by Geothermal Energy--Residential, Commercial and Industrial Markets

	1985	1990	2000	2020
Private Developer	0	64,821	253,571	3,464,285
City Utility	66,785	417,857	2,196,429	4,000,000

The results presented in this section suggest that Northern Arizona could experience significant geothermal development; however, additional factors may play a significant role to improve the potential for geothermal development. Northern Arizona has good potential for a substantial increase in residential and industrial development and is seeking to diversify its economy away from its traditional rural base. As additional industries and people are attracted to Northern Arizona, greater development of its geothermal resource potential becomes possible. Also, geologic investigations in Northern Arizona have been limited. As additional resource

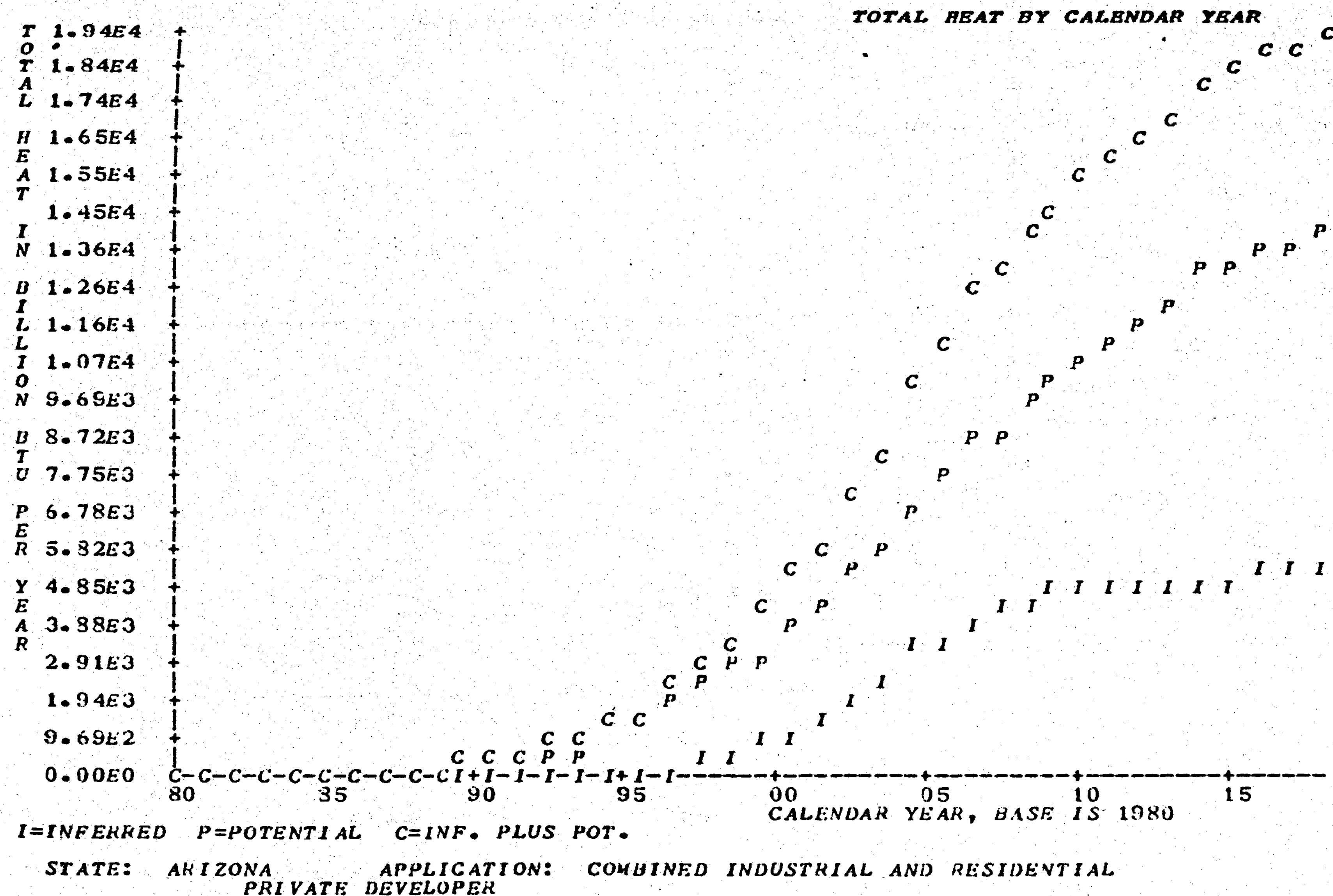


Figure 2-38: Projected Geothermal Heat On Line Under Private Development for the Residential, Commercial and Industrial Sectors - Northern Counties

Source: New Mexico Energy Institute

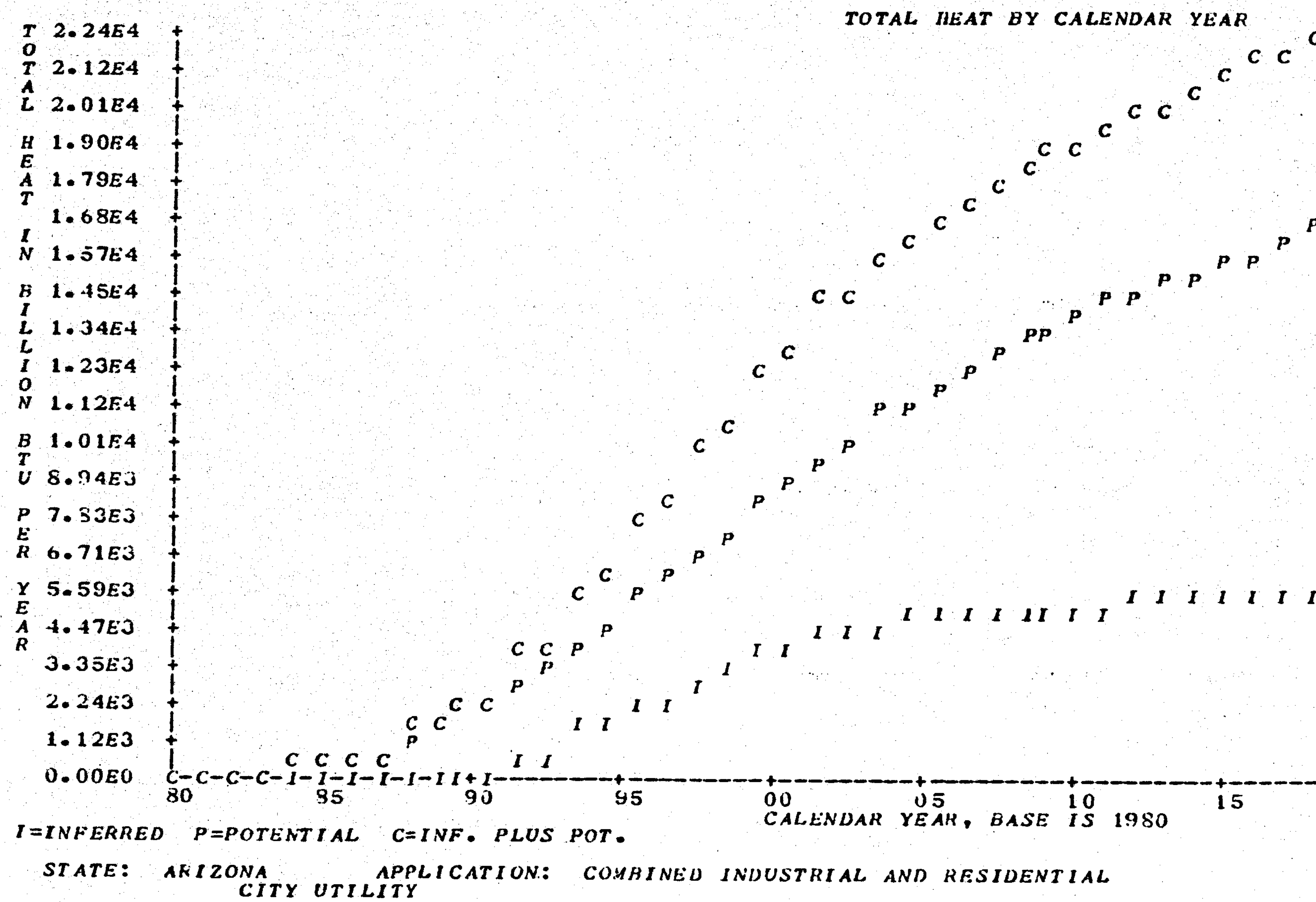


Figure 2-39: Projected Geothermal Heat On Line Under City Development for the Residential, Commercial and Industrial Sectors - Northern Counties
Source: New Mexico Energy Institute

assessment work is performed, greater resource potential may be discovered. Finally, Northern Arizona could also benefit from geothermal space cooling as well as space heating, further adding to the use of geothermal energy resources.

3.0 INDUSTRIAL PROCESS TEMPERATURES

The following analysis represents a preliminary attempt to define potential uses of geothermal energy for specific industrial processes. This analysis was developed through the identification of the largest industrial energy users in each county and the necessary process heat temperatures for each of the unit operations within the industry. This procedure enables the previously assessed average geothermal reservoir temperatures for each county to be matched with individual processes within industries.

These data were developed using the 1980 Arizona Directory of Manufacturers and data from the Solar Energy Research Institute which provided estimates of annual energy consumption by four digit SIC code and the respective process temperatures needed by these industries.

The information of the specific heat temperatures needed in each of the operations within the industry was gathered from three principal sources: the Noyes Data Corporation publication entitled "Energy Saving Techniques for the Food Industry;" Energy Analysis of 108 Industrial Processes, Phase I of an Industrial Applications Study, 1979, completed by Drexel University; and a Survey and Analysis of Solar Energy Process Heat Opportunities in Arizona prepared by the University of Arizona. Only those processes with large energy useage for which the demand for process heat could be supplied by geothermal energy are discussed.

3.1 Maricopa County

Soft Drink Industry (SIC 2080)

The soft drink industry in Maricopa County is comprised primarily of establishments engaged in manufacturing soft drinks and carbonated waters.

Soft drink plants are typically near concentrated population areas. While locational factors may affect energy use in some areas this is not anticipated in Arizona. Total production of the industry is expected to continue to increase. In the past there has been a compounded annual growth rate between 1972 and 1980 of about 4.25 percent.

The soft drink industry has three basic plant types - those which both bottle and can, those which bottle only and those which can only. The most common plant within the industry is that which bottles. Major processes include mixing, bottle washing, cooling and filling.

The soft drink industry in total is an important energy consuming industry within the Food and Kindred Products Group, ranking eighteenth in 1974 among the 47 industries within the group. Although the manufacture of soft drinks is not energy intensive per unit of output (approximately 8,550 Btu per 192 ounce case), the volume throughout the industry necessitates relatively large fuel requirements. It is estimated that direct fuel is consumed by three primary functions: space heating (50%), bottle and can washing (20%) and intra plant transport (30%). Bottle and can washing consumes about 19×10^{10} Btu's/year. The temperatures used in this process are 140°F (60°C) to 180°F (82°C). This appears to be a very suitable application of geothermal process heat, with a good potential for conventional energy displacement as the average geothermal assessed temperature in Maricopa County in 230°F (110°C).

Natural gas is the dominant energy source in the industry. In 1972, approximately 55 percent of all net energy was derived from natural gas. Fuel oils and purchased electricity accounted for 15 and 14 percent of all net energy respectively, coal 10 percent, and other purchased fuels comprised approximately 6 percent of the energy sources.

Ready Mix Concrete Industry (SIC 3273)

There are seven large firms within this industry in Maricopa County. The principal characteristics of the ready-mix concrete industry is that concrete is poured wet and allowed to set at ambient temperature at the job site. Therefore, most of the temperature needed for process heat requirement is between 160^{o}F (71^{o}C) and 200^{o}F (104^{o}C). This is well within the assessed average geothermal temperature in Maricopa County of 230^{o}F (110^{o}C).

Electricity is the dominant energy source in the industry used primarily in the crushing and mixing processes. Fuel is consumed in transportation and mixing in transit. In addition, ready-mix concrete requires large quantities of hot water for cleaning, mixing and storage. Thus, this industry is a good candidate for geothermal heat useage. Further investigation of this sector is required to make any additional inferences.

Beet Sugar Industry (SIC 2063)

The beet sugar industry is comprised of plants primarily engaged in manufacturing sugar from sugar beets. Beet sugar represents about 30 percent of all sugar consumed in the United States.

The various operations required for converting sugar beets into refined sugar are many and complex, but they are basically the same in all plants. The basic processes consist of slicing, diffusion, juice purification, evaporation, crystallization, and recovery of the sugar. Intensive energy consumption is involved in transportation, slicing and the evaporation part of the process and the pumping of water and air in pollution control.

In the direct manufacture of sugar there are no chemical changes that require significant amounts of energy. Almost all the energy intensive steps in the manufacturing sequences involve physical changes or unit operations. These processes consume energy for crushing, pumping, and centrifugation, and heat for solution, evaporation and drying. The steady engineering improvement of the equipment necessary to make these various operations function efficiently has gradually reduced the energy requirement for the sugar process itself; however,recent addition of water and air pollution control devices has tended to reduce the downward trend on energy requirements.

In general, the beet sugar plants located in the northern severe winter climates have a higher energy requirement than those in the milder climates, particularily those in California and Arizona. One example of this difference is that of storage. In the north, stored sugar beets freeze at the plants or at offsite beet dumps; thus, hot water and heat (additional energy) are required in the slicing and diffusing operation to thaw the beets for processing. In addition, some plants use 700 gallons (2649 liters) of water effluent per ton of beets sliced while others run as high as 3,000 gallons (11355 liters) per ton of beets sliced. Disposal of this effluent under Environmental Protection Agency guidelines requires varying energy requirements. In milder climates, irrigation disposal of water is feasible. In colder climates the effluent runs through several control processes which has added an estimated 25 percent to the electrical load of the sugar beet plant in recent years.

In 1972 it was estimated that 64.2 percent of the total energy consumed in this industry was provided by natural gas, while coal provided

26.6 percent. Six percent of the energy requirement was obtained from coke, used as a source of carbon dioxide. Both petroleum products are purchased, electricity provided a relatively small amount of energy.

In sum, the temperatures required for the unit operations in the sugar beet industry are low, ranging between 75°F (24°C) and 250°F (121°C). The average assessed geothermal reservoir temperature is 230°F (110°C) in Maricopa County. The potential for the use of geothermal heat is good, especially in the subprocess where the cascading of heat is used with all steam from boilers used in the evaporators.

Maricopa County has one large plant in this industry, employing over 400 workers.

Ice Cream and Frozen Desserts (SIC 2024)

There are six firms in Maricopa County that fall under this category. These establishments are primarily engaged in manufacturing ice cream and other frozen desserts. This industry is not a major energy consumer within the Food and Kindred Products Industry. Although the freezing process is rather energy intensive the industry ranked thirty-fourth in 1972. The major energy-consuming steps of frozen dairy products are pasteurization, cooling and freezing.

Electricity and natural gas were major energy sources used by the industry in 1972. The direct uses of fuel are primarily for whey drying (60 percent) and milk carton filling (30 percent). The remaining 10 percent is utilized for space heating.

In the ice cream industry 54 percent of the electrical energy is utilized for refrigeration. Processing equipment accounts for 18 percent of the electrical energy. The remainder is utilized for lighting, sales and garage and miscellaneous uses. The industry generated very little or none of its own electricity.

Specific processes and their respective required heat temperatures have not yet been identified. Further research in this industry is necessary.

Cottonseed Oil Mills (SIC 2076)

This industry is comprised of plants primarily engaged in manufacturing vegetable oils. It excludes those plants primarily refining vegetable oils into edible products.

This industry is the smallest within the fats and oils industry group in terms of number of plants, value of shipments, and number of employees. Plants are generally located near the specific crop area from which the vegetable product is obtained. Maricopa County has two cottonseed plants.

Cottonseed oil mills consume about 6200 Btu/lb of cottonseed. Two types of operations are presently being used in the industry to process cottonseed: mechanical screw press and solvent extraction. The screw press operations are used by 75 - 80% of the industry. The energy breakdown for each major step of the process is given in Table 3-1. Steam at about 275°F (135°C) is the process heat transfer medium.

Steam is used in most operations along with a solvent for oil extraction. The toaster solventizer must reach 215°C, but all other operations are not temperature dependent. Geothermal heat could easily be used as the average assessed geothermal reservoir temperature is 230°F (110°C) in Maricopa County.

Table 3-1: Cottonseed Oil Mills Energy End Use Requirements

End Use Activity	Energy Type Used	Percent of Total
Seed Conditioning	Steam	20.7
Extraction and Oil Recovery	Steam	27.6
Mechanical Power	Electricity	30.4
Lighting	Electricity	0.6
Boiler Losses	Fuel to Boiler	20.7

Source: Energy-Saving Techniques for the Food Industry
Noyes Data Corporation, Park Ridge, NJ 1977

Plating and Polishing Industry (SIC 3471)

There are four firms in Maricopa County within this industrial class. A study completed by the University of Arizona, Energy Management and Policy Analysis Group, indicates that various process heat temperatures for the unit operations are necessary in the Plating and Polishing Industry.

The subprocess of plating baths is the only process identified for which geothermal energy has potential. This process requires heat temperatures between 130°F (54°C) and 215°F (102°C). Presently, the industry is using electricity as its fuel type with the medium - hot water used directly.

Thus, the potential for the use of geothermal energy in this operation is good, given the average geothermal reservoir temperature in the county is 230°F (110°C).

3.2 Pima County

Primary Copper (SIC 3331)

Pima County is the largest copper producer in Arizona. It provides 40% of the copper produced in the state. There are about 2,200 million tons of proven copper ores in the area.

The typical process heat requirements for copper smelting and refining are summarized in Table 3-2. Process heat requirements are in excess of 2000°F (1093°C) with the exception of the drying of concentrate and the heating of solutions.

The copper industry in Arizona does not dry the copper concentrate prior to smelting. The smelters utilize a wet-charge of copper concentrate

Table 3-2: Typical Process Heat Consumption in the Copper Industry

Process	Temperature (°F)	& (°C)	MBtu per ton
Smelting			
Drying Concentrate	200	93	1.40
Reverberating Furnace	2200	1204	14.67
Convester	2200	1204	0.89
	2050	1121	3.49
Acid Plant			0
Electrolytic Refining			
Heating Solution	140	60	4.34
Melting Cathode	2050	1121	1.87
TOTAL			28.66

Source: Battelle Labs, Final Report on Survey of the Applications of Solar Thermal Energy Systems to Industrial Process Heat, Vol. 2, Industrial Process Heat Survey, January 1977

and thus do not have the direct drying process. The same total amount of energy is consumed, whether or not the concentrate is dried prior to smelting or during the smelting process. Thus it would seem a geothermal pre-drying of concentrate prior to smelting could afford a significant energy reduction. The potential exists to displace about 1.4×10^{12} Btu's/ yr. of conventional fuel. This represents about 4% of the total thermal energy use in the industrial sector.

The electrolytic refining process uses process heat in the 140°F range for heating of electrolytic solutions. The solutions are constantly maintained at 140°F (60°C) to 170°F (77°C) as shown in Table 3-2. It takes 4.34 MBtu/ton of refined copper to heat the solutions. The total energy required is about 1.2×10^{12} Btu's/yr, for this process. There is a potential application of geothermal to this process. Presently most of the heat required for this process is supplied by natural gas and fuel oil. Table 3-3 indicates the process heat use for all the individual processes.

Table 3-3: Aggregate Process Heat Requirements for Primary and Secondary Copper - Trillion Btu's/year, 1973

Process	Hot Water under 100°C	Steam 100-177°C	Steam Over 177°C
Copper (primary & secondary)			
Drying	0	0	0
Reverberatory Furnace	0	0	0
Converting	0	0	0
Anode Refining	0	0	0
Electrolytic Refining	4.6	0	0

Process	Direct Heat/Hot Air under 100°C	Direct Heat/Hot Air 100-177°C	Direct Heat/Hot Air Over 177°C
Copper (primary & secondary)			
Drying	0	0	0
Reverberatory Furance	0	0	21.4
Converting	0	0	0.8
Anode Refining	0	0	3.0
Electrolytic Refining	0	0	0

Source: See Table 3-2 for Source

A new copper refining process has recently been developed which offers possibilities for geothermal applications. The new process is a hydrometallurgical extraction of copper. This process is a low energy consumer, with an assessed total energy requirement of 32 MBtu/ton. The process energy required for solution heating is normally provided by 30 psi steam, at about 250°F (121°C). The solution temperatures required for this process are about 100°F (37°C) to 225°F (107°C), suitable to geothermal application. The assessed geothermal reservoir temperature for Pima County is 212°F (100°C).

In addition, it is important to note the copper dump leaching process is practiced in some form in all of the mines in Pima County. Given the fact that the increased temperatures of the leaching fluid enhances the rate of copper extraction, geothermal energy could be used to heat the leaching fluid, serving as a substitute for fossil fuels. This application does not require high geothermal temperatures like those required by power generation. Consequently, this application could use the potentially abundant, low-to-moderate geothermal resources in Pima County.

Soft Drink Industry (SIC 2086)

The 1980 Arizona Directory of Manufacturers lists three firms within this industry in Pima County. These are primarily engaged in manufacturing soft drinks and carbonated waters. The most common plant is that which bottles. The significant operations with potential geothermal energy use are: fructose storage, returnable bottle washing, can washing and clean up.

Presently, natural gas is used for all of these operations with hot water as the medium. Fructose storage requires a process heat temperature of 90°F (32°C), bottle washing 170°F - 190°F (77°C - 88°C), can washing between 130°F (54°C) and 140°F (60°C) and the clean-up operation requires water temperatures of 140°F - 170°F (60°C - 77°C). It is estimated that the bottle and can washing processes alone consume about 0.19 x 10^{12} Btu's/yr.

Thus, the above identified processes appear to be very suitable applications of geothermal process heat, given the assessed average geothermal temperature in Pima County is 212°F (100°C).

Ready Mix Concrete Industry (SIC 3273)

There are three large firms within this industry in Pima County. The basic principal associated with this industry is that the concrete is poured wet and allowed to set at ambient temperature at the job site. Therefore, most of the temperature needed for process heat requirement is between 160°F (71°C) and 220°F (104°C). The estimated geothermal well temperature in Pima County is 212°F (100°C). This would indicate potential for geothermal use for this process.

Electricity is the prevailing energy source in the industry used in the crushing and mixing process. Fuel is consumed in transportation and mixing in transit. In addition, the ready mix concrete industry requires large quantities of hot water for cleaning, mixing and storage. All of these factors would seem to indicate that the industry is a good candidate for geothermal heat useage.

3.3 Pinal County

Prepared Feeds Industry (SIC 2048)

The prepared feeds industry is comprised of plants primarily engaged in manufacturing prepared feeds for livestock and poultry and certain feed ingredients and adjuncts, such as alfalfa meal and feed supplements.

There is one plant within this industrial classification in Pinal County which produces complete cattle feeds, range and feedlot supplements and complete horse pellets.

There are significant differences in energy requirements per ton of feed processed among the various industry segments, primarily due to the different amounts of energy required for drying. Approximately 14,000 Btu are required in manufacturing a ton of dehydrated alfalfa as contrasted to about 400 Btu for the other types of prepared feeds.

The plant in Pinal County manufactures dairy and range feed, seed-lot supplements which is a base mix for feedlots, and horse pellets made with alfalfa. The alfalfa in Arizona is sun-cured rather than dehydrated which is the least energy consuming of all the processes. (The former process requires 2.4 million Btu/ton whereas the latter, 13.0 million Btu/ton).

The manufacturing operations for prepared feed and sun-cured alfalfa includes procurement of ingredients, processing (grinding, rolling, steaming, etc.) mixing, forming (pelleting, extrusion) packaging and delivery. The forming processes consume the major portion of energy. Almost 90 percent of the energy required is in the form of steam. Forming also accounts for about one-third of the purchased electricity. Over 90 percent of the purchased fuel is used in the dehydrating process. A significant portion of the fuel, 5.5 percent, is expended in harvesting and transporting (diesel fuel and gasoline). Less than 2 percent of the fuel is used in pelleting.

The breakdown of energy consumed in this industry is estimated to be 52.8 percent provided by natural gas, 10.6 percent by fuel oil, and 27.6 percent by purchased electricity. Over nine percent of the energy was obtained from sources other than those indicated. A large portion of this gasoline and diesel fuel was consumed in harvesting and transporting.

The type and amount of energy used in the prepared feeds segment (excluding dehydrating) for the various manufacturing processes (end use activities) are as shown in Table 3-4.

Table 3-4: Energy Use in the Prepared Feeds Industry

End-Use Activity	Type Energy Used	Percent of Total
Drying (direct use)	Fuel	1.0
Boiler losses	Fuel to boiler	18.6
Conditioning, flaking, and pelleting	Steam	36.6
Plant heating and other steam uses	Steam	6.7
Mechanical power	Electricity	35.2
Lighting	Electricity	1.9
		100.0%

Source: Energy-Saving Techniques for the Food Industry
Noyes Data Corporation, 1977

The largest amounts of energy are expended in the conditioning, flaking and pelleting operations (steam) and obtaining mechanical power (electricity). Flaking and pelleting operations consume close to 37 percent of the total energy, 95 percent of the electricity is used in operating motor and other mechanical equipment and more than a third of the energy consumed in the industry is used in operating these motors and equipment. One percent of the total energy is consumed in drying operations.

The type and amount of energy used in alfalfa dehydrating is indicated in Table 3-5. Almost 85 percent of the energy is used in drying.

The only steam used is for conditioning in pelleting, and represents one percent of the total energy consumed. Transporting and harvesting (direct use fuel) and mechanical power consume about the same amounts of energy (7-8 percent).

Table 3-5: Energy Use in Alfalfa Drying

End-Use Activity	Type Energy Used	Percent of Total
Drying (direct use)	Fuel	83.7
Transport and Harvest	Fuel	7.3
Boiler Losses	Fuel to Boiler	0.3
Conditioning for Pelleting	Steam	0.7
Mechanical Power	Electricity	7.7
Lighting	Electricity	0.3
		100.0%

Source: Energy-Saving Techniques for the Food Industry
Noyes Data Corporation, 1977

Although process heat temperatures for these operations were not identified, geothermal energy could be used as an energy-saving measure. The greatest saving potential is in the boiler operations to heat boiler feed water. Further investigation is necessary to determine the required process heat temperatures for each operation and the potential for geothermal energy. The rising cost of fuels and electricity has stimulated an increasing interest in conservation within the prepared feeds industry.

3.4 Northern Counties

Ready Mix Concrete Industry (SIC 3273)

There are seven large firms in this industry principally located in Mohave County. The ready-mix concrete industry's principal characteristic is that the concrete is paved wet and remains at ambient temperature. Thus, the temperatures needed for process heat generally fall between 160°F and

220°F (104°C). This is well within the assessed average geothermal temperature of Mohave County of 230°F (110°C).

Electricity and fuel are the dominant energy sources, the former used in the crushing and mixing processes, the latter for transportation and mixing in transit. Ready-mix concrete also requires large quantities of hot water for cleaning, mixing and storage. There is good potential for the use of geothermal energy within this industry.

Saw Mills Industry (SIC 2421)

There are four large mills under this industrial classification located in Northern Arizona, principally in Apache and Coconino Counties.

This industry requires warm process heat temperature never greater than 180°F (82°C). Most of the processes require 77°F (25°C). The assessed geothermal reservoir temperature in Coconino County is 122°F (50°C) and 203°F (95°C) in Apache County.

The operation using the highest temperature is that of planing requiring temperatures between 120°F (49°C) and 180°F (82°C). The majority of the processes require temperatures less than 80°F (27°C).

Geothermal energy could be used in the washing of logs, bolts and carts (temperature requirement = 25°C) in the drying kiln (requiring 25°C) and for space heating.

Electricity is the dominant energy source in the industry used in almost all of the processes. A breakdown of the total energy used and the percentage allocations given to fuel, electricity and other sources is not available. Very little research has been completed on this industry to date.

Summary

Table 3-6 presents a tabular summary of industries which may be able to convert to geothermal energy for process heat needs. The information presented is not exhaustive but does highlight some of the largest low-temperature consuming industries in Arizona. Further endeavors should provide further verification of the information presented.

Table 3-6: Largest Process Heat Consumers by County

SIC		Energy Use Btu/yr, x 10^{12}	# of Firms
Maricopa	(110°C = 230°F)		
2086	Bottled & Canned Soft Drinks	0.4402	7
3444	Fabricated & Structural Steel	0.4344	26
3273	Ready Mix Concrete	0.2241	7
2063	Beet Sugar	0.208	1
2024	Ice Cream & Frozen Desserts	0.1856	6
3441	Sheet Metal Work	0.1278	20
3471	Plating & Polishing	0.1138	4
2431	Millwork	0.1042	24
3429	Special Product Sawmills, N.E.C.	0.0937	4
2076	Cotton Seed Oil (only AZ book)	0.5492	2
Pima	(100°C = 212°F)		
3331	Primary Copper		3
3444	Sheet Metal Work	0.1459	6
3999	Misc. Manu. Products	0.1663	3
2086	Soft Drinks	0.0995	3
3273	Ready-Mix Concrete	0.0554	3
2522	Metal Office Furniture	0.0491	1
3441	Structural Metal	0.0424	7
3449	Misc. Metal Work	0.0366	7
2499	Misc. Wood Prod.	0.0351	3
2431	Millwork	0.0188	5
3841	Medical Instruments	0.0168	1
Pinal	(105°C = 221°F)		
3499	Misc. Wood Prod.	0.4526	2
2048	Animal Feed	0.323	1
2519	Misc. Furniture	0.1802	1
2599	Misc. Furniture	0.1395	1
3441	Structural Metal	0.0164	1

Table 3-6 continued

SIC			Energy Use Btu/yr, x 10^{12}	# of Firms
Graham/Greenlee ($105^oC = 221^oF$)				
2086	Soft Drinks		0.0277	
3949	Sporting Goods		0.0083	
Yuma ($95^oC - 203^oF$)				
3299	Non-mineral Metals		0.0085	1
Northern Counties				
3273	Ready-Mix Concrete	Mohave (110^oC)	0.0061	7
2421	Saw Mills	Apache (110^oC)	0.003	4
3451	Screw Machines	Mohave (110^oC)	0.002	1
2591	Misc. Furniture & Fixtures		0.0015	

4.0 EVALUATION OF GEOTHERMAL APPLICATIONS

During the third quarter of CY 1980, the Arizona Geothermal Team continued to make preliminary engineering and economic analyses for ten selected geothermal applications. Each application for which work was performed was deemed worthy of continued study based upon our knowledge of the state's growth rate, climate and industrial expansion. It is intended that the studies performed by the Arizona Geothermal Team will provide much needed technical assistance to potential geothermal developers in both the public and private sectors. The following sections present a review of work performed during the third quarter.

4.1 Space Cooling and Heating

Arizona has a vast market for geothermal heating and cooling systems. The market consists of hundreds of public and private buildings (schools, hospitals, colleges and military installations) as well as new housing subdivisions that may overlie geothermal resources suitable for development. Further, space cooling requires the use of electricity, currently the most expensive energy alternative in Arizona. In addition to these facts, Arizona's rapid population growth and rapid industrial expansion make geothermal space heating and cooling an attractive energy alternative for Arizona.

With these facts in mind, the Arizona Geothermal Team has undertaken two types of studies involving the use of geothermal energy for space heating and cooling. The first is to study the use of geothermal energy space conditioning for new residential districts. Currently, work under this task is proceeding in conjunction with John F. Long Homes, Inc. of Phoenix, Arizona. The newly planned subdevelopment is known as Maryvale

Terrace and is located on the west side of Phoenix. The second task is to study the applicability of geothermal space conditioning for an as yet unknown industrial or commercial facility. When completed, both of these tasks should provide potential developers of geothermal resources with accurate information to assist them in their development plans.

4.1.1 Design Considerations for District Systems

The arrangement of the piping network is the first consideration in designing a district space conditioning system. For a good balance between economics and reliability of supply, a radial network is preferred. However, such a network is often impractical or uncommon for residential districts within the United States.

As was mentioned, the first task involved a preliminary assessment of what we shall call a district space conditioning system. To date, there are no operational district space heating and cooling systems in the world. However, district heating systems for entire communities have been operational for decades in such European countries as Finland, Sweden and Denmark. During the third quarter, efforts were expended to study the design technologies applied in these European district heating systems in order to provide advice to potential developers within the State of Arizona.

Piping networks for district space conditioning systems must meet four general considerations. First, the piping system must have good resistance to corrosion. This is especially true if geothermal waters are to be used directly in the distribution networks. Second, the piping system must employ a simple means of accommodating thermal expansion. Third, pipes should be of standard length and easy to handle. Lastly, the pipes should be easy to lay and easy to bend, thereby minimizing installation expenses. Careful consideration of these four criteria in the design phase can significantly impact the reliability and maintenance of the piping network.

In deciding which pipe to use, several options are available, each with advantages and disadvantages. Pipe is generally available in four materials, steel, copper, concrete and plastic. Concrete pipes are used for district heating pipes greater than 12 inches (30 cm) in diameter and are usually insulated with insulating shells. One serious drawback to using concrete piping is the high friction factor, which makes it expensive to pump water from one location to another. Steel pipes are used for both primary and secondary systems that require diameters between 3 inches (8 cm) and 12 inches (30 cm). Copper pipes are most suitable for primary or secondary distribution systems requiring diameters below 3 inches (8 cm). In addition, copper pipes have excellent corrosion resistance and are flexible and easy to bend. Flow velocities of up to 10 meters per second are also possible with copper pipe without risk of damage to the tube. Plastic pipes are manufactured of high density crosslinked polyethylene of high molecular weight. The flexibility of plastic pipe enables them to be installed and connected at low cost. Plastic pipes are fully resistant to corrosion and are ideal for floor heating systems if the maximum flow temperature does not exceed 95°C and the pipe diameters are less than 3 inches (8 cm). As becomes clear, the choice of piping materials can have a significant impact on the reliability and maintainability of a district heating and cooling system.

Once the piping materials have been chosen, the next decision to make is in choosing the proper type of insulation. Many insulating materials are commercially available; however, only three are discussed here. The first is mineral wood insulation, which consists of grooved disks with associated covers. One benefit of using mineral wood is that the element can easily be jointed to provide smooth bends when laying the pipe. The second option is to insulate with glass wool. Glass wool is water repellent and can withstand temperatures of up to 400°C, though its best insulating characteristics are realized at a temperature of 50°C. The third option is polyurethane foam, not only the most common insulating material in Europe but also the best material in terms of heat transfer and water absorption.

The piping and insulation is then protected in a prefabricated concrete duct. The cross section of these ducts should contain two pipes with about five centimeters of insulation resting about 10 centimeters above a trench bottom. The minimum earth coverage should be .5 meters. Parts of the concrete will require high quality and should be manufactured at the factory. Six meter sections weighing approximately 2.6 tons are preferred so as to minimize transportation problems. It should be noted that dryer climates, such as in southern Arizona, will relax these standards considerably.

Each concrete duct should be placed in a trench so that the top of the duct is between .5 and 15 meters below the surface. Trenches in Europe are designed to withstand an axial load of 10 tons and a cover pressure of 7 atmospheres. Since the trench is not heat sensitive, temperatures between 0°C and 100°C are acceptable.

As has been implied, trenches should protect the pipes from freezing and also from moisture. Several steps can be taken to minimize the effects of moisture. The concrete should be waterproofed and the longitudinal joint between the structure and the base plate should be made out of asphalt. If followed, these suggestions will minimize the effects of heat loss and corrosion.

In constructing the trench, several steps are involved. Following excavation, crushed stone 15 centimeters thick is placed on the bottom and is carefully levelled. A base plate consisting of concrete and asphalt is then laid. The concrete duct molds are then placed on the base plate and sealed with cement. After the cement hardens, hot asphalt is used to seal the cross sectional and longitudinal joints.

Primary and secondary distribution systems typically use copper-polyethylene materials. Systems constructed of these materials can withstand a continuous pressure of 1.6 mpa at 120°C. The copper pipes are flexible and should be laid in a sinousoidal pattern. This allows the pipes to expand and the amplitude of the curve will increase as the temperature of the fluid increases. Copper pipes can be laid around obstacles and can follow the topography of the ground, thereby reducing excavation costs.

Cross-pieces, T-pieces, transition pieces and bends are also used in the system. They are insulated with high density polyurethane foam and act to control the small axial forces caused by thermal expansion. It is also recommended that when laying long pipes without branches, a

T-piece without the branch plugged should be used at intervals of 100 meters.

For lower temperature circuits, plastic pipe is commonly used. Plastic piping is fully resistant to corrosion and is designed for a maximum flow temperature of 95°C and a maximum pressure of .6 mpa. It is constructed of high density cross-linked polyethylene and is easy to handle, bend, cut and connect. The workability of these pipes enable them to be installed and connected at considerably low cost. Further, the pipes are supplied in coils of 100 meters thus facilitating long and jointless installations. They are especially ideal for floor heating systems.

In conclusion, concrete is the only material that should be used for primary lines with diameters larger than 12 inches (30 cm). If other materials such as steel or copper are used, the piping system becomes very expensive. However, large concrete pipes are difficult to handle, transport, store, install and construct. They are also very rough, implying a high friction factor which results in increased pumping costs.

For small communities the hot water demand is not too large; therefore, pipes with diameters greater than 12 inches are not necessary. In this case, steel pipes with diameters between 3 and 12 inches should be used. Polyurethane foam should be used over polyethylene foam as the insulating material because it is better in terms of heat transfer and water absorption.

For small communities requiring pipes less than three inches (8 cm) in diameter, two options are available. When the water temperature exceeds 95°C, copper pipe should be used. Not only does it have excellent corrosion resistance but its flexibility makes it easy and simple to install thereby reducing installation and connection costs. Polyurethane or polyethylene can be used as the insulating material.

If the water temperature is less than 95°C, plastic pipe should be used. Plastic pipes are simple to install and connect thereby reducing installation costs. Further, insulation is not required for plastic pipe, again reducing installation costs. Other advantages also include reduced friction factor, low corrosion factor and easy repair of mistakes. It is felt that most systems installed in Arizona could use plastic pipe.

4.1.2 Potential Barriers to District Systems

As stated earlier, cooling and heating of entire subdivisions appears to be an attractive geothermal application for Arizona. The economics of such systems are reasonable and the required technology is commercially available. However, other factors exist that may act as a barrier to development of district systems. Of major concern is the legal and regulatory treatment of such systems by the Arizona Corporation Commission. Conflicts and ambiguities exist in current Constitutional and statutory provisions relating to geothermal district heating/cooling systems. These could impede the development of such systems in Arizona.

The Arizona Corporation Commission has jurisdiction over "public service corporations." Article 15, section 2 of the Arizona Constitution defines such corporations as follows:

> All corporations other than municipal engaged in carrying persons or property for hire; or in furnishing gas, oil, or electricity for light, fuel, or power; or in <u>furnishing water</u>

for irrigation, fire protection, or other public purposes; or in furnishing, for profit, hot or cold air or steam for heating or cooling purposes; or engaged in collecting, transporting, treating, purifying and disposing of sewage through a system, for profit; or in transmitting messages or furnishing public telegraph or telephone service, and all corporations other than municipal, operating as common carriers, shall be deemed public service corporations.

The underlined provisions indicate provisions relating to geothermal development.

It appears that neither the quoted provisions, nor judicial authority interpreting them, provide coherent guidelines for regulatory treatment of geothermal direct uses. According to a 1957 Arizona Attorney General's Opinion, a corporation which circulates hot and cold water for heating and cooling residences and business establishments would be considered a public service corporation even though the Constitutional definition does not mention hot and cold water for heating and cooling purposes. Thus a Certificate of Public Convenience and Necessity must be obtained from the Corporation Commission. In the 1966 Arizona Supreme Court case Williams v. Pipe Trades Industry Program of Arizona (100 Ariz. 14,409 P. 2d720), the Court concluded that "there ... is no contemplated transfer of possession" in supplying water for heating and cooling purposes as distinguished from consumptive uses. Such activities are therefore outside the Corporation Commission's jurisdiction. Those supplying water for heating and cooling purposes would be exempt from Commission jurisdiction, while those supplying steam for heating and cooling purposes would be subject to Commission jurisdiction.

Whether this precedent will hold today is uncertain.

The likelihood of regulation is even more uncertain when it comes to Arizona's treatment of "pipeline corporations." Article 15 section 2 of the Constitution defines public service corporations to include "common carriers." Article 15 section 10 of the Constitution declares that common carriers include "... all ... pipeline corporations ... for the transportation of water, oil or other property for profit." However, Arizona statues define "pipeline" as "all property used in transmission thru pipelines for compensation of air, steam or fluid substances, except water, through pipelines."

Such ambiguities in regulations may prove to be a deterrent to the development of district heating and cooling systems and other direct uses utilizing geothermal energy. It may be that an Arizona Attorney General's Opinion regarding the status of a geothermal district heating/cooling system (whether it is considered a public service corporation or not) may be sufficient to clarify the regulations. However, litigation may prove to be the only way of clarifying the regulations. As it stands, until and unless Arizona clarifies its Constitutional and statutory provisions in this area, it will be difficult to predict the legal and regulatory treatment of geothermal direct uses.

4.1.3 Heat Pumps for Heating and Cooling

One characteristic of geothermal resources in Arizona is the fairly low temperature of the resource. Often the temperatures encountered are less than suitable for driving an absorption chiller. In these circumstances the use of groundwater heat pumps can turn low temperature energy into economically usable energy for both heating and cooling. During the third quarter of 1980, an investigation of heat pumps was undertaken in order to provide potential developers of geothermal energy with needed facts relating to heat pump technology.

Heat pumps are conventional vapor compression refrigeration machines which can drive heat from areas of lower temperature to areas of higher temperatures. When used with geothermal water, heat pumps allow the extraction of more energy per unit mass than heat exchangers can provide, so smaller flow rates are required. Also, because the heat is transferred from regions of lower to higher temperatures, the geothermal fluid can be at quite low temperatures. Therefore, shallow wells with fairly small flow rates and low pumping power requirements can be used as sources of energy by the addition of a heat pump to the system.

A schematic of how a heat pump works is presented in Figure 4-1 and accompanies the following discussion. As was mentioned, a heat pump is a machine which transfers heat from a low temperature source, T_c', to a higher temperature sink, T_h'. T_c and T_h are the temperatures of the working fluid within heat exchangers (HE) #1 and #2. $T_c \approx T_c' - 15^oF$ and $T_h \approx T_h' + 15^oF$. Throughout this system the working fluid is a mixture of its liquid and gaseous phases. The quality of the mixture or the amount of working fluid in the gaseous phase varies as it passes through each device in the system. The compressor and the expansion value keep the pressure in HE #1 low and the pressure in HE #2 high. Energy flows in the form of heat are denoted by $\dot{Q}$, and expressed by $\dot{W}$ when they are supplied by shaft work.

As the working fluid enters HE #1, it is primarily liquid. The heat flow from the low temperature source, $\dot{Q}_{in}$, is transferred to the working

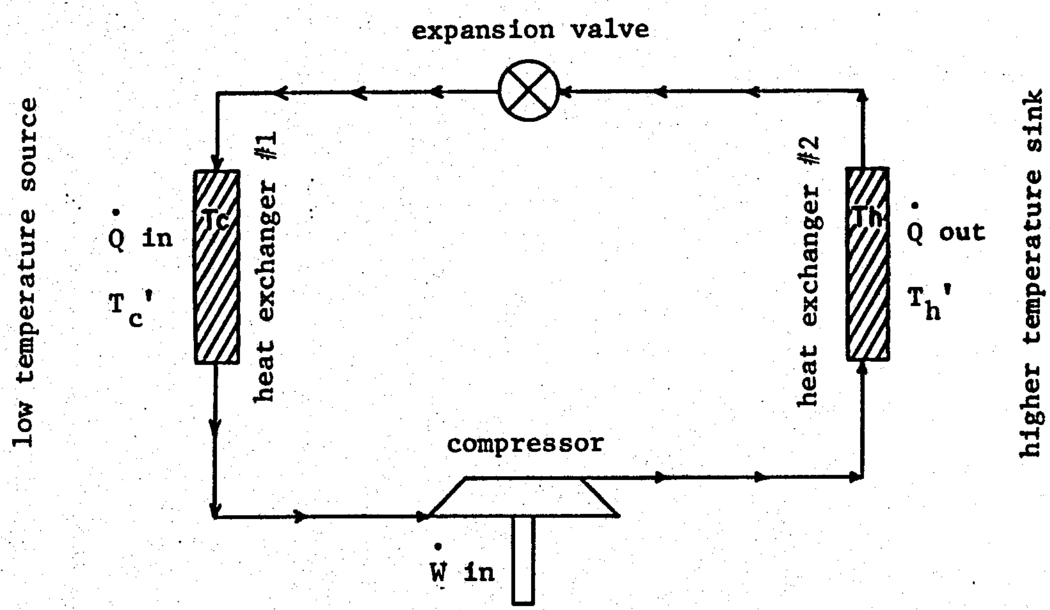


Figure 4-1: Heat Pump Schematic

fluid as some of the liquid phase evaporates due to the low pressure in HE #1. At this low pressure, T_c is above the working fluids boiling point.

The compressor adds more energy, $\dot{W}_{in}$, to the working fluid as it raises it to a higher pressure.

At this high pressure, T_h is less than the working fluid's boiling point, so a portion of the gaseous phase of the working fluid condenses in HE #2, releasing the heat flow, $\dot{Q}_{out}$, to the high temperature sink.

The pressure of the working fluid is then decreased by the expansion value, and the cycle begins again.

By conservation of energy arguments, it can be seen that

$$\dot{Q}_{out} = \dot{Q}_{in} + \dot{W}_{in}$$

Heat can be pumped in the opposite direction by reversing the direction of flow of the working fluid within the system. Heat pumps which provide heating and cooling do this by means of reversing valves and suitably designed heat exchangers and expansion valves.

The effectiveness of a heat pump is given in terms of a coefficient of performance or C.O.P. The C.O.P for a heat pump is defined as

$$\text{C.O.P.} \equiv \frac{\dot{Q}_{out}}{\dot{W}_{in}}$$

and usually lies in the range from 2.0 to 9.0 for this particular type (vapor compression) of heat pump. Other types of heat pumps have been designed, but will not be discussed, as they are not commonly used or available commercially as off-the-shelf items.

The absolute maximum C.O.P. that a heat pump can have for a particular application with T_h' and T_c' is called the Carnot C.O.P. and can be found by

$$C.O.P._{Carnot} = \frac{T_h'}{T_h' - T_c'}$$

where T_h' and T_c' are in terms of absolute temperature. The absolute temperature for the English system, $T(^oR)$, can be found as

$$T(^oR) = T\ (^oF) + 460$$

This equation tells us two important things about C.O.P.'s:

1. The C.O.P. increases as the difference $(T_h - T_c)$ decreases, and
2. the C.O.P. increases as the temperatures at which the system operates increases.

Therefore, the C.O.P. for driving heat from 150°F to 200°F is the same as for driving heat from 58°F to 100°F;

$$C.O.P_{Carnot} = \frac{660}{660-610} = \frac{560}{560-518} = 13.2$$

The actual C.O.P. of a system is rarely greater than 40% of the Carnot C.O.P. for that application.

Reversible heat pumps usually have two C.O.P.'s, one for heating and one for cooling. The heat pump can be designed so that either one is the larger of the two. This may be useful in some circumstances, such as here in Arizona where the cooling C.O.P. could be maximized to decrease the peak electrical power loads which occur here during the summer.

Finally, the C.O.P.'s for water to water heat pumps are the highest, followed by water to air, and then air to air machines. Also the C.O.P.'s for heat pumps which drive heat in only one direction are higher than the C.O.P.'s of reversible heat pumps.

4.2 Geothermal Power Plants

During 1979, a preliminary theoretical evaluation of a 50 MW geothermal power plant was completed for the Clifton area. This task was included for FY 1980 because a cost analysis was needed. This cost analysis was to be performed by NMEI; however, it appears that the NMEI computer model for electric power generation is not functioning properly. Also, NMEI doubts whether the program will be updated during the 1980 calendar year.

New work on this task includes interactions with Joe Hall of the Western Area Power Administration (WAPA). During the third quarter of 1979, there was a request from DOE Headquarters for the correlation of state geothermal resources with electrical grids as indicated on maps provided by WAPA and the Bonneville Power Administration (BPA). The objective was to identify and match geothermal resources with electric potential to municipal, cooperative or investor-owned utilities that could in turn benefit from WAPA/BPA transmission and marketing capabilities. The Arizona team in turn supplied DOE with a WAPA grid map (Figure 4-2) showing potential geothermal resources in Arizona which may have electrical generation possibilities and a table (Table 4-1) giving resource characteristics and locations.

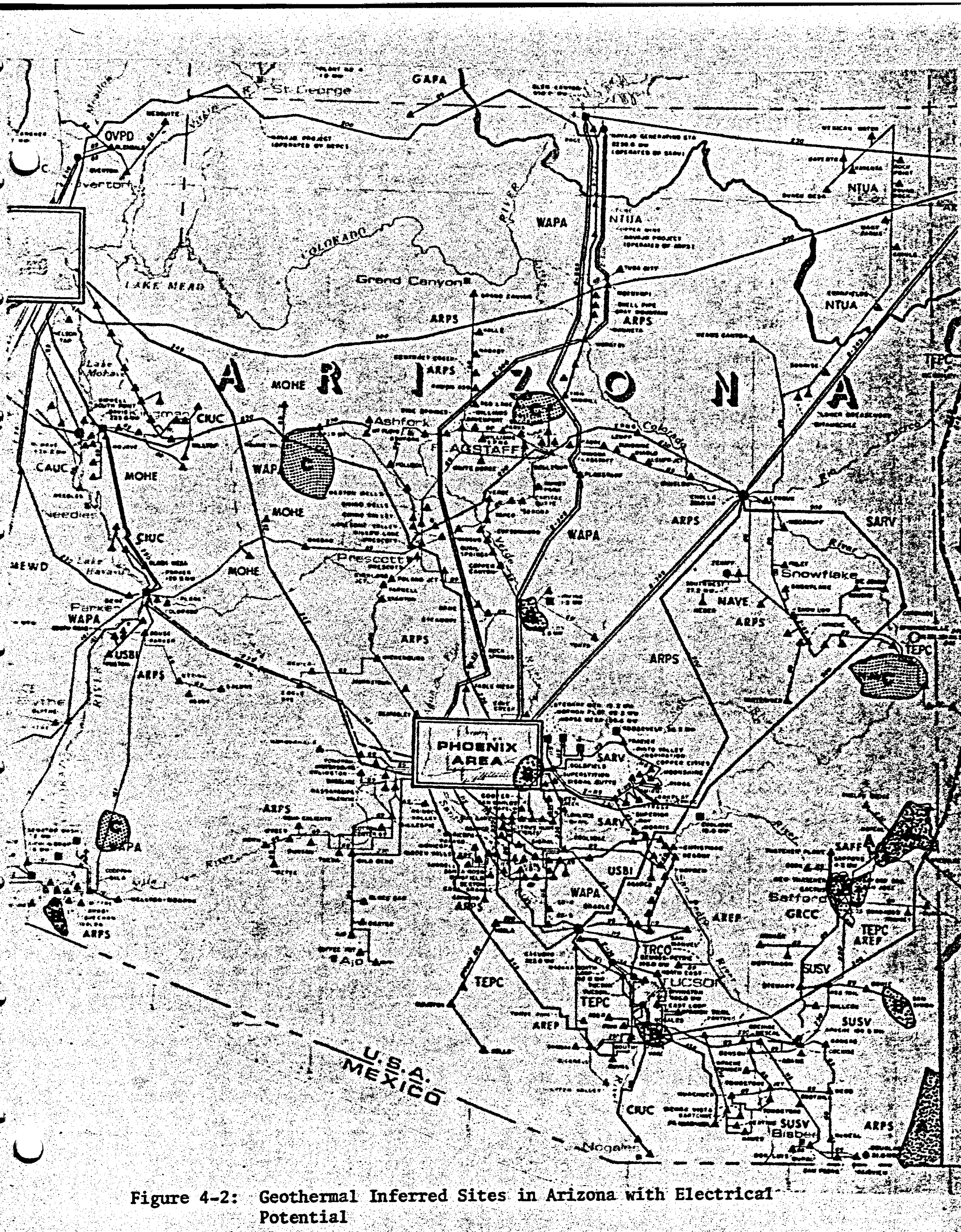


Figure 4-2: Geothermal Inferred Sites in Arizona with Electrical Potential

TABLE 4-1: Inferred Geothermal Sites with Electrical Potential

A. High temperature areas with good potential for binary cycle electrical generation.

Name	County	Location	Depth (km)	Temp. (°C)
1. Clifton Hot Springs	Greenlee	T4S,R30E	2.0	170
2. Eagle Creek Hot Springs	Greenlee	T4S,R28E	2.0	130
3. Gillard Hot Springs	Greenlee	T4S,R30E	2.0	140
4. Martinez Ranch	Greenlee	T3S,R31E	2.0	130
5. San Bernardino Area	Cochise	T20-24S,R29,31E	2.5	150

B. Inferred high temperature areas where additional resource assessment is needed.

1. Cactus Flat-Artesia	Graham	T7-9S,R26E	2.0	110
2. Buena Vista	Graham	T6-7S,R27-28E	2.0	120
3. San Simon	Cochise	T13-14S,R29-30E	2.0	120
4. Tucson Basin	Pima	T14-15S,R14-15E	2.5	130
5. Power Ranch Area	Maricopa	T1-2S,R6E	2.5	130
6. Alpine-Nutrioso	Apache	T5-7N,R30E	2.0	120
7. Verde Hot Springs	Yavapai	T11N,R6E	2.0	130

C. Areas with potential for hot dry rock technology

1. Springerville	Apache	T6-7N,R27-30E	na	na
2. Aquarius Mountains	Mohave	T17-22N,R8-12W	na	na
3. Dome Mountains	Yuma	T6-1S,R19-15W	na	na
4. Flagstaff	Coconino	T23-25N,R6-7E	na	na

Source: Jim Witcher, Arizona Bureau of Geology and Mineral Technology - Geothermal Group (1979).

4.3 Geothermal-Assisted Copper Dump Leaching

Work on this task, including the study of the use of chelating agents for the recovery of copper from leach liquors using solvent extraction is pretty much complete. Results of the study will be evaluated by a mining process expert (from Phelps Dodge) who is to begin work at the Arizona Bureau of Geology and Mineral Technology.

4.4 In-Situ Leaching of Uranium, Zinc and Copper

Work on this task is also pretty much completed. As with the copper-dump leaching task, results will also be evaluated by the Bureau's mining process expert.

4.5 Geothermal Steam Turbine Pumping

Work on this task consisted of several interactions with Hugh Matthews and Warren McBee of Sperry Research Center. Sperry Research Center, the coporate research facility of Sperry Corporation, has been designing and field testing a new geothermal technology that could greatly improve future utilization of geothermal energy in Arizona.

Their new technology, a steam powered downhole geothermal pump, is designed to boost efficiency for high volume pumping. This pump could be used in irrigation pumping and other direct use applications. Instead of using conventional shaft driven or submersible pumps, Sperry's system would utilize the downhole energy of the geothermal brine. The pump would cut energy costs because once fired, it can virtually drive itself.

Arizona appears to exhibit certain characteristics which are necessary for Sperry's pumping system to work. These characteristics are the following:

- A geothermal resource of at least 200-250^{o}F (93^{o}-121^{o}C) at some depth less than 10,000 feet (3048 meters).

- Shallow groundwater aquifers of less than 1000 feet (305 meters) at the same location as the geothermal resource.
- Wide temperature extremes between the two waters.

Sperry has proposed a three phase project in conjunction with the Arizona Geothermal Team. These phases are as follows:

- Phase one would consist of a six-month study to define the number and locations of occurences of the previously mentioned characteristics.
- Phase two would consist of a six-month study to do economic studies of the locations where the characteristics do occur.
- Phase three, pending favorable results on the previous two phases, would consist of a field experiment or demonstration project.

If the three phases were successful, it would lead to product development and marketing by Sperry.

4.6 Direct Thermal Use For Food Processing

4.6.1 Introduction

Arizona has a few food processing plants, located mainly in the Phoenix and Tucson areas. Typically Arizona producers have sent their crops to be processed in Wisconsin, Minnesota and California. The food processing industry in Arizona is attractive provided that a stable, cheap supply of produce is locally grown, and there is a cheap source of energy available. For these reasons and the unpredictable supply of water in the state the industry has not grown rapidly in Arizona.

There are two major processing applications which illustrate the above. The processing of chili peppers in Douglas, Arizona has been profitable because Arizona is one of the largest producers of chili peppers and they are cheap to grow. The canning and dehydrating operations are performed in Douglas. Pickling cucumbers is another area in which processing was started in Arizona; however, due to large water requirements, this process is expected to be discontinued.

4.6.2 Description of Methodology

The methodology for this evaluation was to identify the future for food processing in Arizona and assess the potential for geothermal energy use within the industry.

4.6.3 General Overview of Economic Markets

Arizona potentially has a large market for use of geothermal energy as a relatively cheap energy source in order for the food processing industry to become attractive. This industry is a good potential user of moderate-temperature geothermal resources, similar to the industries of the Snake River Valley of Idaho. Preliminary estimates of the potentially usable energy in geothermal reservoirs indicate that the moderate temperature geothermal resources (90^{o}-150^{o}C) could provide the energy needed for food processing.

4.6.4 Geothermal Application Evaluation

The purpose of this geothermal application evaluation is to evaluate the use of geothermal energy for food processing.

A major use of process heat is in the cleaning and sterilization of cans and jars. This requires temperatures in the range of 180 to 190^{o}F (82^{o}-88^{o}C). Another major use for process heat is in the sealing and sterilization of canned products.

The primary medium for process heat in this industry is steam.

Figures 4-3, 4-4 and 4-5 give a generalized flow chart of the three sub-categories processes. Due to different plant types and processes, a more detailed analysis was not conducted.

4.6.5 Summary and Recommendation

The use of geothermal energy for the food processing industry could provide the relatively cheap source of energy necessary to encourage the development of the food processing industry in Arizona. It is thought that if the present trend of price increases in conventional energy sources continues, geothermal energy will become cost competitive with electricity and gas during the next decade.

It is recommended that this application be considered further during the FY 1981 of this project. Presently the College of Agriculture at the University of Arizona has shown interest in developing this application for industries in the Phoenix area.

4.7 Geothermal Energy Utilization in Modern Cattle Feedlots

4.7.1 Introduction

The cattle feedlot business is an important segment of the Arizona economy. Arizona ranks 10th in size in the United States, based on its own agriculture being supplemented by the importation of grain feed from Texas and feeder cattle from Texas, Colorado and Mexico. Arizona also provides much of the necessary grain from wheat and maize, and its own protein from alfalfa and cottonseed meal. The state has 128 cotton gins to provide the cottonseed meal. Most of the feedlots are moving from the Phoenix area to the agricultural belt extending from Casa Grande to Yuma. Most of the feedlot beef is exported to California.

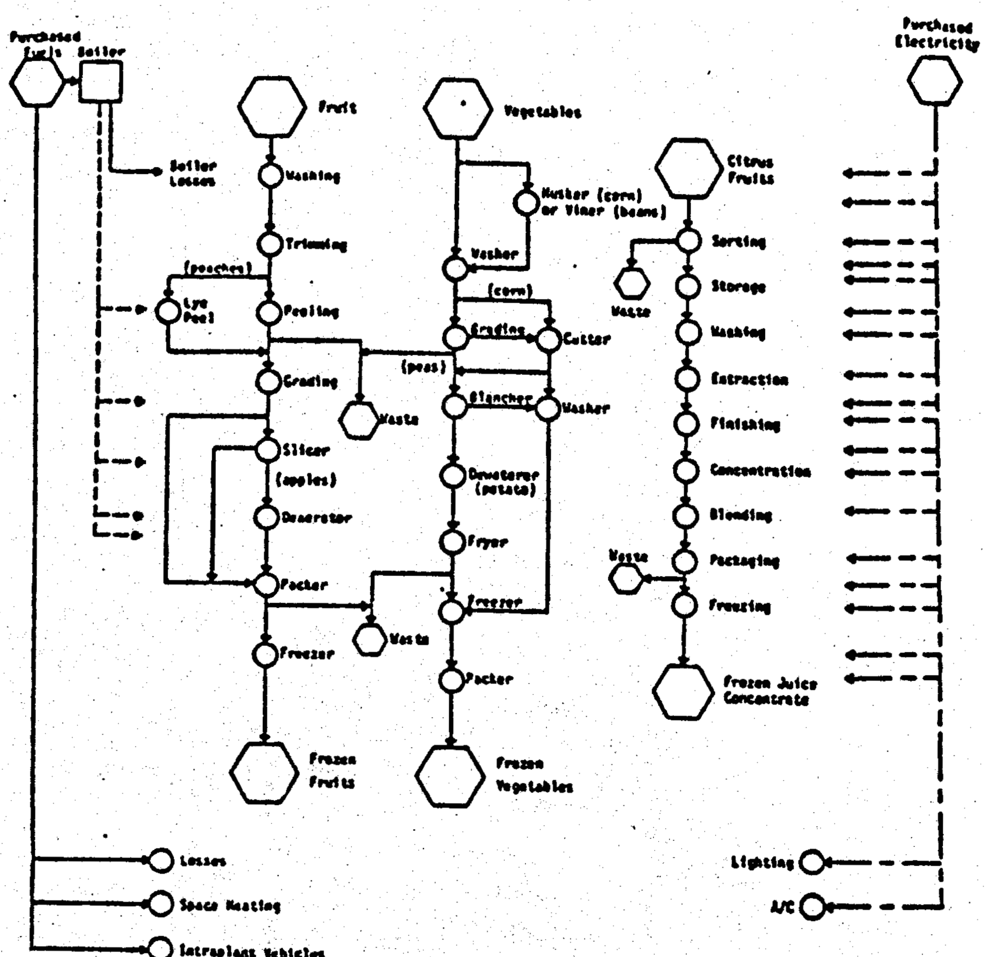


Figure 4-3: Material and Energy Flow--Frozen Fruits, Vegetables and Juice Concentrate
Source: Energy-Saving Techniques for the Food Industry, Noyes Data Corporation, Park Ridge, NJ, 1977

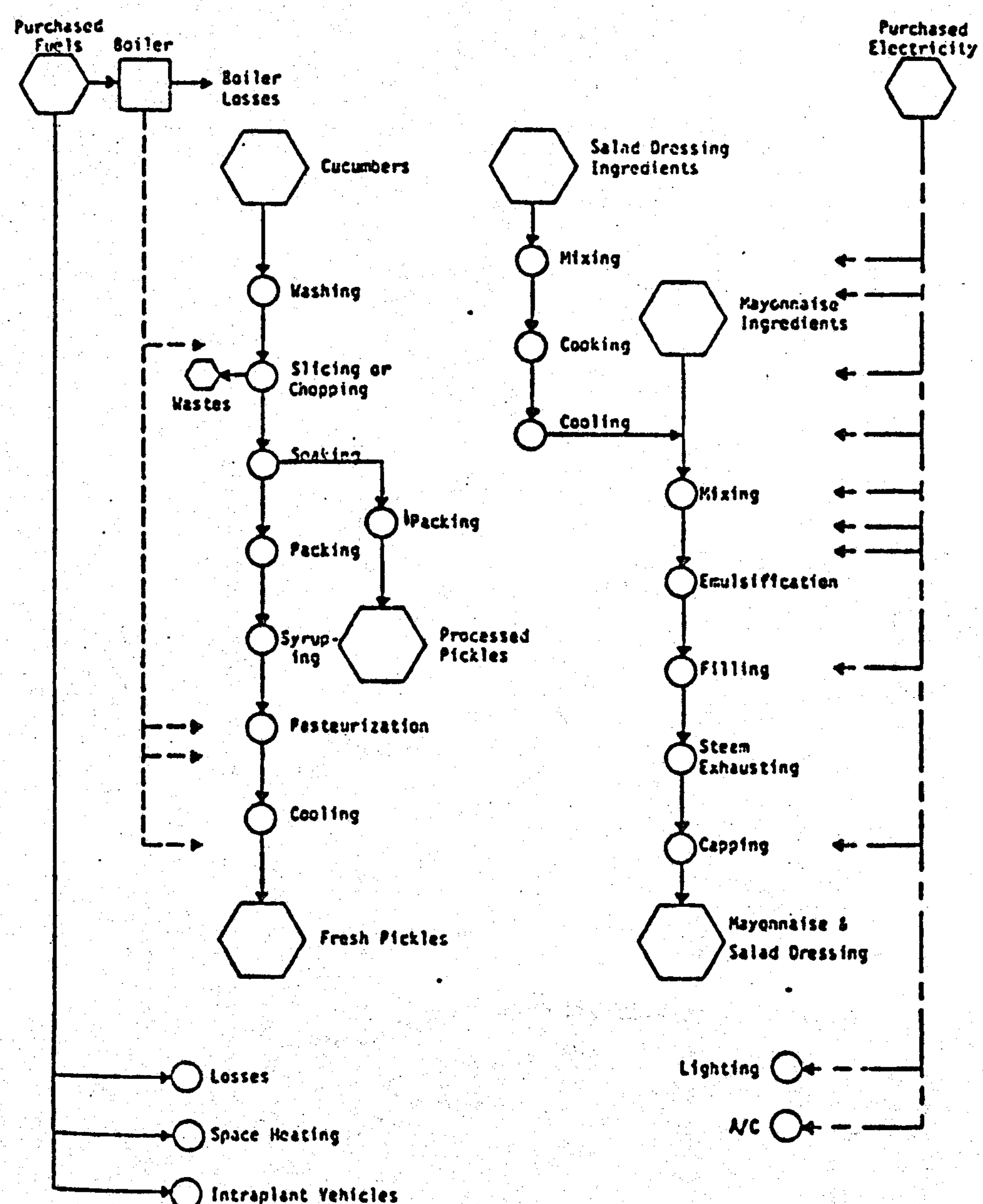


Figure 4-4: Material and Energy Flow--Pickles, Sauces and Salad Dressings
Source: Energy-Saving Techniques for the Food Industry, Noyes Data Corporation, Park Ridge, NJ, 1977

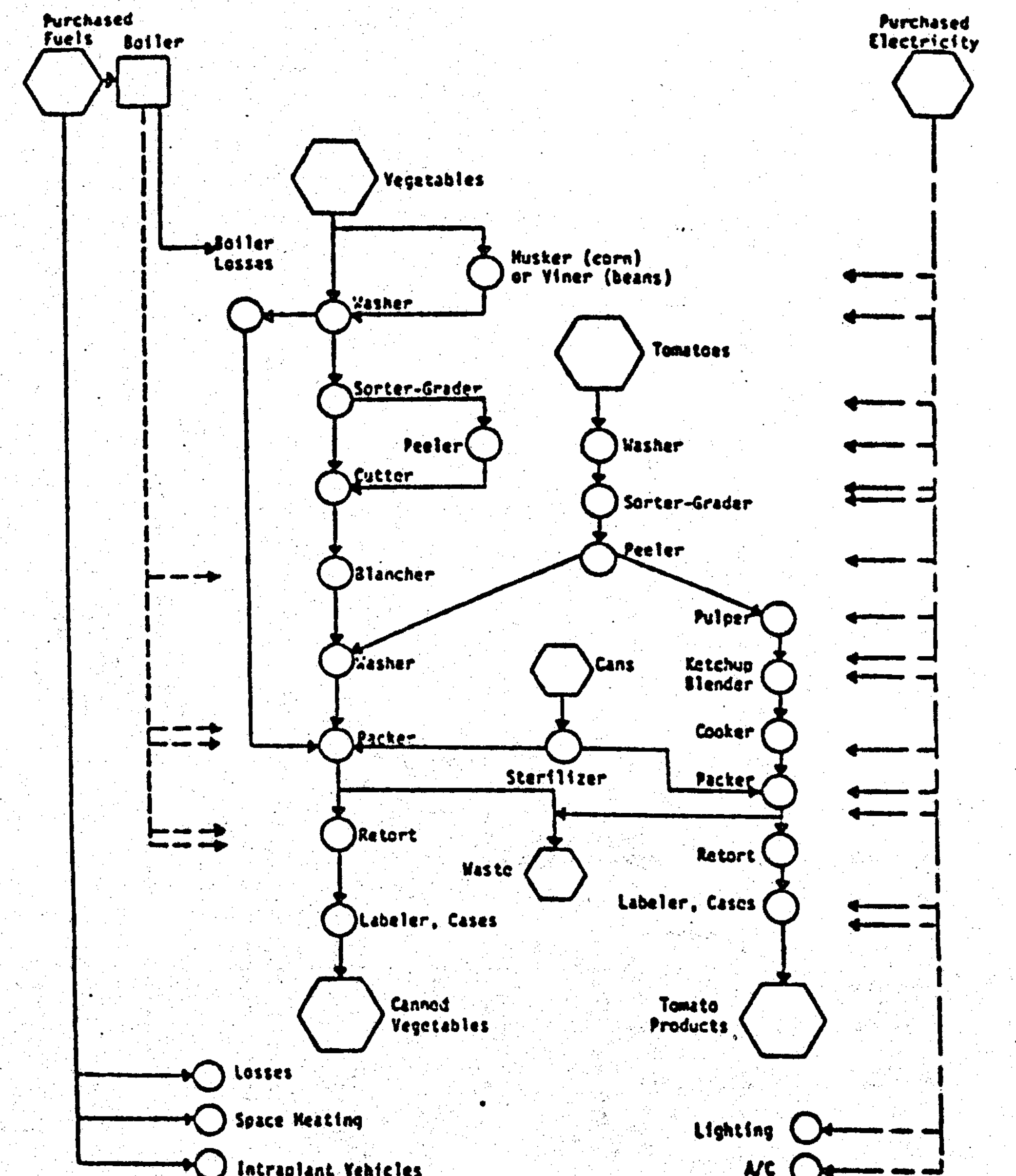


Figure 4-5: Material and Energy Flow--Canned Vegetables and Tomato Products Segment of Canned Fruits and Vegetables

Source: Energy-Saving Techniques for the Food Industry, Noyes Data Corporation, Park Ridge, NJ, 1977

4.7.2 Description of Methodology

The methodology for this evaluation was to identify the largest cattle feedlots in Arizona and their location in terms of a potential geothermal resource. Essentially all of the energy requirements of the new developments in modern cattle feedlot operations are low temperature in nature. Geothermal energy may be important in these considerations, especially since these industries already have incentives to go to more sophisticated operations and also to more remote areas to minimize their environmental problems.

4.7.3 General Overview of Geothermal Use Potentials

The use of geothermal resources for cattle feedlots is particularly attractive when combined with ethanol production. If the government decides to subsidize ethanol production as a gasoline additive, it becomes important to see how the by-products of an integrated cattle feedlot industry would fit into such a situation.

4.7.4 General Overview of Economic Markets

Modern technology is beginning to impact upon the cattle feedlot business, especially due to the pressures of rising grain and energy costs. There is a fundamentally sound basis for expecting future (also existing) feedlots to become larger, more integrated business operations. Presently 64.5 percent of the feed cattle in Arizona are now produced in lots of 1,000 head and larger.

A feedlot has many requirements. The critical temperature of feeder cattle gaining 1.5 kg per day is from -31°C in November to -48°C in January.

The water and power requirements are extensive. A 700 - 1,000 lb.

feeder steer consumes 10-20 gallons of water per day. Additional water is needed for the feedmill, equipment, labor and other uses. Water from muncipal water systems is usually too expensive to use for cattle. The water supply generally comes from wells or irrigation districts.

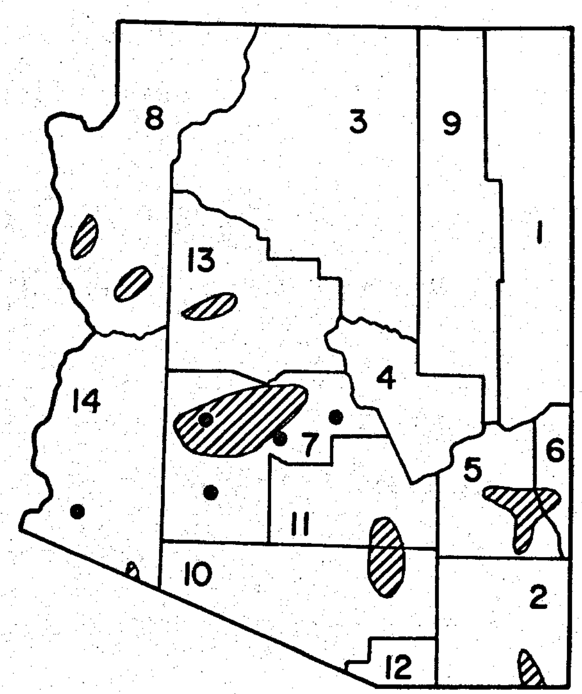
Electricity and gas or oil is used in feedlots to power the motors and to fire the boilers used for steaming or rolling in the feedmill. Preliminary estimates of the potentially usable energy in geothermal reservoirs indicate that the moderate temperature geothermal resources (90^{o}-150^{o}C) could provide the energy needed in cattle feedlots. Consequently economic markets for these geothermal resources should be available especially due to the pressures of rising grain and energy costs.

4.7.5 Resource Evaluation

The largest cattle feedlots in Arizona are in Maricopa and Yuma ounties. As shown in Figure 4-6, the majority of the feedlots lie close to or within a potential geothermal area.

County Names

1. Apache
2. Cochise
3. Coconino
4. Gila
5. Graham
6. Greenlee
7. Maricopa
8. Mohave
9. Navajo
10. Pima
11. Pinal
12. Santa Cruz
13. Yavapai
14. Yuma



● Feedlots with # of cattle > 70,000 heads

Geothermal prospects

Figure 4-6: Cattle Feedlot Operations and Geothermal Resources in Arizona

4.7.6 Geothermal Application Evaluation

Feed processing in beef cattle feedlots comprises the largest thermal energy for process use within the agricultural sector. Typically, the raw grain component of the feed is steam moistened prior to mixing with other ingredients in the final feed product. Of all the agricultural thermal processes examined, cattle feed processing offers the most promising potential for geothermal energy.

The feed processing chain requires natural gas to deliver steam to the boiler at atmospheric pressure. Steam is then funneled through holes in order to cook the grain. Temperature requirements for steam generation are in the 212-215°F (100°-102°C) range, ideal for geothermal energy use.

4.7.7 Summary and Recommendation

Modern technology is beginning to impact upon cattle feedlots creating a trend for feedlots to become larger business operations. As energy costs rise the economics of integrating gasohol production with the by-products of a cattle feedlot industry becomes more attractive.

Essentially all of the energy requirements of the new developments in modern cattle feedlot operations are low-temperature in nature. Thus, geothermal energy may be important for these considerations, especially since these industries already have incentives to go to more sophisticated operations and at the same time to move to more remote areas to minimize their environmental problems. The proposed evaluation of this geothermal energy application in 1981 would find wide interest in Arizona and possibly could provide leadership for similar evaluations in California, Texas and other Western states that depend heavily on grazing and feedlot operations as part of their economy.

4.8 Geothermal-Assisted Coal Power Plants

4.8.1 Introduction

As stated earlier, there are a few coal-fired power plants under design or in construction in Arizona which overlay potential geothermal resource areas. Two of these plants include one in Springerville, Arizona owned by Tucson Electric Power Company and a second tentatively planned by Arizona Public Service Corporation near Bouse, Arizona. Both sites appear to be near potential geothermal resource areas and could possibly integrate the use of geothermal energy with their coal-fired plants. Further, as Table 4-2 illustrates, the majority of further additions to Arizona's power production capability will be coal-fired plants. Therefore, future consideration of hybrid coal/geothermal power plants may be of benefit to the state.

Research into utilizing geothermal energy resources in coal-fired power plants was completed in 1978 for the City of Burbank, California by the Ralph M. Parsons Company. During the third quarter of 1980, a review of this study was completed by the Arizona Geothermal Commercialization Team. In essence, the hybrid system combines geothermal energy and coal to increase the thermodynamic advantages of a single coal-fired power plant, while burning lesser quantities of fossil fuel.

4.8.2 System Description and Methodology

The conventional method of utilizing geothermal energy for electrical production is to generate saturated vapor from saturated liquid and then introduce it into a turbo-generator. The liquid phase expands isenthalpically through one or more additional stages of separation. The hybrid system,

Table 4-2: Future Availability of Electricity Production

POWER PLANT	NO. OF UNITS	LOCATION (NEAREST TOWN)	DATE COMMERCIAL	OWNERSHIP - BY PERCENTAGE	TYPE OF GENERATION	TOTAL NET CAPACITY (Mw)	NET CAPACITY AVAILABLE TO AZ UTILITIES[1]
Additions							
Apache	1	Willcox, Arizona	Aug, 1979	AEPC 100%	Steam Gen - Coal	175	175
Coronado	1	St Johns, Arizona	Aug, 1979	SRP 70%, Other[7] 30%	Steam Gen - Coal	350	245
	1	St. Johns, Arizona	Late, 1980	SRP 70%, Other 30%	Steam Gen - Coal	350	245
	1	St. Johns, Arizona	Indefinite	SRP 70%, Other 30%	Steam Gen - Coal	350	245
Cholla	1	Joseph City, Arizona	1980	APS 100%	Steam Gen - Coal	250	250
	1	Joseph City, Arizona	1981	APS 100%	Steam Gen - Coal	350	350
	1	Joseph City, Arizona	Indefinite	APS 100%	Steam Gen - Coal	350	350
Springerville	1	Springerville, Arizona	June, 1985	TEPC 100%	Steam Gen - Coal	350	350
	1	Springerville, Arizona	June, 1987	TEPC 100%	Steam Gen - Coal	350	350
	1	Springerville, Arizona	About 1991	TEPC 100%	Steam Gen - Coal	350 flexible	350 flexible
Craig	1	Craig, Colo.	Sept. 1979	SRP 29%, Other 71%	Steam Gen - Coal	400	116
	1	Craig, Colo.	1980	SRP 29%, Other 71%	Steam Gen - Coal	400	116
San Juan	1	San Juan, N.M.	1980	TEPC 50%, Other 50%	Steam Gen - Coal	468	234
	1	San Juan, N.M.	1995	TEPC 60%, Other 40%	Steam Gen - Coal	468	281
Palo Verde	1	Buckeye, Arizona	1982	APS 29.1%, SRP 29.1%, Other 41.8%	Nuclear	1,270	739
	1	Buckeye, Arizona	1984	APS 29.1%, SRP 29.1% Other 41.8%	Nuclear	1,270	739
	1	Buckeye, Arizona	1986	APS 29.1%, SRP 29.1% Other 41.8%	Nuclear	1,270	739
TOTAL ADDITIONAL CAPACITY						7,771	5,874

PLANNED DECREASES	BEGINNING DATE	ENDING DATE	EXPLANATION		NET CAP. INVOLVED (Mw)
To Colo - UTE Power Co from SRP	January, 1982	None	Recapture of 30% of Hayden #2		78.3
Total Decreases					78.3
OVERALL INCREASE				7,771	5,795.7

List of Abbreviations

AEPC - Arizona Electric Power Cooperative
APS - Arizona Public Service
SRP - Salt River Project
TEPC - Tucson Electric Power Company

on the other hand, is more efficient than the conventional system from a thermodynamic sense, but the economics of the hybrid system are still in doubt. The answer to the economic questions depends on site specific conditions, since a hybrid plant would have to be located near the geothermal resource.

In the hybrid cycle, saturated water is used to preheat the boiler feedwater; therefore, less steam is required. Consequently, for a fixed power output the coal requirement will be reduced and a smaller boiler size will be required. However, the reduction in steam increases the mass flow for the intermediate and low pressure turbine; therefore, larger turbines are required for the hybrid plant. The final result is more efficient use of both geothermal energy and the extraction steam.

Two methods of preheating the boiler feedwater are available, the flash system and the binary system. In the flash system, saturated vapor from the brine is produced. In the binary system, vaporizing a secondary organic fluid requires heat transfer with a large temperature difference between the organic fluid and the brine. This cycle maximizes the use of the geothermal resource in terms of available work and power. The binary system is capable of utilizing between 60 percent and 80 percent of the hydrothermal energy.

Several general considerations must be adhered to before a decision regarding a hybrid plant can be made. Piping high temperature geothermal fluid over long distances is impractical; therefore, the hybrid plant should be located near the geothermal resource area. In most cases, geothermal resources are not optimally sited with respect to sources of coal, fresh water, or transmission networks. The economic competitiveness of the hybrid system depends on the particular geothermal resource and its location.

In order to properly compare hybrid systems with conventional coal-fired plants, one must select a reference all coal plant, a range of plant sizes and a geothermal resource. The reference all coal plant is necessary for comparing the economic performance of the hybrid plant. The coal-fired plant is a guide for calculating the costs of the major components. The range of plant sizes to be compared to the reference all coal plant should not be smaller than those typical of coal-fired power plants. Finally, the geothermal sites should be chosen to exhibit a wide variety of resource conditions.

For the City of Burbank study, the Intermountain Power Project (IPP) was selected as the reference coal plant for cost considerations in the hybrid-plant analysis. The IPP and hybrid plants would face similar requisites relative to federal, state and local regulations, similar costs for land, components and labor and similar environmental requirements. Economic calculations between the two plants would vary as the temperature of the geothermal resource, cost of coal, cost of makeup water, cost of electrical transmission, seismic factors and climatic parameters change.

Most of the power plants that are currently operating or under construction have a generating capacity between 250 MW and 750 MW, therefore, a cycle was selected such that it minimized the cost of power for the 750 MW and 250 MW hybrid plants. Several assumptions were made for comparison purposes. First, the IPP and the hybrid plants that are being compared utilize a subcritical steam cycle. Second, the IPP plant used a single reheat cycle. Analysis indicated that hybrid cost optimization would occur when reheat enthalpy was less than the amount normally used. Third, all of the extraction steam in the hybrid plant would be used only to heat feedwater to temperatures above the ones achieved by the use of geothermal fluid. It appeared that a single extraction minimized the hybrid plant complexity. Lastly, the IPP cycle used a turbine with a 90 percent efficiency rating and the hybrid cycle an overall turbine efficiency of 85 percent. In comparing the two systems, the assumptions approximately balanced out.

The costs for the IPP design were used as a base for indexing all costs. The cost functions for the power plant optimization calculations fell under three categories: plant component capital costs, site-specific costs and plant financing costs. Primary emphasis was placed on establishing power plant costs in a relative sense rather than an absolute sense. Consequently, the results cannot be generally applied to all planned coal-fired power plants.

A number of parameters were considered under each of the above three categories. Plant component capital costs included:

1) land and land rights

2) structure and improvements

3) station electricity, miscellaneous equipment and tools

4) auxiliary boiler, steam, fuel, mechanical systems

5) coal handling

6) industrial waste

7) steam generator

8) turbine generator

9) feedwater heat exchange

10) flash task separator

11) condenser

12) cooling tower

13) pumps

14) construction, labor, management

Site-specific costs included:

1) drilling and surface piping costs for geothermal wells

2) coal

3) cooling water

4) transmission

5) seismic risk

The annual average plant costs take into account assumed inflation rates, bond interest, and coal price increases.

In the hybrid cycle, any thermodynamic parameter may be specified as an optimizable parameter. The following were considered when performing optimization calculations:

1) turbine inlet temperature and pressure

2) geothermal feedwater heater - outlet temperature

3) condensate water temperature

4) superheater pinch point, ΔT

5) resuperheater pinch point, ΔT

6) geothermal-feedwater heater pinch point, ΔT

7) condenser pinch point, ΔT

8) preheat air temperature

9) cooling tower reject temperature

In cases where the brine chemistry affected the performance of the heat exchanger, the brine could be flashed and the vapor produced could be used to preheat the feedwater. This effectively isolated the heat exchanger from any unfavorable effects of the brine chemistry. This approach led to the idea of the multi-stage flash/separator.

In choosing the number of flash/separators, it was necessary to look at the balance between heat transfer efficiency and the cost of using additional stages. Sometimes additional analysis was required to determine whether or not five stages represented the precise cost optimum. The choice of the flash/separator method increased the heat transfer coefficient three times.

4.8.3 Thermodynamic Behavior

For purposes of interpreting the conclusions of the study some notation must be defined. Consider a geothermal power plant that accepts a mass, M_g, of geothermal fluid and produces work, W_g; and a fossil fuel plant that accepts a mass, M_f, of fuel and produces work, W_p. If the combined mass input M_g+M_f is used in a hybrid plant, it would produce work, W_h. A hybrid plant would be thermodynamically superior if in using the same inputs that $W_h > W_g+W_f$. A figure-of-merit is then defined to be $F \equiv \frac{W_h}{W_g+W_f}$. A hybrid plant is thermodynamically superior whenever $F > 1$.

It is also useful to express the gain in work of a hybrid power plant in terms of the fuel inputs. As stated, an all fossil fuel plant by itself would produce work, W_f. The amount of work, W_h-W_f, would be the amount of work attributed to the use of a geothermal resource in a hybrid plant. If the same geothermal resource were used in an all geothermal plant, it would yield W_g. The study then defines a geothermal figure-of-merit $F_g \equiv \frac{W_h - W_f}{W_g}$. The hybrid plant uses a geothermal resource more efficiently than an all geothermal plant whenever $F_g > 1$.

In the same manner, a fossil fuel figure-of-merit is defined to be $F_f \equiv \frac{W_h - W_g}{W_f}$. In this case, the hybrid plant would use coal more efficiently than an all coal plant if $F_f > 1$.

Finally, an overall work amplification factor, ψ, is defined as $\psi = \frac{W_h}{W_g}$. When $\psi > 1$, the work obtained by the hybrid plant is greater than the work obtained by the geothermal plant.

4.8.4 Study Results

Table 4-3 presents results of the comparison between the IPP coal-fired power plant and the proposed hybrid geothermal/coal plant. Note that the values presented represent index numbers or figures-of-merit as discussed in the previous section.

Table 4-3: Figures-of-Merit for Hybrid Geothermal System

Variable	Maximum	Minimum
F	1.07	1.03
F_g	2.38	1.52
F_f	1.10	1.03
ψ	32.6	10.9

Source: System Design Verification of a Hybrid Geothermal/Coal Fired Power Plant. City of Burbank, September, 1978.

An F value of 1.07 means that a fixed geothermal and coal input will produce seven percent more power in a hybrid plant than when used in separate plants. Similarly, an F value of 1.03 means that a fixed geothermal and coal input will produce three percent more power in a hybrid plant than when used in separate plants. An F_g value of 1.52-2.38 means that the same hybrid plant will obtain between 52 percent and 138 percent more useful work from the geothermal resource than would an all geothermal plant. Another way to interpret this result is that the hybrid plant would be approximately 1.5 to 2.5 times more efficient than a geothermal power plant. Similarly, an F_f value between 1.03 and 1.10 means that the hybrid power plant would obtain between 3 percent and 10 percent more useful work than an all coal plant. Finally, an ψ value of 10.9 to 32.6 means that the hybrid plant would produce 10 to 32 times more power than an all geothermal power plant. The results of the study suggest that advantages are to be gained in combining the two systems.

The economics of the hybrid plant were found to be more attractive when the geothermal resource was of high quality and coal at reduced unit cost. A good geothermal resource could be able to offset the high cost of coal transportation. Coal savings per year for a 750 MW power plant were found to be between 6 percent and 16 percent of an all coal power plant. Depending on the criteria used, this savings alone could justify the use of the hybrid system.

In addition to coal savings, several other issues were addressed within the study. Spent geothermal fluid was used for condensate makeup water and cooling tower water. Each of these uses would require purification of the geothermal fluid. In addition, extra power could be generated when the hybrid plant was operating at less than capacity by using the geothermal fluid. Other investigations included the use of the geothermal fluid for coal beneficiation, air preheating, flue gas reheating and plant space heating. For each case, positive benefits were found which led to an improved set of economic circumstances for the hybrid system.

4.8.5 Conclusions

The study concluded that a hybrid geothermal/coal power plant was economically attractive. Not only did it use the geothermal resource more efficiently than an all geothermal plant, but it also used coal more efficiently and at an attractive cost. Several other reasons were cited as advantages for the hybrid system. The hybrid system was found to be less capital intensive, used existing technology, and is insulated from failures in the geothermal resource. For all of these reasons, it is felt that the concept deserves careful consideration.

4.9 Satellite Urban Development

The Arizona Geothermal Team has continued to support Dr. Mike Pasqualetti of Arizona State University for work in the Phoenix area and for work in collecting data on how geothermal energy might be utilized in certain areas of Arizona. The results of his work are as follows.

4.9.1 Introduction

Geothermal energy may be used nonelectrically for a variety of purposes, including the heating and cooling of our homes and businesses. However, the development of the resource is site-specific. This means that the resource must be developed where it is found. Unlike coal, oil, gas or uranium, heat cannot be moved long distances without costly pipelines and rapid loss of efficiency. The site-specific restruction of nonelectric geothermal resources means that the user as well as the resource must both be in the same location in order to have potential for development. Several of the sites in Arizona may have this potential.

The site-specific nature of nonelectric geothermal resources puts substantial emphasis on the existing and planned land use of a promising site. For this reason it is essential that the relationships between land use and the geothermal resource be understood as soon as the potential for such use is recognized. The purpose of the proposed project is to investigate these relationships with regard to the Arizona sites with the aim of speeding the commercialization and development potential of the resource.

Alternative energy development always faces obstacles of economic feasibility, technical constraints, and environmental impact. This is a burden that conventional sources usually do not carry; the conventional sources have essentially solved the basic economic and technical constraints. Of the environmental issues facing alternative energy development, land use obstacles are the most troublesome. This is particularly true with regard to a site-specific resource such as geothermal energy.

It would be counterproductive and unnecessary to allow land use to add to the burden faced by developers of geothermal energy. The aim should be at removing as many barriers as possible, especially in view of the rising cost of conventional fuel sources. This is particularly important to those on fixed incomes. Removal of these barriers can be a relatively inexpensive step, especially when compared to the benefits.

Early geothermal/land use planning can be compared to architectural planning. If you wanted a building designed that would accomodate handicapped people, it would be no problem for the architect if you told him before actual design began. However, if you told him your needs after he finished all the plans and specifications it would be expensive and time consuming to make the requested adjustments. With regard to geothermal energy development, it is a much wiser practice to plan for the development of the resource now than to wait until everything else is proved perfectly; without planning, all development which occurs between now and some future time when development is attempted can slow the commercialization of the resource. If it happened not to impede development it would be by chance only, not design.

4.9.2 Scottsdale Project

Several sites in Arizona may have potential for nonelectric geothermal development. Scottsdale has been examined as a possible 'model' city for purposes of the project because it has a balance of ingredients useful for such study and application. It has had a steady history of progressive leadership and planning. This history indicates a willingness to lend cooperation to new ideas and suggestions such as geothermal planning. It encompasses areas already occupied as well as areas presently vacant. Thus, the study can investigate the geothermal planning considerations in a retrofit circumstance as well as attempt to develop the 'ideal' patterns possible in a vacant area. It has a blend of residential, commercial, institutional and industrial land uses. This blend allows the variety of application potential necessary to meaningful study. The city engineering office has personnel with geothermal experience, itself an unusual circumstance. Finally, the size of Scottsdale's population is neither too large to be manageable nor too small to be insignificant. Thus Scottsdale is well suited as a site for the development of a geothermal-energy/land-use-planning methodology.

The use of geothermal energy has been investigated for several possible applications at various sites in Arizona. Several industrial and commercial operations and at least three housing developers have expressed interest in applying geothermal energy to their needs. Preliminary economic analyses and engineering have been carried out for these applications, and these results could be applied to Scottsdale and other Arizona sites.

Arizona State University has funded a nonelectric geothermal study aimed at determining the key land use factors in an urban area. Now that these topics have been identified and geothermal developments elsewhere have been observed, it is important to apply the results in Arizona communities. After the methodology has been developed for a 'model' site, it would be applied to other sites in Arizona.

The project will consist of two basic themes: optimization over the short term, and protection over the long term. The optimization will aim towards commercializing the geothermal resource in the near future. Such optimization will depend on the geological findings, but it will also be directly related to the land use characteristics in the occupied parts of cities and in the parts of cities where commitments are in hand or are imminent.

The protection theme is one which also stresses the need for planning, with special regard to the land which will be occupied in the future but for which no definite commitments exist at present. Both parts of the study can proceed concurrently with or in advance of reservoir assessments and will lead to the development of planning suggestions to optimize the use of the resource.

Thus, the suggestions will come to cities in two parts. One part will deal with how to optimize the use of the resource in the occupied areas. The second part will address the development of the resource in areas not yet occupied.

Once the suggestions are put into effect by a city, they will protect the city from those types of developments which would unnecessarily limit the potential use of the resource. The city would know where geothermal development is most feasible within the occupied areas, and the city could plan for the optimum use of the resource in the presently vacant lands.

The cities in Arizona overlying geothermal potential are in an enviable position. If the resource proves out immediately, the planning suggestions will be used to develop and apply the resource in the near future. If the resource is marginal at present, the plan can be used to ensure the future development potential of the resource against any inadvertant actions which could impede it.

4.9.3 Methodology

The following five phases constitute the methodolgy for the model city concept:

Phase I - The Geothermal Setting. The resource will be discussed in general terms as to how it may be applied to nonelectric purposes. History of use of geothermal energy in Arizona and nearby locations will also be discussed.

Phase II - The Developmental Setting. Geothermal development will be investigated in terms of interest and support. State and private interests will be mentioned.

The institutional aspects will be addressed and an analysis will be presented of the local level of geothermal understanding and impressions regarding land use barriers to commercialization.

Phase III - Application of Experience from Outside Arizona. A report will be made on the efforts to commercialize the nonelectric geothermal resource at selected sites in Utah, Nevada, California, Oregon, and Idaho. This discussion will be in terms of the land use barriers.

Foreign experience will be examined with particular interest in the development of optimum patterns for development.

Phase IV - Application of Model City. The findings in the first three phases will be applied to a model city in Arizona. Existing and planned land use will be examined for several criteria: (a) juxtaposition of existing energy users which would allow cascading of the resource; (b) juxtaposition of existing energy users with the resource in general; (c) adjustments to zoning and ordinances applying to areas already occupied as a means to increase the usefulness of the resource; (d) development of ideal patterns of areas presently unoccupied in terms of piping layout, well location, orientation of streets, and juxtaposition of possible users; location of parcel size as a means to minimize disturbance of certain conditions of quality of life, particularly quiet; (f) distribution of different parcel ownerships to increase the options of the city if they choose to develop the resource themselves; (g) identification of environmentally sensitive areas and problems; (h) prioritization of areas for development.

Phase V - Application of Other Arizona Cities. Once the methodology is proved useful in a model city, it will be applied to several other cities in Arizona which appear to have potential for the development of geothermal energy.

4.10 Geothermal-Assisted Aquaculture

Studies have shown that some fish grow faster in warmer water. Similar work has also been done on shrimp and prawns. The integration of geothermal water and aquaculture (which is generally defined as fish farming in fresh or brackish water) may help improve the economics of fish or shrimp farming.

For many years, through aquaculture, Japan has been producing larger amounts of trout, sweetfish, carp and eel. The United States has basically centered its aquaculture efforts on raising rainbow trout and channel catfish. Both types of fish seem to have an increasing market in the U.S. The main roadblock to farming of different species of fish may be consumer acceptance. According to a 1976 study on aquaculture, consumer acceptance of sea food has been restricted to the higher forms in the food chain. Even among the higher forms, preference for certain species are limited to about 20% of the total available species. Overcoming the problems of color, texture and names with negative connotations all stand in the way of using one of the most practical sources of protein.[1] Attempts to increase the markets of other types of fish are currently underway.

The economics of aquaculture using geothermal water becomes attractive because the fish grow bigger and faster than non-cultured fish. Another factor making the economics of aquaculture more attractive may be a number of new fish processing techniques incorporated by the fish industry. Such new technologies such as better de-boning equipment, commercial extruders

[1] "Aquaculture", Feedstuffs, April 26, 1976, p. 13.

for minced fish products and binding agents will eliminate much of the waste thus increasing the amount of meat recovered from each fish.

Efforts to farm shrimp and giant prawns have been going on in the U.S. for at least the past five years. In 1975 the attempt to commerically grow giant Malaysian prawns in temperate surroundings was begun by a research subsidiary of Sun Oil Company in Texas. In 1977, a project growing Malaysian shrimp commercially in ponds fed with warm water from a Sierra Pacific Power Company generating plant in central Nevada was begun. The idea was to mix 100 degree-plus water from the cooling ponds with colder water to bring it down to the 83-degree habitat for shrimp. Since that time, more projects raising shrimp in warm water have proved successful. The market for shrimp is growing and with a supermarket retail price of approximately $7-$8 per pound, the economics of farming shrimp are attractive.

During the third quarter of 1980, the Arizona Geothermal Team was contacted by Aquaculture Production Technology Ltd., of Denver, a firm interested in locating geothermal sites for the growing of shrimp. They requested information on sites with the following characteristics:

- Fresh or brackish water having a temperature of approximately 90°F.
- A warm climate to allow the water to remain at that temperature for as much of the year as possible.

They plan to filter the water coming into and leaving the ponds so that they could cascade with other uses. Information on areas in Arizona with potential for geothermal aquaculture was compiled and supplied to the interested company. Table 4-4 presents the results of that information.

Table 4-4: Preliminary Table Of Areas In Arizona With Potential For Geothermal Aquaculture

County/Number	Location	Temperature (°C)	Depth (Feet)	TDS (mg/l
Yuma 1	T.8-9S., R.19W.	50-60	< 50	< 3000
Yuma 2	T.7-8S., R.11-12W.	30-40	< 700	< 3000
Yuma 3	T.4-6S., R.10-12W.	30-45	< 1500	< 3000
Pima 4	T.19-20S., R.31E.	30-45	< 1000	< 500
Graham 2	T.7-9S., R.24-26E.	30-45	< 2000	< 5000 (Artesian Wells)
Graham 4	T.10S., R.28-29E.	30-45	< 2000	< 1000 (Artesian Wells)
Cochise 1	T.12S.-15S. R.28-31E.	30-40	< 1000	< 500
Cochise 2	T.13S., R.24-25E.	30-50	< 2500	< 1500
Maricopa 1	T.1N., T.1S., R.6-7E.	30-40	< 500	< 1000
Maricopa 3	T.2N., R.1-2E.	30-45	< 2000	< 1000
Maricopa 4	T.1N., R.1-2W.	30-60	< 2000	< 5000
Maricopa 6	T.1-2S., R.5-6W.	30-35	< 1500	< 2000
Maricopa 7	T.1-2N., R6-7W.	30-50	< 700	< 1500
Maricopa 8	T.1S.T.1-2N., R.8-10W.	30-40	< 2000	< 1500
Maricopa 9	T.4-6S., R.7-9W.	30-40	< 1000	< 3000
Maricopa 10	T.2-7S., R.3-6W.	30-50	< 2000	< 3000
Maricopa 11	T.2-3S., R1-2W.	30-40	< 1500	< 2000
Maricopa 12	T.2-3S., R5-8E.	30-40	< 1000	< 1000

Note: The data in the table is a summary of numerous warm and hot wells (30°C) known to exist in each of the areas listed. Also, higher temperatures than those listed are possible at greater depth. Prudent geologic and geophysical studies may identify higher temperature resources in these areas

5.0 CONTINUED EVALUATION OF GEOTHERMAL RESOURCES

During the third quarter, the Arizona Geothermal Commercialization Team continued to provide in-depth information on geothermal resource locations and qualities in Arizona. This task involved interaction with the Geothermal Resource Assessment Team of the Arizona Bureau of Geology and Mineral Technology, other state agencies and geothermal developers. During this period, leasing and drilling activities were also reported.

Leasing activity in Arizona increased after a relatively inactive first half of 1980 (January-June). Three geothermal lease applications were submitted by Southland Royalty to the BLM in August. The applications, were for a total of 3675.76 acres in the San Bernardino Valley (Cochise County). Also, the Arizona State Land Department called for bids on a total of 1915.40 acres of state land in Pinal County. Anschutz Drilling Company, with a high bid of $1.25 per acre received geothermal leases for these acres. Currently, Anschutz is deep drilling for oil and gas in this area.

Drilling activities in Arizona also increased during the third quarter. As mentioned above, Anschutz has been deep drilling for oil and gas in the "Overthrust Belt" near Florence (Pinal County). Phillips has since gained controlling interest in the well. They expect to drill between 20,000-25,000 feet. Also during this quarter, Union Oil of California received a permit to drill from the Arizona Oil and Gas Conservation Commission. The permit is for a 1000 foot geothermal heat-flow hole in the San Bernardino Valley. Drilling is expected to begin in early October. Lastly, the BLM and USGS have issued six permits to Phillips Petroleum to drill shallow gradient holes in the Clifton area. Drilling is expected to begin in October or November.

6.0 ENGINEERING AND ECONOMIC ANALYSES

6.1 Alcohol Production Facility

Work began in the final days of the second quarter and continued on into the third quarter on a preliminary design of a 30 million gallon alcohol production plant to be located in the Willcox-Safford area. Work was performed in conjunction with Water and Power Resource Service (WPRS) of Boulder City, Nevada. WPRS is currently interested in a desalination facility to be located near Willcox which would use geothermal energy to generate electricity and provide potable water to the City of Willcox. The design of the alcohol production facility is to utilize waste heat from the desalinization facility, thus improving the economics of the entire system.

6.1.1 Introduction

The Arizona Geothermal Commercialization Team has been accumulating information on gasohol production by fermentation over the past few months to evaluate the possibility of supplying part of the energy requirements by geothermal energy.

This brief, preliminary design of an alcohol plant for a Willcox, Arizona location was a rush job, taking only five days, in order to have some information for use in a June 24-25 meeting with the Water and Power Resource Services, U.S. Department of Interior, Boulder City, Nevada. The design and rough economics are probably within 30 percent of real values, and are dependent to some extent upon the design premises.

6.1.2 Process Descriptions and Technology

The conversion of cellulose to ethanol consists of four basic steps: 1) Grinding and pretreatment, 2) Saccharification, in which the cellulose is hydrolyzed to fermentable sugars, 3) Fermentation, in which sugar is converted to alcohol and other byproducts, 4) Separation process, in which ethanol is separated from other products and purified as required.

Pretreatment involves grinding, cooking and cooling. The starch content of corn can be liberated into solution by cooking. The optimum times appear to be 1-5 minutes at 350°F (177°C) (1,2). The temperature of 350°F (177°C) (1, 2) is produced by sparging steam at 247 Psia into the mash. The mash is then cooled by flashing to 1 atm and then to 3.3 Psia. Some of the steam produced from the 1 atm flash operation is used to preheat the mash before its entrance into the main cooker. There are two procedures. The first mixes corn with the correct amount of desalinated water (@ 60°C) to achieve a concentration of 25 gal/bushel (3). If the mash is too viscous, a small amount of amylase can be added at this point to liquify it.

The cooled mash leaves the vacuum flash at 145°F (63°C), and is mixed with a stream of fungel amalase (α -amylase). After mixing, the stream is centrifuged to remove corn solids and aspergillus oryzae solids. The clear liquor containing amylase and dissolved starch is sent to a converter (Saccharifier). The residence time is 3 minutes. Acid can be added keeping the pH at 5.5 (1,2). The average velocity is maintained at 3 ft/sec. The saccharifier has an 80% conversion of starch to sugar. The amylase continues to convert starch to sugar in the fermenter (1). The overall conversion of starch to sugar is 95%. After conversion, the mash is cooled and diluted to a concentration of 36 gal/bu. The temperature of the mix entering the fermenter is 35°C (4).

The fermenter is a continuous fermenter with a 95% efficiency. Efficiencies over 93% are common (1,2,5). The residence time in the fermenter is 7 hours where sterile air is added (4). The fermenter product is 5.8% alcohol (by wt.). The fermenter is equipped with a cooking gasket, an agitator, and a draft tube with cooling coils.

The α-amylase enzyme needed to convert the starch is prepared in a batch process using Aspergillus Oryzae as the producing organism. Aspergillus Oryzae is initially innoculated into a seeding tank. The culture in the seeding tank is allowed to propagate for 30 hrs. at 30°C and a pH of 6.0 (6). The entire culture is then transferred to a fermenter where a mixture of corn mash, water and nutrient salts have been prepared. The Aspergillus Oryzae is fermented for 72 hrs. at 30°C and pH of 6.0. All fermenters are equipped with internal steam nozzles for sterilization and cleaning. The liquor leaving the alcohol fermenters is heated and pumped to the upper sections of the beer still. As the beer passes down the beer column, it gradually loses its lighter-boiling constituents. The liquid discharged from the bottom of the still through a heat exchanger is known as slop. The liquid carries proteins, some residual sugars, and some vitamin products, and is passed through a pulsating centrifuge where the solids are removed and used as a constituent of animal feed. The overhead (15 mol Y. Ethanol) is sent to the ethanol fractionation column. The overhead leaving this fractionation column (89 mol Y. Ethanol) is sent to a vacuum still which overcome the azeotype and produces 98 mol % Ethanol. Molecular seives will be used to produce the anhydrous ethanol.

A corn stover fueled boiler system will be used to produce 620 Psia, 600°F (316°C) steam. The boiler will require $384^{T/D}$ of corn stover producing 154 MMBtu/hr.

A dry ice plant could be built near the distillery as one means of generating revenue from the CO_2 produced in the fermentation process.

6.1.3 References

1. Gallagher, F.H., et. al., Ind. Eng. Chem., 34, 1395-1397 (1942).
2. Unger, E.D., et. al., AIChE Journal, 40, 421-443 (1944).
3. Altsheler, W.B., et. al., Ind. Eng. Chem., 43, 467-472 (1947).
4. Cysewske, G.R., and Wilke, C., Biotech. Bioeng., 18, 1297-1313 (1976).
5. Rut, E.W., et. al., Ind. Eng. Chem. 40, 1154-1158 (1948).
6. Johnson, S., Industrial Enzymes - Recent Advances.

6.1.4 Discussion of Heat Duties and Available Energy

This section will discuss the use of the available low-temperature heat in the proposed 30 mm gallon ethanol plant.

Heat exchanger #1 will use 371 gpm of the distilled water (cooling it from 60°C to 29°C) to heat the feed. The heat duty of this first exchanger is 10.2×10^6 Btu/hr heating the feed to 100°F (38°C).

Heat exchanger #2 uses brine to heat the feed from 38°C to 77°C. The brine flow would be 475 gpm, and the heat duty is 23.8 mm Btu/hr.

Heater exchanger #3 is located between the first and second precooker. It utilizes brine to bring the feed steam up to 88°C. Steam will be used to raise the temperature in the second precooker up to 93°C. The flow of brine through this heat exchanger will be 380 gpm with a heat duty of 6.81×10^6 Btu/hr (exit brine is 82°C, or a $\Delta T = 2°C$).

Heat exchanger #5 before distillation uses distilled water to preheat feed to the beer still from 35°C to 52°C. The water flowrate is 420 gpm, and the heat duty is 8.5 MM Btu/hr ($\Delta T = 4°C$).

Heat exchanger #6 uses brine to bring feed to the beer still from 52°C to 92°C. The heat duty is 20.73 MM Btu/hr, and the brine flowrate is 594 gpm.

The reboiler for the vacuum still will use brine with a heat duty of 16 MM Btu/hr. The brine flowrate will be 533 gpm ($\Delta T = 16^{o}C$).

Heat exchangers 8 and 11 will use steam produced by the boiler. While duties of heat exchangers 4, 7, 10, and 12 will use cooling water from a cooling tower. Cooling water will also be needed in the alcohol fermentation process (498 gpm).

Table 6-1: Available and Used Heat

Available HEAT		mm Btu/hr
(6,040 gpm) distilled water ($\Delta T = 140 - 85^{o}F = 12^{o}C$)	=	166.3
(29,120 gpm) Brine assumed ($\Delta T = 21^{o}C$)	=	1020.3
		1686.6

Used HEAT in Ethanol Plant	mm Btu/hr
Distilled water	18.7
Brine	67.34
	86.04

Table 6-2: Mass Balances

INPUT	OUTPUT
$969 \frac{\text{TON CORN}}{\text{DAY}}$	$9.1 \times 10^4 \frac{\text{GAL ETOH}}{\text{DAY}}$
$1.56 \times 10^6 \frac{\text{GAL WATER}}{\text{DAY}}$	$1.31 \times 10^6 \frac{\text{GAL } H_2O}{\text{DAY}}$
$9.3 \frac{\text{TONS } NH_4Cl}{\text{DAY}}$	$76 \frac{\text{TONS YEAST}}{\text{DAY}}$
$0.765 \frac{\text{TONS } MgSO_4 \cdot 7H_2O}{\text{DAY}}$	$271 \frac{\text{TONS CORN SOLIDS}}{\text{DAY}}$
$0.42 \frac{\text{TONS } CaCl_2}{\text{DAY}}$	
$21.8 \times 10^6 \frac{ft^3 \text{ STERILE AIR}}{\text{DAY}}$	
$94.6 \times 10^6 \; ft^3 \frac{\text{AIR}}{\text{DAY}}$ to boiler	

Table 6-3: Utility Table (For 30 mm gal ETOH/year)

Application	Temp.	Energy Load (Btu/hr)	Steam Temp.	Cooling Water
Corn Precooker #1	170°F	34.2 mm	212°F	-
Corn Precooker #2	200°F	7.5 mm	240°F	-
Corn Cooker	350°F	50.1 mm	402°F	-
Flashtank #1	-	(50.1 mm)*	-	-
Flashtank #2	-	(15.9 mm)*	-	-
Mash Cooling	-	18.6 mm	-	210 gpm (ΔT = 20°F)
Fermentation	95°F	36 mm	-	138 gpm (ΔT = 20°F)
Preheat to Beer Still	-	29.3 mm	230°F	-
Beer Still Reboiler	210°F	22 mm	240°F	-
Beer Still Condenser	201°F	20 mm	-	1,000 gpm (ΔT = 40°F)
Ethanol Fractionator Reboiler	210°F	15 mm	240°F	-
Ethanol Fractionator Condensor	174°F	12 mm	-	600 gpm (ΔT = 40°F)
Vacuum Still Reboiler	110°F	16 mm	145°F	-
Vacuum Still Condenser	95°F	12 mm	-	600 gpm (ΔT - 40°F)
Boiler	-	(154 mm)*	-	-
DDG Drying and Recovery	-	15 mm	-	-

* ( ) denotes energy produced

Table 6-4: Utility Summary

	Steam (mm Btu/hr)	Electricity (KW)
Raw material storage and handling	0	302
FERMENTATION	50	4,207
DISTILLATION	97	24
Drying and DDG Recovery	15	1,351
Product storage and shipping	0	37.2
Utilities	13	3,037
	175	8,959

Table 6-5: Capital Investment

Capital cost (in 1980 $)

Fermentation Section

Major Equipment = $\$12,300,000 \left(\frac{3}{5}\right)^{0.6}$

= $\$9.05 \times 10^6$

Raw Material Storage and handling

Capital cost = $\$1,149,000 (0.6)^{0.6}$

= $ 845,690

Distillation Section

Total section capital cost = $\$631,000 (0.6)^{0.6}$

= $464,430

DDG Recovery and Drying

Total section cost = $\$7,140,000 (0.6)^{0.6}$

= $5,255,197

Product Storage and Shipping

Total section capital cost = $\$1,630,000 (0.6)^{0.6}$

= $1,199,716

Utilities Section

Total section cost = $\$8,855,000 (0.6)^{0.6}$

= $6,517,474

Total Cost of Purchased Equipment = $23,330,000

From Peters & Timmerhaus Page 104

Purchased equipment = 23% of TOTAL Fixed capital investment

$$\text{Total fixed capital investment} = \frac{\$23.33}{0.23} \times 10^6$$

$$= \$101,400,000$$

Component	Fixed Capital Investment % of FCI*	Cost (mm$)
Purchased Equipment	23	23.33
Equipment	9	9.126
Instrumentation & controls (installed)	3	3.042
Piping (installed)	7	7.098
Electrical (installed)	4	4.056
Buildings (including services)	8	8.112
Yard Improvements	2	2.028
Service facilities (installed)	13	13.182
Total direct cost	70	70.98
Engineering & supervision	9	9.126
Construction expense	10	10.14
Contractor's fee	2	2.028
Contingency	9	9.126
Fixed-capital investment	100%	101.4

* % of FCI taken from Peters & Timmerhaus page 104.

7.0 TECHNICAL ASSISTANCE

During the second quarter, limited technical assistance related to space cooling for district type systems was provided to John F. Long, a Phoenix land developer. Further detailed work was undertaken during the third quarter for a subdevelopment (planned by Long) on the west side of Phoenix. A detailed report was completed. This report for the Long subdivision, is currently under review by P.R.C. Toups.

Technical assistance was also provided to Western Electric Corporation, a large cable manufacturing corporation, located in Phoenix. Western Electric expressed interest in utilizing geothermal energy for space heating and cooling. Western Electric received preliminary technical information from the Arizona Geothermal Team and has since requested more detailed technical assistance from Los Alamos Scientific Laboratory.

Lastly, detailed technical assistance was provided to the Agricultural Extension Service at the University of Arizona in alcohol production. Recent interest in alcohol production in Arizona coupled with geothermal resources which could be used as a primary energy source resulted in the Arizona Geothermal Team's active participation.

8.0 IMPACT OF VARIOUS GROWTH PATTERNS UPON GEOTHERMAL ENERGY UTILIZATION

Work under this task hinges on the willingness of the New Mexico Energy Institute to assist in this task. Data are available to input to the system; however, the required man-hours at NMEI may not be available at this time. This task will be completed by April 1981.

9.0 OUTREACH

Outreach during the third quarter of 1980 consisted of telephone contacts and personal discussions with various persons within the state. A meeting was held with the Mayor of Scottsdale to assess the geothermal potential of the city and to develop a method by which Scottsdale (or any other city) could incorporate plans for geothermal development and usage into their long-range city development planning.

A meeting was also held with the Mayor, City Manager and other interested persons of Willcox to discuss the geothermal potential of that area, geothermal applications and possible funding sources. Willcox has plans for a large size industrial park to possibly include an alcohol production plant and a pork-kill plant. In addition, Willcox has an olympic-sized pool which is only used a couple months during the summer due to the high cost of heating the water the rest of the year. All these could utilize geothermal energy.

The Arizona Geothermal Commercialization Team continued to provide geothermal information to P.R.C. Toups. P.R.C. Toups, an engineering consulting firm, has been working to determine the feasibility of using geothermal energy to provide heat and hot water for the new 120-bed Mesa Lutheran Hospital. As a result of their study, a proposal was submitted to the DOE under the User-Coupled Drilling Program. Word on whether drilling money will be granted is still pending.

A major outreach program, in the way of a newsletter, was also undertaken during this quarter. The Arizona Geothermal Team now publishes a monthly newsletter called the Geothermal Resource. The mailing list, of approximately 500 names, includes federal, state and local officials and policy-makers, engineering firms, developers, financers, and other interested persons.

Lastly, outreach activities also included the completion of the J.K. Lesser sound slide show for Arizona and a newspaper article entitled "Earth's Heat Studied for Industrial Use." This article was a result of an industry study completed by the Arizona Geothermal Team.