EVALUATION OF GEOTHERMAL ENERGY IN ARIZONA

Arizona Geothermal Planning/Commercialization Team

Quarterly Topical Progress Report
April 1, 1980 - June 30, 1980

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1.0: INTRODUCTION

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. Therefore, several sections of this progress report will be devoted to past accomplished work in order to provide interested persons with a brief overview of the status of geothermal potential within the State. The final sections of this report will deal with tasks for 1980 and accomplished work under each task as of the date of this quarterly report.

The Arizona Geothermal Commercialization Team at the University of Arizona has been working under contract to the DOE via Arizona Solar Energy Commission for over two years (since June 12, 1977). During the first year, 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 undertaken 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. In order to accomplish the stated tasks within 1980, the Arizona Geothermal Commercialization Team has been organized under the direction of James Warnock and Dr. Frank Mancini of the Arizona Solar Energy Commission and Dr. Don H. White of the Department of Chemical Engineering at the University of Arizona. Figure 1 shows the organizational chart for the 1980 calendar year with key persons and responsibilities outlined.

During the current quarter, several engineers, an economist, and political scientist were hired to perform specific work on tasks for 1980.

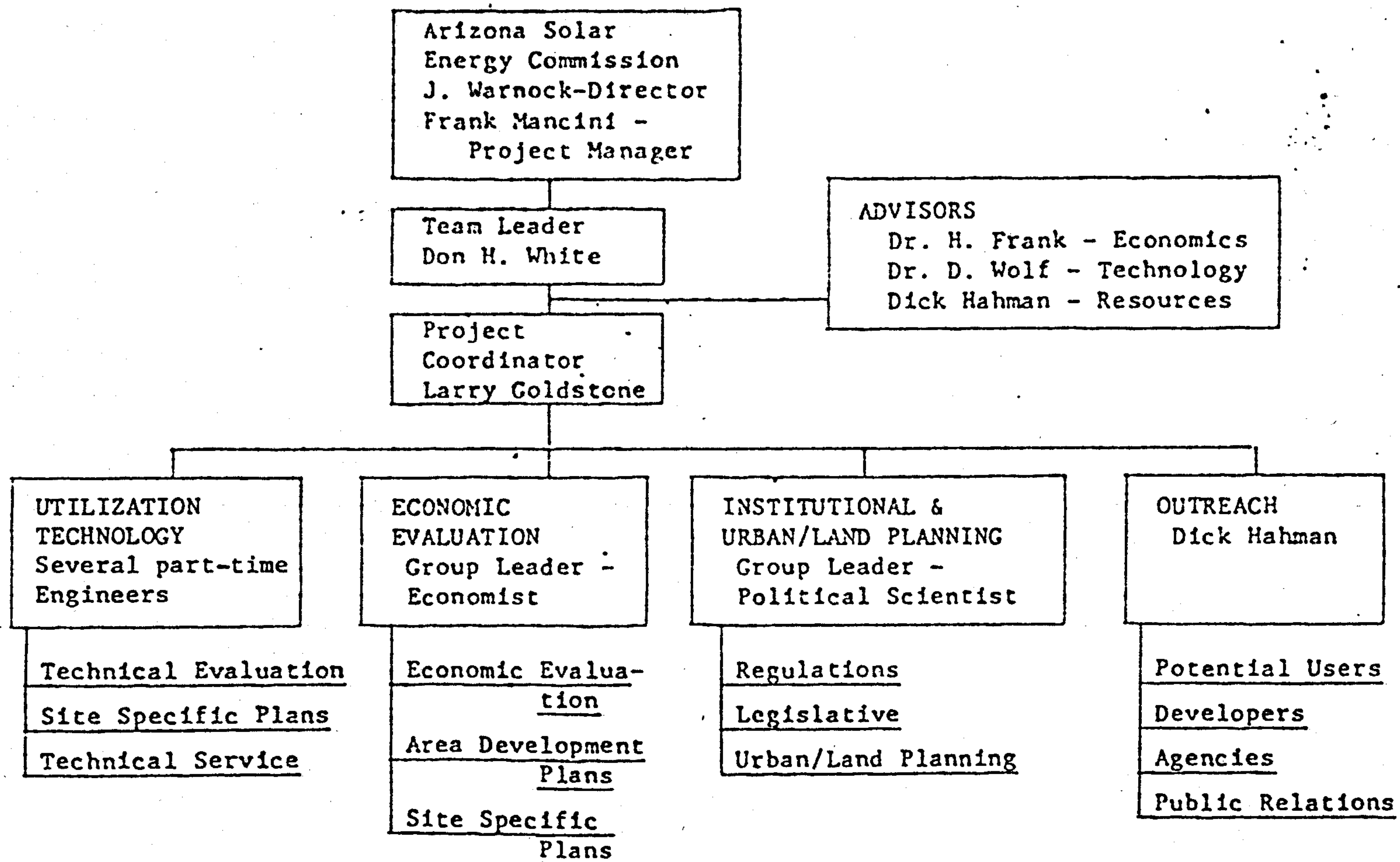

Figure 1-1: Organizational Chart
Arizona Geothermal Commercialization Team

2.0: BACKGROUND

The following sections will serve as an introduction to past work performed by the Arizona Geothermal Commercialization Team and provide an overview of resource potential within the state.

2.1: GEOTHERMAL PROSPECT IDENTIFICATION

During 1978 and 1979 the effort expended to delineate Arizona's known geothermal resources has been concentrated upon the Basin and Range physiographic area, characterized on the surface by alternating mountain ranges and broad valleys. Most of the valleys overlie structural basins somewhat smaller than the area of the valleys themselves. The Basin and Range constitutes the southwestern-most two-thirds of the state and is also characterized by higher than normal heat flow on the average. Some of these basins are filled with deep piles of reasonably porous sediment, most of which has eroded from adjacent mountains since their formation between 13 and 5 million years ago. These sedimentary piles are generally between about 600 and 1200 meters deep, and a few basins contain thick evaporite masses, e.g., anhydrite, halite, or gypsum. Deposited before and thus lying beneath the evaporites are usually conglomerates intermixed with volcanics. Where observed on the land surface, these porous conglomerates often are found to be deposited directly on igneous basements.

Thirty-seven of these sedimentary basins are known to store warm to hot (35-85°C) water at relatively shallow depths (less than 1200 meters) and are thus proven direct thermal resources. Figure 2-1 shows these basins as boxes, numbered by county; locations and estimates are given in Table 2-1. The circled, stippled areas on this figure represent potential and inferred geothermal prospects, keyed to Table 2-1 and 2-2, where higher temperatures (>90°C) may be discovered as inferred by J. C. Witcher of the State Bureau of Geology. The Bureau is investigating areas near Tucson, Phoenix, Hyder Valley, Tonopah,

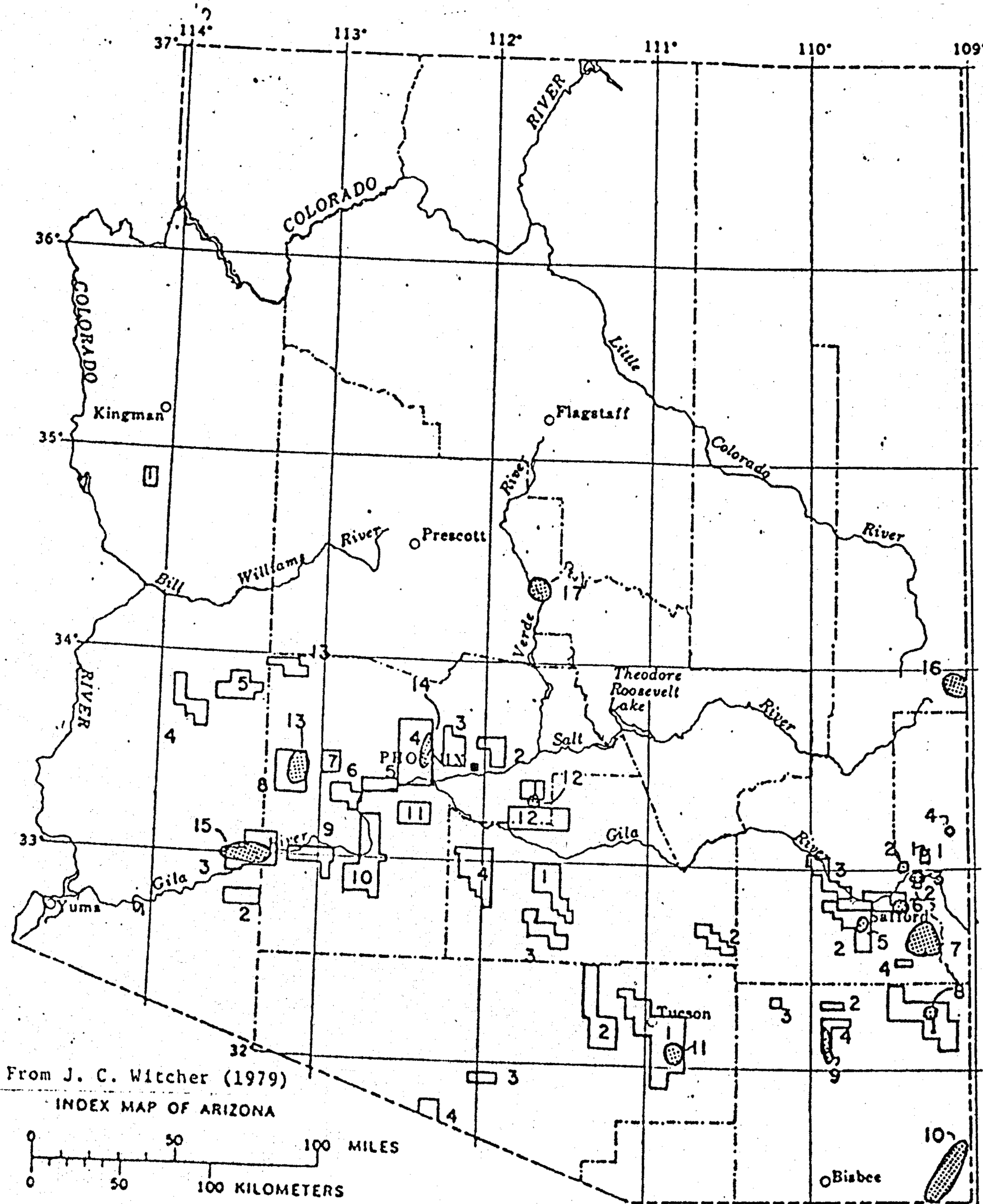

Figure 1: Arizona's proven, potential, and inferred resources.

TABLE 2-1: PROVEN AND POTENTIAL GEOTHERMAL RESERVOIRS LESS THAN 1.2 KM DEPTH
Modified from (Witcher, 1979)

Tr - Average temperature of the reservoir

County/Area	Location	Volume km^3	Measured °C Temperature	Depth (Feet)	Tr°C	Geothermometry Temperature °C	Method	Source
Greenlee 1	T4S, R30E	18.6	30 - 67	Surface	80	130 - 180	Quartz Mixing Model, 2Na-K-Ca/mg corr.	7
Greenlee 2	T5S, R30E	18.6	30 - 83	Surface	80	130 - 140	Quartz, Na-K-Ca	6
Graham 1	T6-7S, R26-28E	61.9	30 - 50	<1000	75	70 - 115	Quartz, Na-K-Ca	7
Graham 2	T7-9S, R24-26E	111.5	30 - 45	<2000	70	30 - 90	Quartz, Na-K-Ca	7
Graham 3	T4-6S, R23-25E	71.2	30 - 60	<3500	60	70 - 90	Chalcedony, Na-K-Ca	7
Graham 4	T10S, R28-29E	61.9	30 - 40	<2000	60	90 - 110	Quartz, Na-K-Ca	7
Cochise 1	T12-15S, R28-31E	204.3	30 - 40	<1000	60	60 - 85	Chalcedony, Na-K-Ca	6,8
Cochise 2	T13, R24-25E	15.5	30 - 50	<2500	60	60 - 70	Chalcedony	3,8
Cochise 3	T12-13S, R21E	12.4	30 - 50	Surface	60	50 - 90	Quartz, Na-K-Ca	6
Cochise 4	T14-15S, R24-25E	80.5	30 - 40	<1000	70	80 - 110	Quartz, Na-K-Ca	3
Pima 1	T12-17S, R12-15E	287.9	30 - 50	<2500	60	50 - 65	Chalcedony, Na-K-Ca	7
Pima 2	T12-15S, R10-11E	157.9	30 - 45	<2000	60	30 - 60	Chalcedony	8
Pima 3	T17S, R3-5E	30.9	35 - 40	< 700	55	50 - 60	Chalcedony	8
Pima 4	T19-20S, R31E	40.3	30 - 45	<1000	65	50 - 80	Chalcedony	8
Pinal 1	T5-8S, R7-9E	126.9	30 - 45	<2500	55	40 - 80	Chalcedony	8
Pinal 2	T8-10S, R16-18E	61.9	30 - 45	<1000	60	50 - 70	Chalcedony	8
Pinal 3	T8-9S, R6-8E	80.5	30 - 45	<2500	55	40 - 80	Chalcedony	8
Pinal 4	T4-7S, R2-4E	164.1	30 - 40	<1500	55	-	Reservoir Temp. for gradient = 35°C/km	-
Yuma 1	T8-9S, R19W	3.1	50 - 60	< 50	60	60 - 70	Quartz	6
Yuma 2	T7-8S, R11-12W	65.0	30 - 40	< 700	65	40 - 70	Chalcedony	2
Yuma 3	T4-6S, R10-12W	148.6	30 - 45	<1500	70	60 - 80	Chalcedony	8
Yuma 4	T3-6N, R14-16W	83.6	30 - 45	<1500	60	40 - 70	Chalcedony	8
Yuma 5	T5-6N, R11W-13W	123.8	30 - 40	<1500	50	30 - 40	Chalcedony	8
Mohave 1	T17N, R17W	18.6	30 - 35	-	50	40 - 50	Quartz	8
Maricopa 1	T1N, T1S, R6-7E	46.4	30 - 40	< 500	60	50 - 60	Chalcedony	8
Maricopa 2	T2-3N, R3-5E	68.1	30 - 45	<1500	60	30 - 60	Chalcedony	8
Maricopa 3	T2-3N, R1-2E	55.7	30 - 45	<2000	60	35 - 60	Chalcedony	8
Maricopa 4	T1-4N, R1-2W	222.9	30 - 60	<2000	60	30 - 70	Chalcedony	8
Maricopa 5	T1N, T1S, R3-4W	37.1	30 - 40	<2000	55	30 - 40	Chalcedony	8
Maricopa 6	T1-2S, R5-6W	52.6	30 - 35	<1500	70	40 - 70	Chalcedony	8
Maricopa 7	T1-2N, R6-7W	49.5	30 - 50	< 700	75	45 - 85	Quartz, Na-K-Ca/Mg corr.	Jones pers. comm.
Maricopa 8	T1S, 1-2N, R8-10W	148.6	30 - 40	<2000	65	30 - 110	Chalcedony	8
Maricopa 9	T4-6S, R7-9W	74.3	30 - 40	<1000	60	30 - 80	Chalcedony	8
Maricopa 10	T2-7S, R3-6W	182.7	30 - 50	<2000	60	30 - 65	Chalcedony	8
Maricopa 11	T2-3S, R1-2W	74.3	30 - 40	<1500	60	30 - 70	Chalcedony	8
Maricopa 12	T2-3S, R5-8E	123.8	30 - 40	<1000	60	40 - 60	Chalcedony	8
Maricopa 13	T6-7N, R8-10W	61.9	30 - 40	2000	55	30 - 40	Chalcedony	8

TABLE 2-2: INFERRED INTERMEDIATE TO HIGH TEMPERATURE (<90°C) GEOTHERMAL RESERVOIRS LESS THAN 2.5 KM
Tr - Average Reservoir Temperature

	Name	County	Location	Depth km	Volume km^3	Tr $^{\circ}$C	Inferences based on
1.	Clifton Hot Springs	Greenlee	T4S, R30E	2.0	2.5	170	1, 5
2.	Eagle Creek Hot Springs	Greenlee	T4S, R28E	2.0	2.5	130	1, 5
3.	Gillard Hot Springs	Greenlee	T4S, R30E	2.0	2.5	140	1, 5
4.	Martinez Ranch	Greenlee	T3S, R31E	2.0	2.5	130	1, 5
5.	Cactus Flat-Artesia	Graham	T7-9S, R26E	2.0	2.5	110	1, 3, 5
6.	Buena Vista	Graham	T6-7S, R27-28E	2.0	2.5	120	1, 3, 5
7.	Whitlock Mountains Area	Graham	T8-10S, R28-30E	2.0	2.5	110	1, 3, 5
8.	San Simon	Cochise	T13-14S, R29-30E	2.0	2.5	120	2, 3, 5
9.	Willcox Playa	Cochise	T14-15S, R24E	2.0	2.5	110	1, 3, 5
10.	San Bernadio Valley Area	Cochise	T20-24S, R29, 31E	2.5	2.5	150	1, 3, 4, 5
11.	Tucson Basin	Pima	T14-15S, R14-15E	2.5	2.5	130	2, 3, 5
12.	Power Ranch Area	Maricopa	T1-2S, R6E	2.5	2.5	130	2, 3, 5
13.	Harquahala Plain	Maricopa	T1S, T1N-2N, R8-10W	2.5	2.5	110	1, 3, 5
14.	Luke-Litchfield	Maricopa	T1-4N, R1-2W	2.0	2.5	110	3, 5
15.	Hyder Area	Maricopa	T4-6S, R10-12W	2.0	2.5	110	1, 3, 4, 5
16.	Alpine-Nutrioso	Apache	T5-7N, R30E	2.0	2.5	120	3, 4, 5
17.	Verde Hot Springs	Yavaipai	T11N, R6E	2.0	2.5	130	1, 3, 5

(1) Geothermometry
(2) Deep well tests
(3) Geophysics/heat flow
(4) Young volcanism
(5) Structure

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Willcox, Springerville, Yuma, Kingman and the Safford-San Simon Basin. Leasing interest has been greatest in the Clifton and San Bernardino Valleys, and many applications currently await processing. These areas of great leasing interest also exhibit the geologic properties most favorable for geothermal electrical generation in the state.

Leasing of State and Federal lands in Arizona for prospective geothermal development resumed in 1979 after several years of no leasing activity. As of December 1979, Federal leases totalled 21,541 acres and the State leases totalled 1,844 acres.

2.2: AREA DEVELOPMENT PLANS

During 1979 and 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 2-2 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

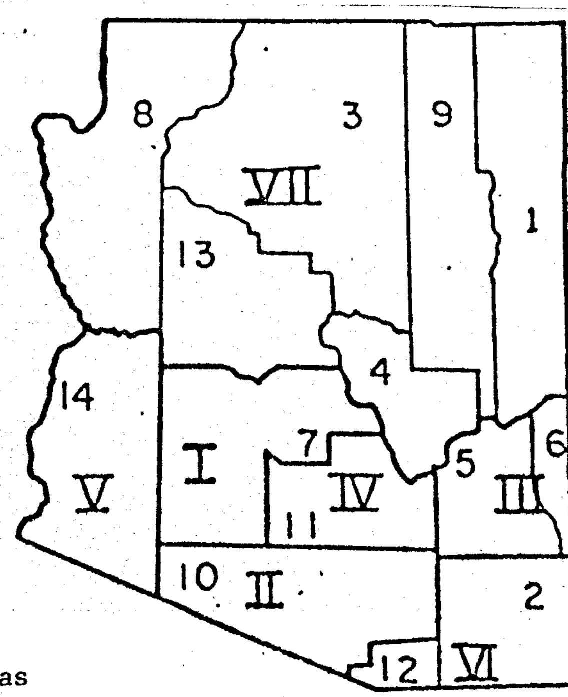


Figure 2-2: Geothermal Planning Areas

For each completed Area Development Plan, 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. This information was then correlated to define potential users of geothermal energy within each planning area. Potential users were defined within various economic sectors of the state including industrial process heat users, commercial, residential and agricultural users. Results of this work were provided to the New Mexico Energy Institute for modeling geothermal energy on line between 1979 and 2020. Figures 2-3 to 2-6 present the results of this modeling under private sector development for combined industrial process heat and residential and commercial space heating within each area. In addition, similar modeling was performed under city utility development. However, results are not presented in this report.

Table 2-3 provides an aggregation of energy supply and demand for each of the four completed Area Development Plans. The energy supply figures represent the potential impact which geothermal energy could have in supplying space heat in the residential and commercial sector and process heat needs in the industrial sector. On the other hand, the demand figures represent projected energy consumption for all needs within each sector excluding transportation.

TABLE 2-3: PROJECTED GEOTHERMAL SUPPLY/TOTAL DEMAND* (BILLION BTUs)

ADP	COUNTY	1979	1985	2000	2020
I	MARICOPA	0/143,800	7,700/165,400	45,300/232,570	77,100/373,000
II	PIMA	0/ 52,390	0/ 59,250	816/ 78,690	6,061/116,520
III	GRAHAM/GREENLEE	0/ 2,296	134/ 3,892	232/ 4,522	3,200/ 5,574
IV	PINAL	0/ 10,897	2,490/ 12,370	10,470/ 16,600	13,150/ 25,930
	TOTAL	0/209,383	10,324/240,912	56,818/332,382	99,511/521,024

*Total demand excludes transportation

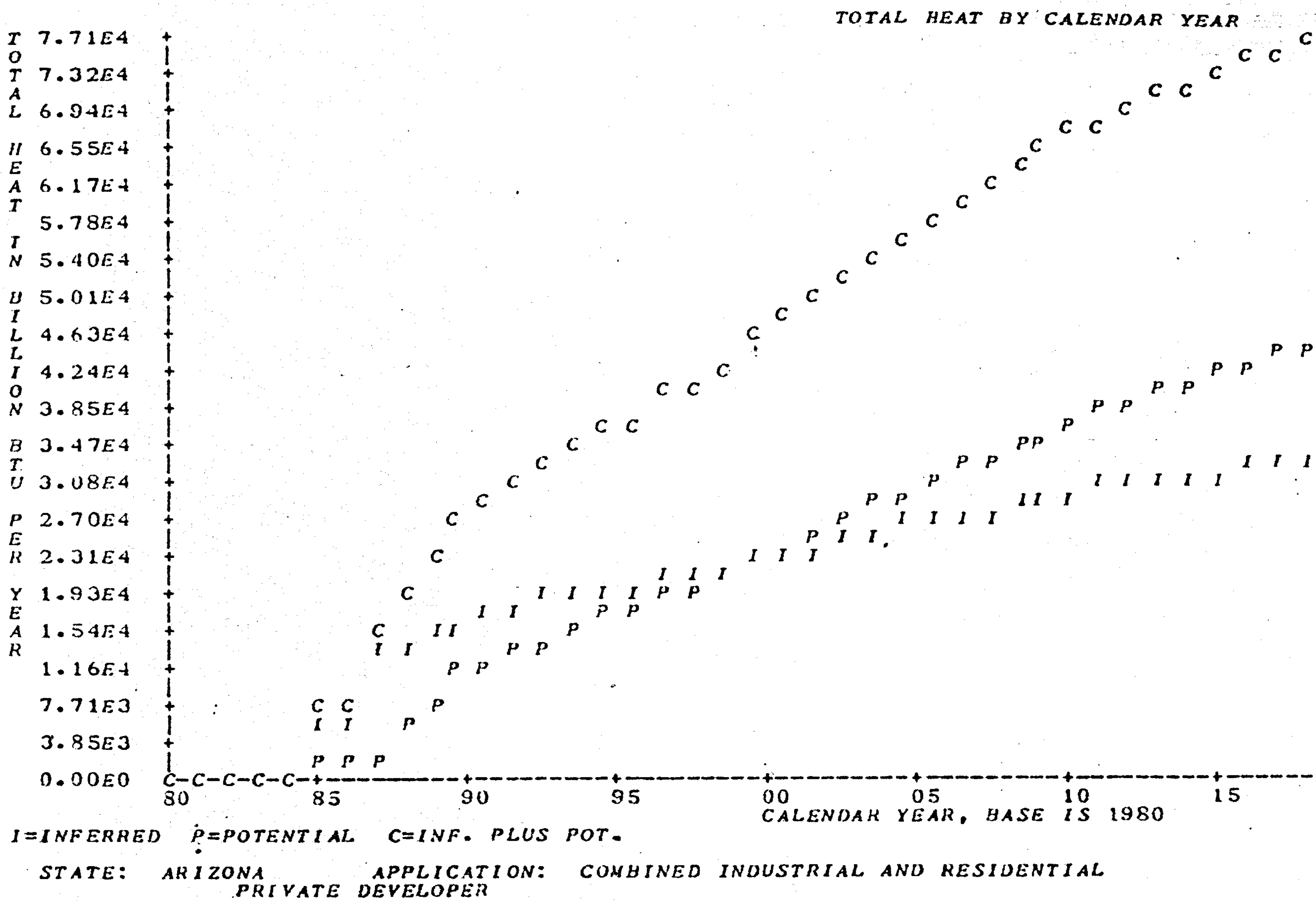


Figure 2-3: Geothermal Energy on Line Through 2020 in Maricopa County
Source: New Mexico Energy Institute

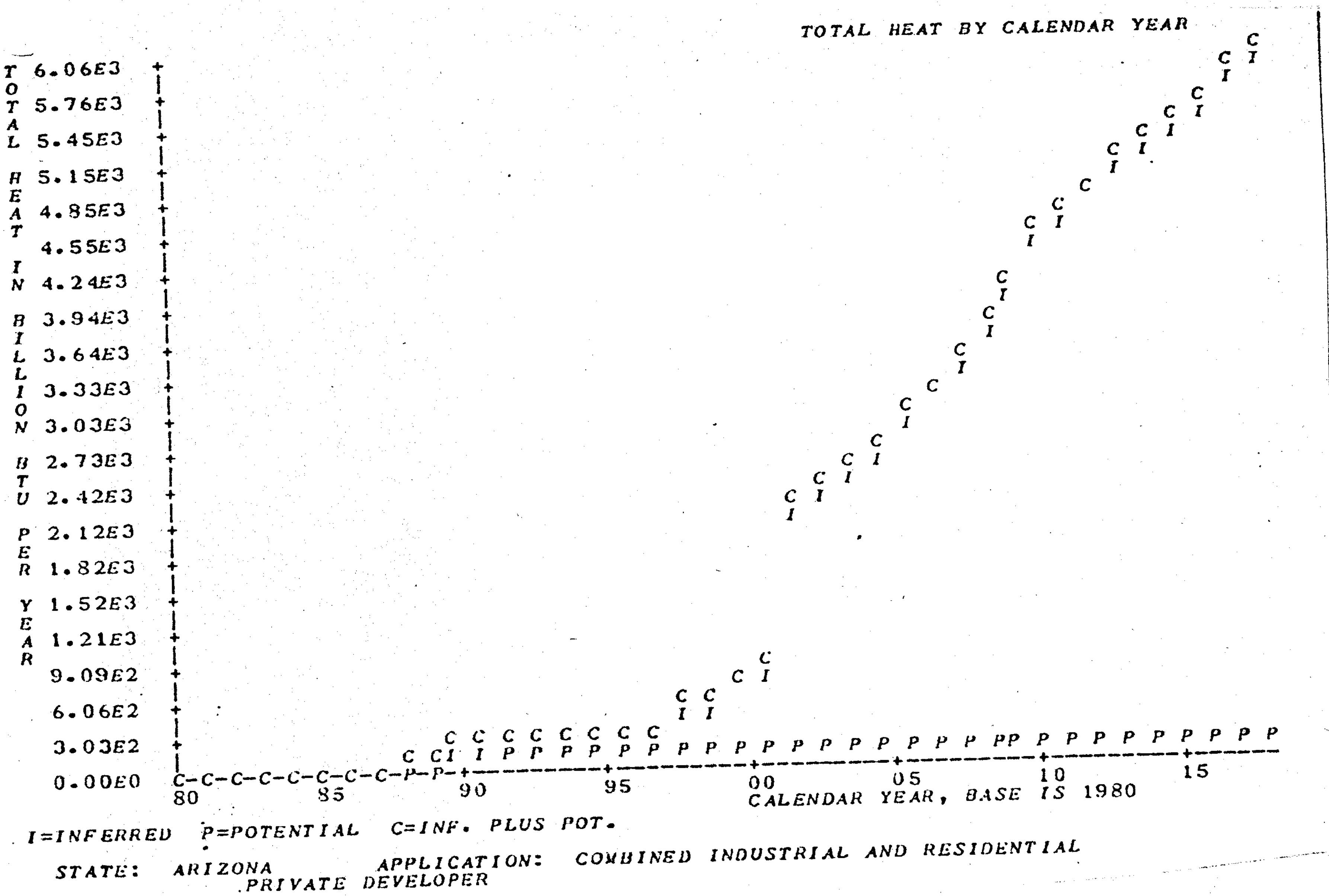


Figure 2-4: Geothermal Energy on Line Through 2020 in Pima County
Source: New Mexico Energy Institute

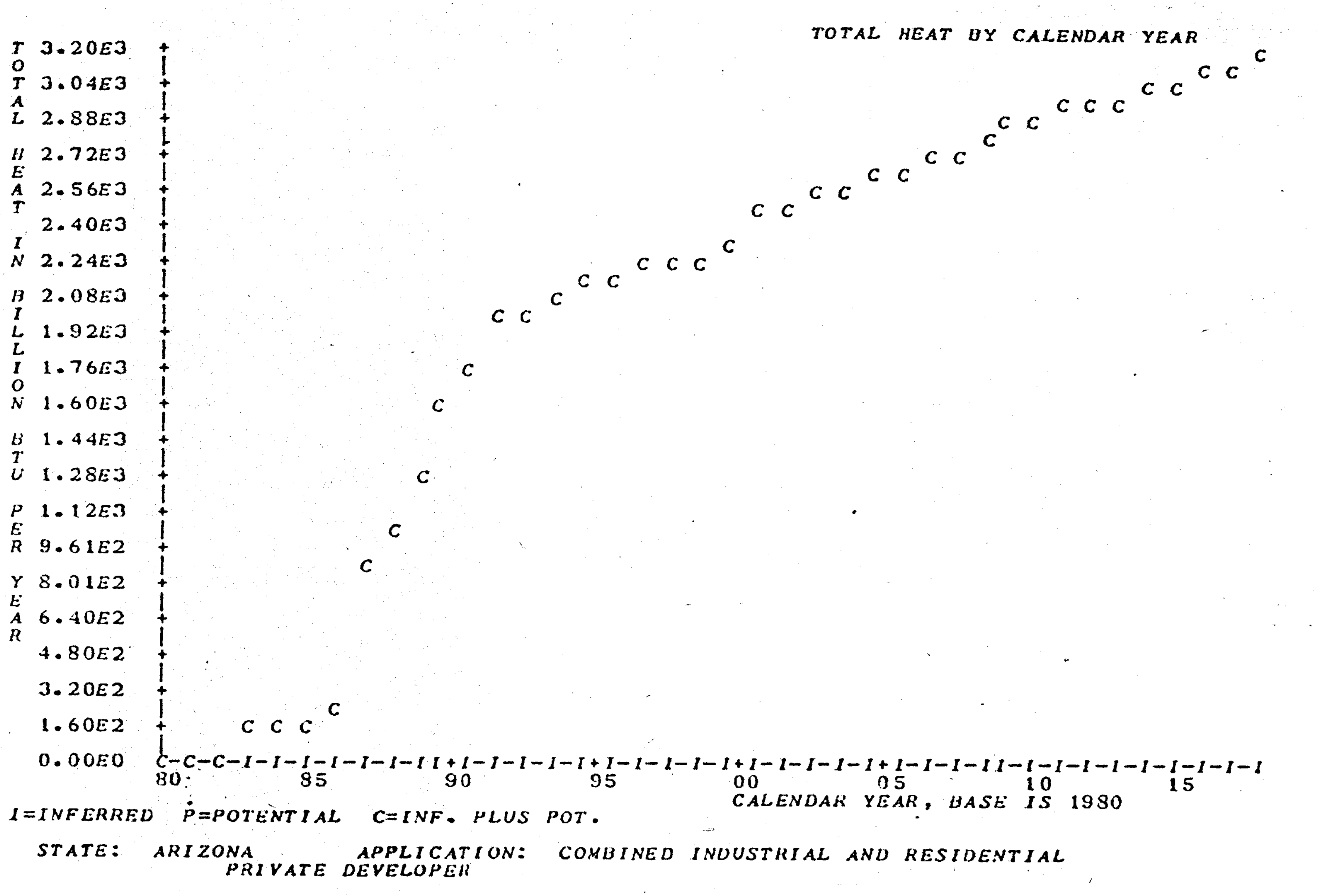


Figure 2-5: Geothermal Energy on Line Through 2020 in Graham and Greenlee Counties
Source: New Mexico Energy Institute

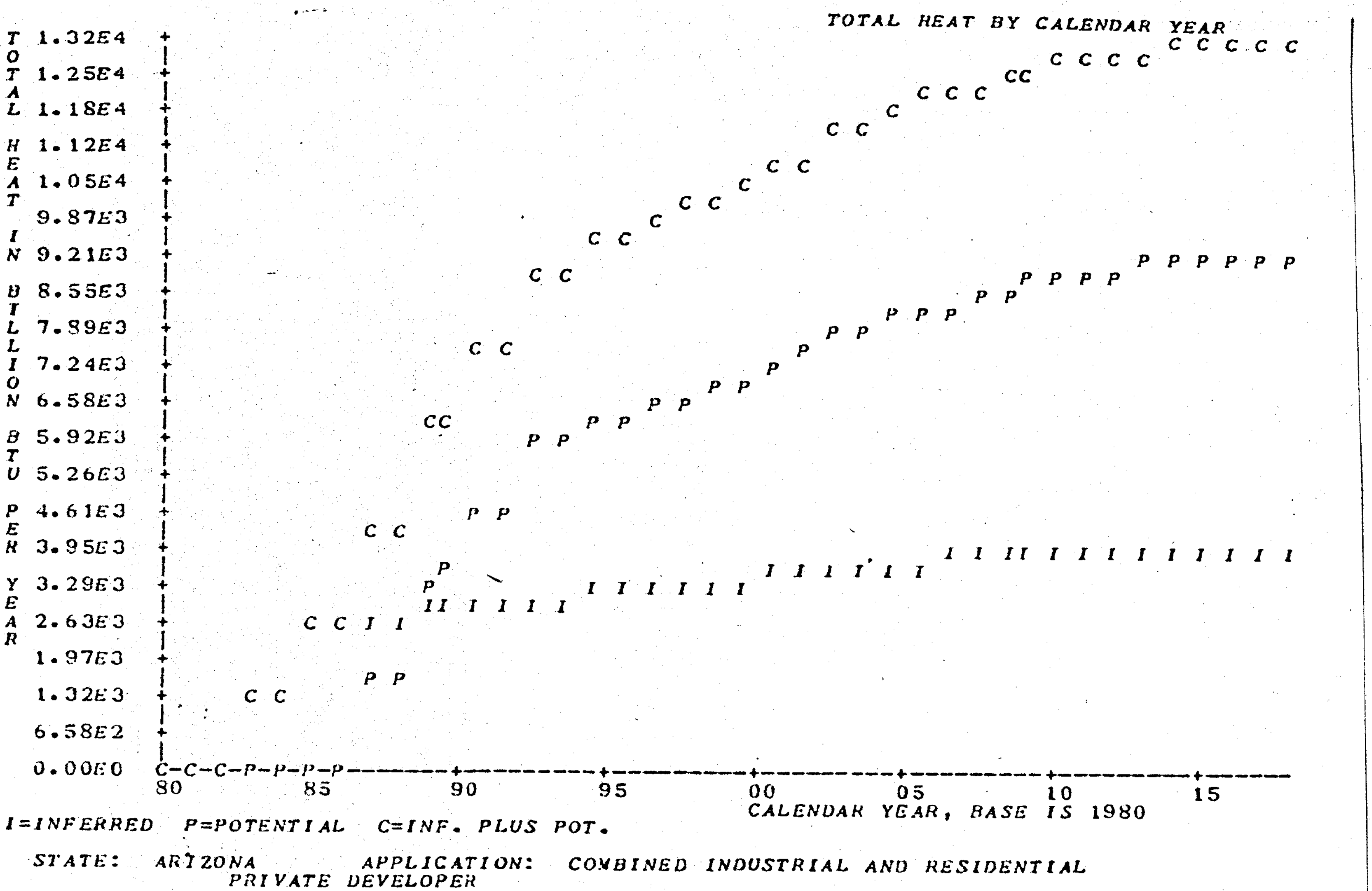


Figure 2-6: Geothermal Energy on Line Through 2020 in Pinal County
Source: New Mexico Energy Institute

By the year 2000, geothermal energy for space heating and industrial process heat could potentially serve 17% of the total energy needs excluding transportation within these four major areas of the state and that figure could increase to almost 20 percent by the year 2020. However, results such as these will require positive steps by Federal and State government agencies in terms of resource confirmation and incentive programs.

2.3: SITE SPECIFIC DEVELOPMENT ANALYSIS

Based on the recommendation of the preliminary study of 1978 and recent developments in the state, ten site specific development analyses (SSDA) were chosen as candidates for further evaluation. It is important to note that none of these proposed applications are under actual development at the present time. Five SSDAs were completed during 1979. The technical, financial, environmental and institutional aspects of each of these five SSDAs were studied. The results of these evaluations are presented in section 2.3.1.

2.3.1 Completed SSDAs

a) Space Cooling and Heating for Williams Air Force Base - Chandler, Arizona.

Williams Air Force Base, is located in south-central Arizona, nine miles east of Chandler and 35 miles southeast of Phoenix. During 1979, the Department of Energy along with E.G. & G. Idaho, Inc., Williams Air Force Base personnel and the Resource Advisor of the Arizona Geothermal Planning Team conducted a study on the technical and economic feasibility of using geothermal energy for space cooling and heating of the base. The results of the study were encouraging and the project is being pursued further by the Air Force.

The study prepared by E.G. & G. Idaho Inc., considered three sources of energy (geothermal, solar and coal) to power a centralized unit which could provide space cooling and heating for the base area. The total installed load in the major buildings in the central base area was determined to be 4,300 tons of cooling and 86.5 MMBtu/hr for heating. An economic evaluation was conducted for different scenarios using the three energy sources. The results indicated that one of the geothermal options which required two new production wells was the most cost-effective scenario. The total cost of this project would be about $7,828,000 as opposed to $42,532,500 for a similar solar system. The earliest this project could be included in the Federal budget would be in the year 1981. If approved, environmental assessments and environmental impact statements must be completed prior to the drilling and construction phases.

b) Space Cooling and Heating of an Industrial Complex - Tucson, Arizona

This SSDA considers the feasibility of using a specific geothermal resource to provide space cooling and heating for an industrial complex near the Tucson area. After interaction with E.G. & G. Idaho, Inc., it appears that attitudes are in favor of developing geothermal if studies prove that it will be beneficial from both an energy conservation and economical stand point. The required cooling load of the complex is 2700 tons while the heating load is somewhat smaller.

c) District Heating and Cooling - Green Valley, Arizona

Rapid population growth in Southern Arizona is triggering the planning and establishment of new communities. For example, in 1961 plans were adopted to establish a community in Green Valley and by the year 1979 the population of Green Valley was 8500. This analysis provides an example of the use of geothermal energy for district cooling and heating for a planned community.

The application site is located on privately owned land, which is presently undeveloped. The water temperature in the reservoir is probably in the range of 123^{o} - 158^{o}C. Each house requires an average cooling load of 170 MMBtu/hr., and an average heating load of 30,000 Btu/hr. Under the conditions of our analysis and current energy prices, we could expect the energy on line to occur before the year 1990.

d) Geothermal Assisted Copper Dump Leaching - Silver Bell, Arizona

Arizona is the largest copper-producing state in the nation, accounting for 65% of all domestically produced copper in 1978. Theoretical studies have shown that the rate of extraction of copper increases with the increase in the temperature of the leaching fluid. The result of this concept of geothermal - assisted copper dump leaching would be a more efficient copper recovery from low grade leach materials.

Silver Bell was chosen for this analysis due to the availability of data on its mining operations and the compatibility of the geothermal resource. (It should be noted that this application would apply to a number of mining operations in Southern Arizona.) Required resource temperatures for this application range from 50^{o}C to 80^{o}C. Heat demand for a theoretical dump leach process would be 8.16 MMBtu/hr, with an 80% recovery of copper being desired.

e) Geothermal Power Plant - Clifton, Arizona

This analysis presents a theoretical evaluation of a hypothetical 50MW geothermal power plant in the Clifton area of Greenlee County. Gross capacity of the power plant is about 61MW. Assuming a heat level of 145,135.8 Btu/sec., and a flow rate of 140,000 kg/hr for each production well, the required number of production wells is sixteen. Two potential barriers to development do exist. First, extensive leasing time would be required due to the mixture of Federal, State and private land in the area. Second, the Forest Service may designate the area a wild and scenic river which could hinder development.

2.3.2 Partially Completed SSDAs

In addition to the previous five completed SSDAs, five other SSDAs were analyzed and partially completed. These include the following:

1. Geothermal Assisted In-Situ Solution Mining - Miami, Arizona.
2. Geothermal/Coal Fired Power Plant - Springerville, Arizona.
3. Geothermally-Assisted Central Arizona Project Pumping.
4. Geothermal Steam Turbine Pumping - Casa Grande, Arizona.
5. Integrated Citrus Juice Concentrate/Peak Power/Irrigation Pumping Geothermal System - Yuma, Arizona.

2.4: TIME PHASED PROJECT PLANS

Geothermal projects in Arizona have not yet progressed to this point.

2.5: INSTITUTIONAL ANALYSIS

During CY 1979, the Arizona Geothermal Commercialization Team completed the institutional analysis of Federal, State and local rules and regulations relating to the development of geothermal energy in Arizona. The resulting product of this analysis is the Arizona Geothermal Institutional Handbook. The purpose of this handbook is to assist interested persons in understanding the various procedures and requirements necessary for geothermal development in Arizona.

2.6: HYDROTHERMAL COMMERCIALIZATION BASELINE REPORT FOR ARIZONA

In an effort to provide a comprehensive, but brief synopsis of various aspects of the geothermal program in Arizona, the Hydrothermal Commercialization Baseline Report for Arizona was prepared by E.G. & G. Idaho Inc., using information submitted by the Arizona Geothermal Commercialization Team and the Arizona Resource Assessment Team.

2.7: PUBLIC OUTREACH PROGRAM

An extensive Outreach Program was conducted during CY 1979 within the State of Arizona. The Arizona Geothermal Commercialization Team's approach to the task of outreach was three-fold. First, numerous phone calls were made to potential developers, potential users, and State officials which served to increase their awareness of the potential geothermal resources in Arizona.

Secondly, the Judi Kirby Public Relations Firm was hired with the purpose of assisting the Arizona Geothermal Team in a coordinated effort towards educating the public and providing a broader base of understanding of geothermal energy. The third approach to outreach involved the use of all forms of the media and direct meetings with interested State and community leaders. The Arizona Outreach Program was responsible for approximately 25-30 newspaper releases, three television interviews, five radio talk shows, a number of articles published in professional journals and newsletters, speaking engagements at 10 professional meetings, and speaking at the Governor's Commission on Arizona Environment. In addition to these, the geothermal display and sound-slide show have been shown at various places around the state.

3.0: TASKS AND OBJECTIVES FOR CY 1980

The following are the contractual tasks for CY 1980 along with planned objectives:

Task 1. Completion of Area Development Plans (ADP)

The Contractor shall complete the Area Development Plans (ADP) for the three remaining areas of the State of Arizona. This work involves detailed energy and economic analyses, which should result in a market analysis evaluating the potential penetration of geothermal energy. Attempts will be made to better define energy consumed for space cooling as opposed to space heating and other uses for areas in Southern Arizona. In addition, further work will be devoted to identification of potential users in each area.

Task 2. Continuation of Site Specific Development Analyses (SSDA)

The Contractor shall continue making preliminary engineering and economic analyses for selected applications. These studies will provide technical assistance to potential developers in the private and public sectors. The following subtasks will be considered:

2-a: Space Cooling and Heating - The heating aspects of this task have been completed. Therefore, attention will be devoted to applications of absorption chillers and heat pumps to potential users in the state.

2-b: Geothermal Power Plants - Most work on this SSDA has been completed; therefore, a minimum of new work will be done.

2-c: Geothermal-Assisted Copper Dump Leaching - Efforts will be made to visit copper mines in Arizona and to refine cost studies. Future interactions hopefully will lead to a commercial geothermal project.

2-d: In-Situ Leaching of Uranium, Zinc and Copper - Additional efforts will be made to define the geological mining criteria necessary for each type of ore. In addition, studies of chelating agents will be undertaken.

2-e: Geothermal Steam Turbine Pumping - Pumping requirements and land area involved will be determined for the irrigated areas of Arizona. A model site will be chosen and studied in a more detailed manner.

2-f: Direct Thermal Use for Food Processing - An assessment will be made of current and future food processing, crops likely to be grown in Arizona, and temperature requirements for processing local crops.

2-g: Geothermal Energy Utilization in Modern Cattle Feedlots - Existing feedlot and alfalfa operations in Arizona will be identified and assessments will be made of energy and temperature requirements based on these existing operations.

2-h: Geothermal-Assisted Coal Fired Plants - This SSDA will consist of summarizing the City of Burbank study on a hybrid geothermal/coal fired power plant and applying it to future power plants in Arizona.

2-i: Satellite Urban Development - Work will be done on planning for the development and growth of a new community based on geothermal energy. Required population and local necessities will be defined. Research currently being done at Arizona State University may prove useful in this SSDA.

2-j: Geothermal-Assisted Aquaculture - This SSDA will consist of reviewing current work being done by E.G. & G, Idaho and the University of Arizona. Possible sites will be located in Arizona based on the environmental requirements of the shrimp and other seafoods.

2-k: Alcohol Production for Gasohol - Work will involve interaction with persons interested in the production of alcohol to provide technical assistance in evaluating the use of geothermal energy as a major energy source in the distillation process. Energy balance and cost studies shall be performed for a specific site in Arizona.

Task 3. Continued Evaluation of Geothermal Resources

The Contractor shall continue to provide information on geothermal resource locations and qualities, including that on Federal lands. Leasing activity will also be reported. This task involves liaison with the Arizona Bureau of Geology and Mineral Technology, other State agencies and geothermal developers. Particular emphasis will be placed on evaluating the geothermal resource locations and qualities in the remaining three ADP's.

Task 4. Engineering and Economic Analyses.

The Contractor shall make 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.

Areas that could be studied in depth include a gasohol plant and/or the cooling/heating of a new community.

Task 5. Technical Assistance in State of Arizona

The Contractor shall provide 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 will involve the dissemination of information as opposed to new research in areas of inquiry.

Task 6. Impact of Various Growth Patterns upon Geothermal Energy Utilization

The Contractor shall identify probable growth patterns of population and the resultant economy, so that the future potential of geothermal energy under these scenarios can be evaluated. This work will be performed with the assistance of NMEI and their modeling capabilities. Various growth scenarios have been postulated; thus major work involves quantifying these ideas into workable form.

Task 7. Outreach Program

The Contractor shall continue its outreach program, which involves interactions with potential users, resource developers, various agencies and other groups. Information on geothermal energy will be supplied to industry, institutions, State agencies and local governments and the general public, through publications, workshops, meetings, etc.

4.0: WORK COMPLETED DURING THE SECOND QUARTER

The following is a compilation of work accomplished by the Arizona Geothermal Commercialization Team from April 1 to June 30, 1980, arranged in accordance with the stated tasks in the previous section.

In addition to work accomplished under the various tasks below, activities also included the completion of a detailed two volume report on work for CY 1979, participation on the Ethanol Task Force in conjunction with the Cooperative Extension Service, University of Arizona and interactions with several potential developers in the Phoenix area, the most notable being Western Electric and John F. Long Homes, Inc.

Task 1. Completion of Area Development Plans (ADP)

In addition to studies on the remaining three ADP's for Arizona, revision of previously completed plans was undertaken as new and more current information became available.

Information on Maricopa, Pima, Pinal, Greenlee and Graham Counties for the Area Development Plans continues to be updated and new resources tapped to reach a more complete understanding of the counties. The following sources, among numerous 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 Chambers of Commerce in the key communities.

1) Maricopa County

a) Energy Consumption

Data on energy consumption, both electricity and natural gas, is currently being compiled by the Arizona Public Service Company and the Salt River Project, the two major utility companies within the county. To date, the information has not been received by our office.

b) Industry and Growth

With the use of information from the Solar Energy Research Institute and the 1980 Arizona Directory of Manufacturers, industries which have process heat requirements of less than 110^{o}C were identified within Maricopa County. The list presented in Table 4-1 represents an update of industries not previously identified in past work and their estimated annual energy consumption. All of these firms are believed to be a potential market for geothermal aplications.

TABLE 4-1: MARICOPA COUNTY

ESTIMATED PROCESS HEAT ENERGY REQUIREMENTS NOT ELSEWHERE REPORTED.

ASSUMED RESERVOIR TEMPERATURE: 110°C

SIC	# of firms	Description	Annual Est. Energy Use. (BTU x 10^{10})
2016	3	Poultry Dressing Plant	.266
2024	6	Ice Cream & Frozen Desserts	8.027
2026	3	Fluid Milk	1.895
2086	4	Soft Drinks	14.805
2097	1	Ice	1.48
2431	1	Millwork	9.68
2511	14	Wood Furniture	8.99
2512	4	Wood Office Furniture	.365
2951	1	Paving Mixtures and Blocks	269.37
3273	12	Ready Mix Concrete	1.006
3281	10	Cut Stone Products	.406
3441	3	Structural Metal	.44
3442	2	Metal Doors	1.36
3444	3	Sheet Metal Work	.721
3451	2	Screw Machines	.054
3479	2	Misc. Metal Surface Treatment	1.627
3499	4	Misc. Metal Products	3.049
3811	3	Engineering Instruments	.434
3851	4	Opthalmic Goods	.657
3949	1	Sporting Goods	.142
3999	3	Misc. Manuf. Products	.634
Subtotal			325.408
Previous estimated process heat demand			307.800
Total Process Heat Demand For Maricopa County Adaptable To Geothermal Energy			633.208

2) Pima County

a) Energy Consumption

Tucson Electric Power Company provides electricity to 90 percent of the customers in Pima County. Residential customers are the largest consumers of electricity in the county; the percentage breakdown of energy sales by sector and projections are indicated in Table 4-2 to 1995.

Table 4-2: Projected Distribution of Electricity Sales in Pima County

	Percent of Sales			
Customer Class	1980	1985	1990	1995
Residential	26	30	33	35
Commercial	19	20	20	22
Industrial & Large Users	50	46	42	39
Others	5	4	5	4

Source: Tucson Electric Power

As indicated in Table 4-2, sales in the residential sector are projected to increase by 35 percent between 1980 and 1995. In forecasting residential load, population growth and electric heating factors emerge as major determinants of sector growth.

The commercial sector includes mostly businesses which generally serve residential customers. In the past, the number of commercial customers has closely followed the trend established in the residential sector.

Currently, the industrial and large-user sector accounts for nearly one-half of Tucson Electric Power Company's energy sales. Copper mining is the predominant consumer. Tucson Electric Power Co. serves four major industrial customers (two military bases, a cement plant, and an aircraft manufacturing facility).

For 1979, data has been collected for monthly electricity sales by user class. Figure 4-1 shows that peak demand for electricity is in the summer months and substantially tapers off in the winter months due to a decline in usage of space cooling. This pattern is also followed by the commercial and industrial users. Mining, however, shows a steady increase in demand throughout the year.

Natural gas for Pima County is provided by Southwest Gas Corporation which serves all of Pima County. Figure 4-2 shows booked volume sales for 1979. Booked volume sales represent revenues received during the month for previous sales. Southwest Gas Corporation does not collect sales data by month; thus revenue provides their closest estimate.

Natural gas sales, as anticipated, show peak demand for residential and commercial consumption in the winter months. This increase is attributed to the use of natural gas for space heat during the winter months. The majority of the residential dwellings in Tucson and the surrounding area use natural gas heating.

In summary, natural gas is primarily used in Pima County for heating in the winter months and electricity is used for cooling in the summer months. However, current natural gas shortages and future supply uncertainties have changed this trend. A prohibition against new gas connections after January 1, 1977, was instituted. It is projected that after January 1, 1977, 95 percent of all new residential customers connected will be totally electric (space heating, water heating, lighting, appliances, and space cooling). This pattern would change only if the Federal government and El Paso Natural Gas (the main basic natural gas supplier) make arrangements for additional natural gas from some new source, such as coal or imports from Mexico. Thus, considering population growth and the estimated energy requirements for electric space and water heating, growth in electric energy usage will be substantial throughout the forecast period despite efforts to conserve energy.

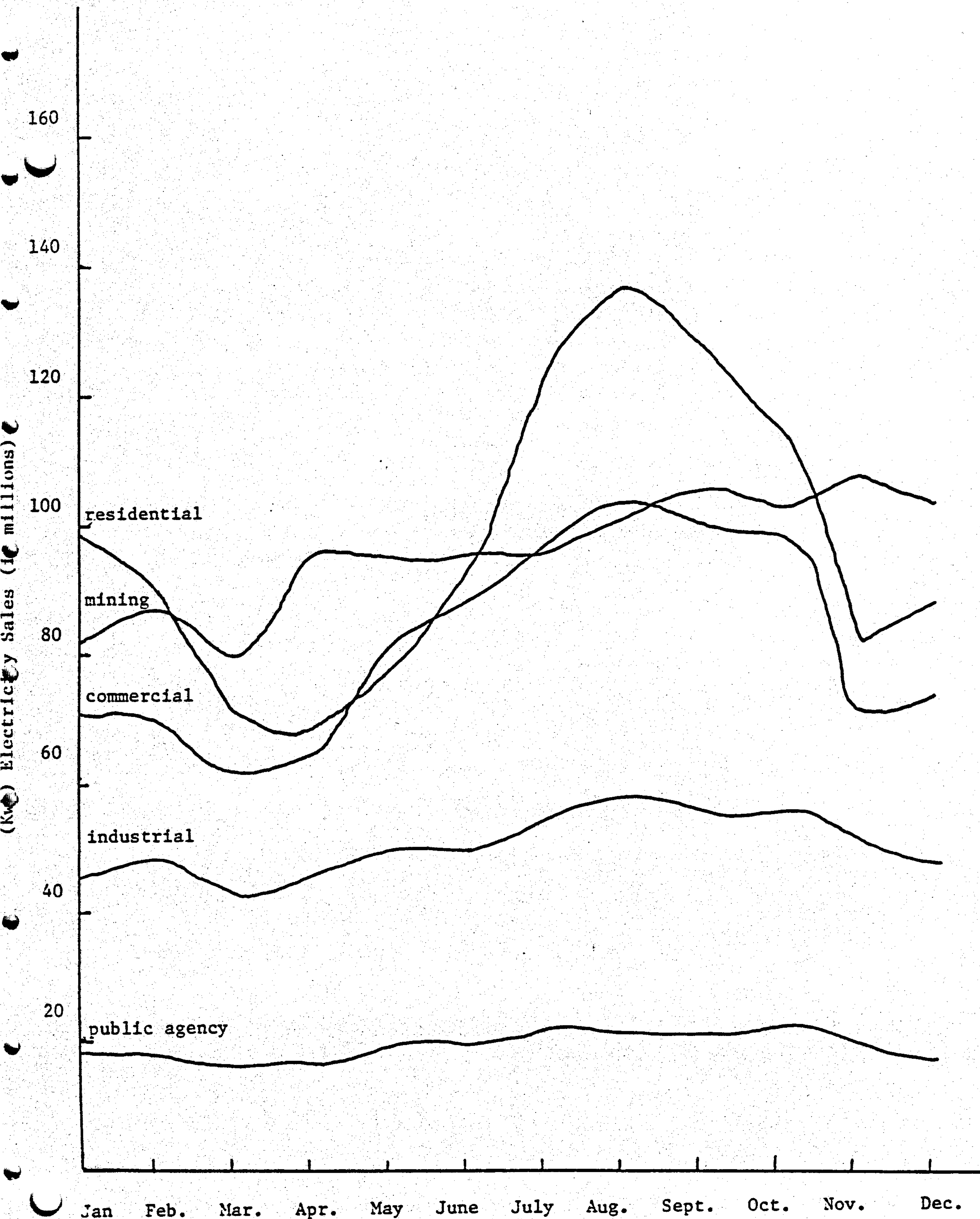


Figure 4-1: Estimated Electricity Sales By Month For 1979 Pima County

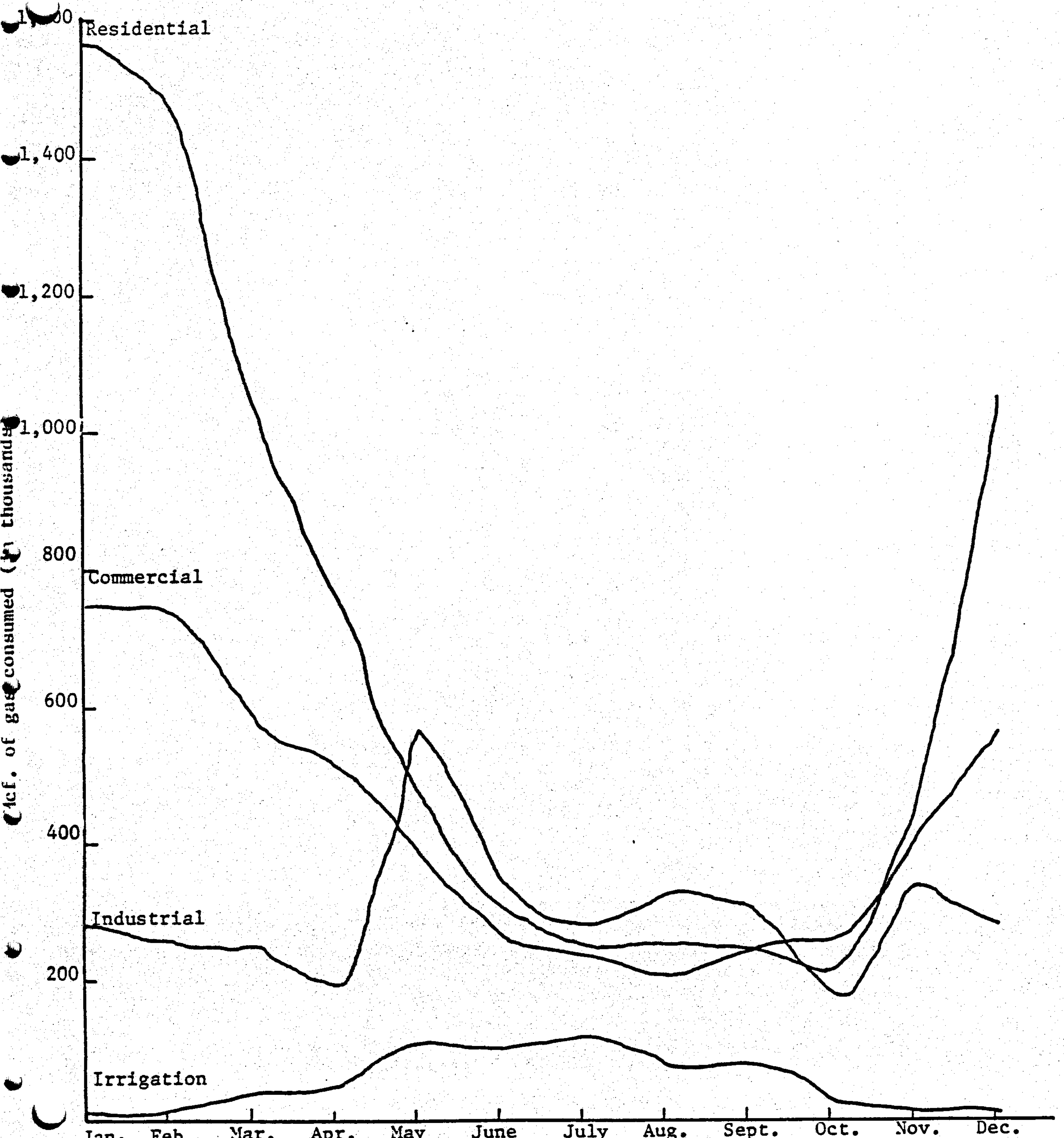


Figure 4-2: Estimated Natural Gas Sales By Month For 1979 Pima County

b) Industrial Process Heat Demand

With the use of information from the Solar Energy Research Institute and the 1980 Arizona Directory of Manufacturers, industries with process heat requirements of less than 100°C were identified within Pima County and their annual energy use estimated. Table 4-3 presents additional industries found and not previously reported.

Table 4-3: PIMA COUNTY
ESTIMATED PROCESS HEAT ENERGY REQUIREMENTS NOT PREVIOUSLY REPORTED
ASSUMED RESERVOIR TEMPERATURE: 100°C

SIC	# of firms	Description	Est. Annual Energy Use (Btu x 10^{10})
2026	1	Fluid Milk	.417
2086	5	Soft Drinks	4.831
2097	3	Ice	.286
2431	1	Millwork	.010
2499	1	Misc. Wood Products	11.280
2511	5	Wood Furniture	1.382
3273	2	Ready Mix Concrete	.022
3281	6	Cut Stone Products	.154
3449	1	Misc. Metal Work	.283
3519	1	Internal Cumb. Engines	8.391
3949	1	Sporting Goods	.291
3999	1	Misc. Manuf. Products	.283
		Subtotal	27.63
		Previously estimated process heat demand	76.44
		Total Process Heat Demand For Pima County Adaptable To Geothermal Energy	104.07

3) <u>Graham and Greenlee Counties</u>

Energy Consumption

All of the utility companies were contacted in Greenlee County. Currently, only figures from Morenci Water and Power have been received. Figure 4-3 shows electricity sales for the Clifton/Morenci area in which over 73% of the Greenlee County population resides. These figures show an unusual pattern for industrial electricity consumption. From March to September, which is the summer season in Arizona, there is a steady decline in consumption. In the summer months, electric utility companies usually experience peak sales due to the extensive use of air conditioning and cooling devices. Residential consumers are clearly the largest consuming sector and, as expected, peak demand occurs in July and August.

Several Utility companies serve Graham County. Data were received from the City of Safford, Town of Thatcher, Graham County Electric Coop., Inc. and Duncan Valley Electric Cooperative. Figure 4-4 shows monthly electricity demand for 1979 by user class.

Residential consumption shows a substantial increase in July which follows the general pattern for Arizona's peak demand schedule. The summer months, in particular, are those which use the greatest amount of electricity as witnessed by the increase in use of space cooling units. The commercial sector exhibits peak demand in August while the industrial peak occurs in October and minimum consumption during July. No explanation to date has been offered.

Figure 4-5 presents estimated sales of natural gas for the major consuming sectors in Graham County. The pattern of consumption is typical of Southern Arizona with peak usage occurring in December and January. Also of interest is the absence of natural gas users in the industrial sector.

b) Industry and Growth

Agriculture and agricultural services employment declined significantly

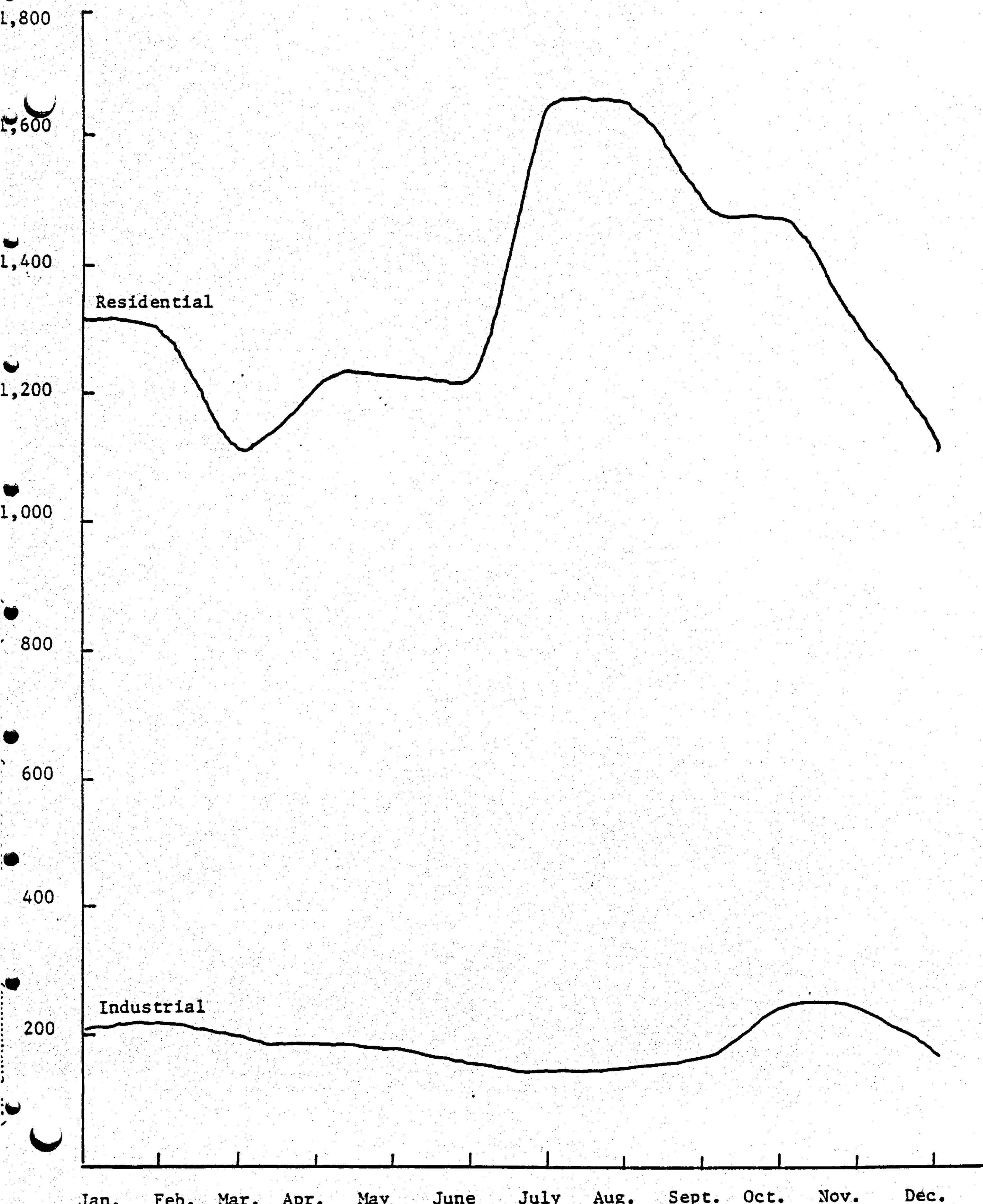


Figure 4-3: Estimated Electricity Sales By Month For 1979 For The Morenci/Clifton Area In Greenlee County

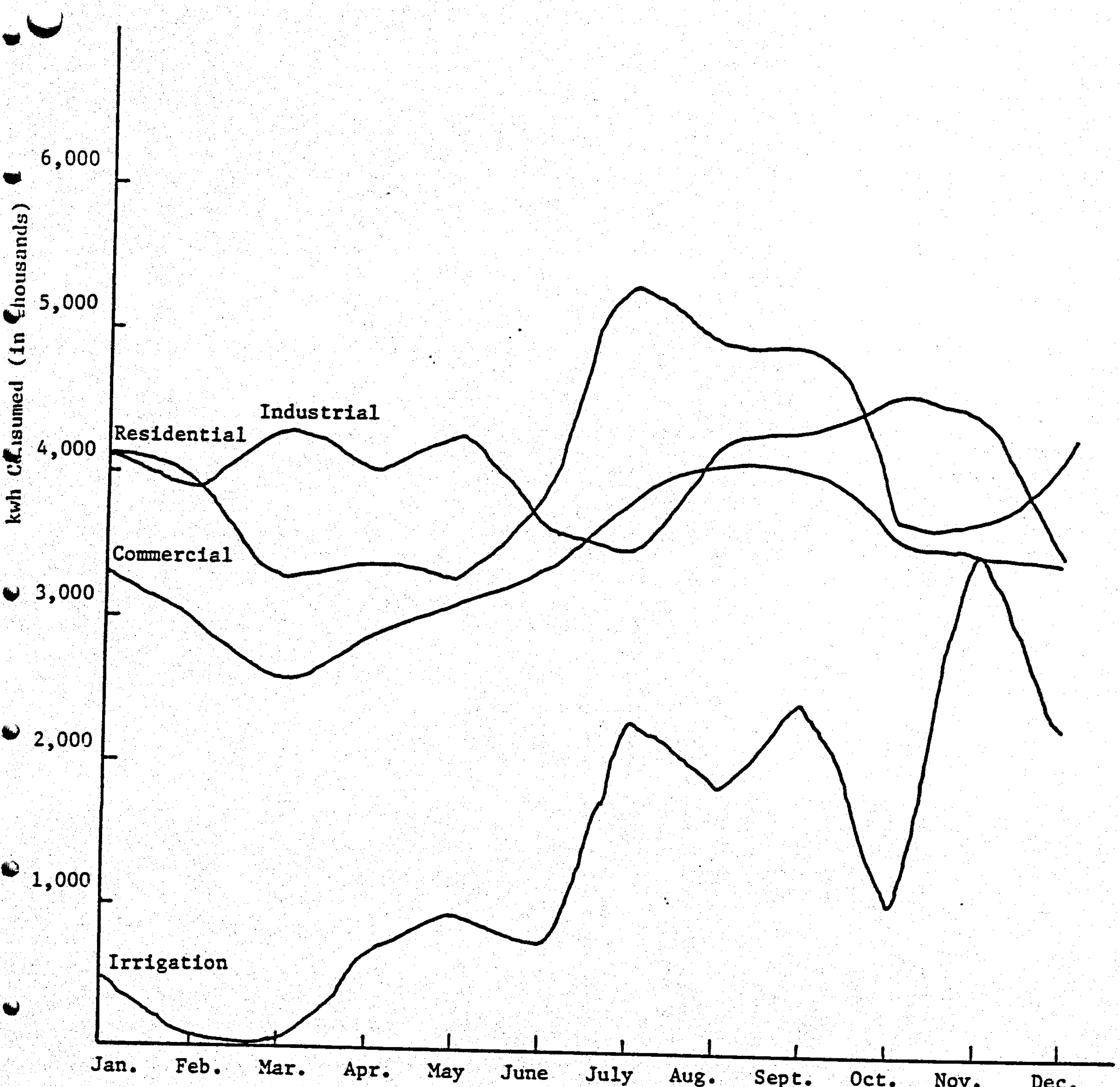


Figure 4-4: Estimated Electricity Consumption By Month For Graham County (1979)

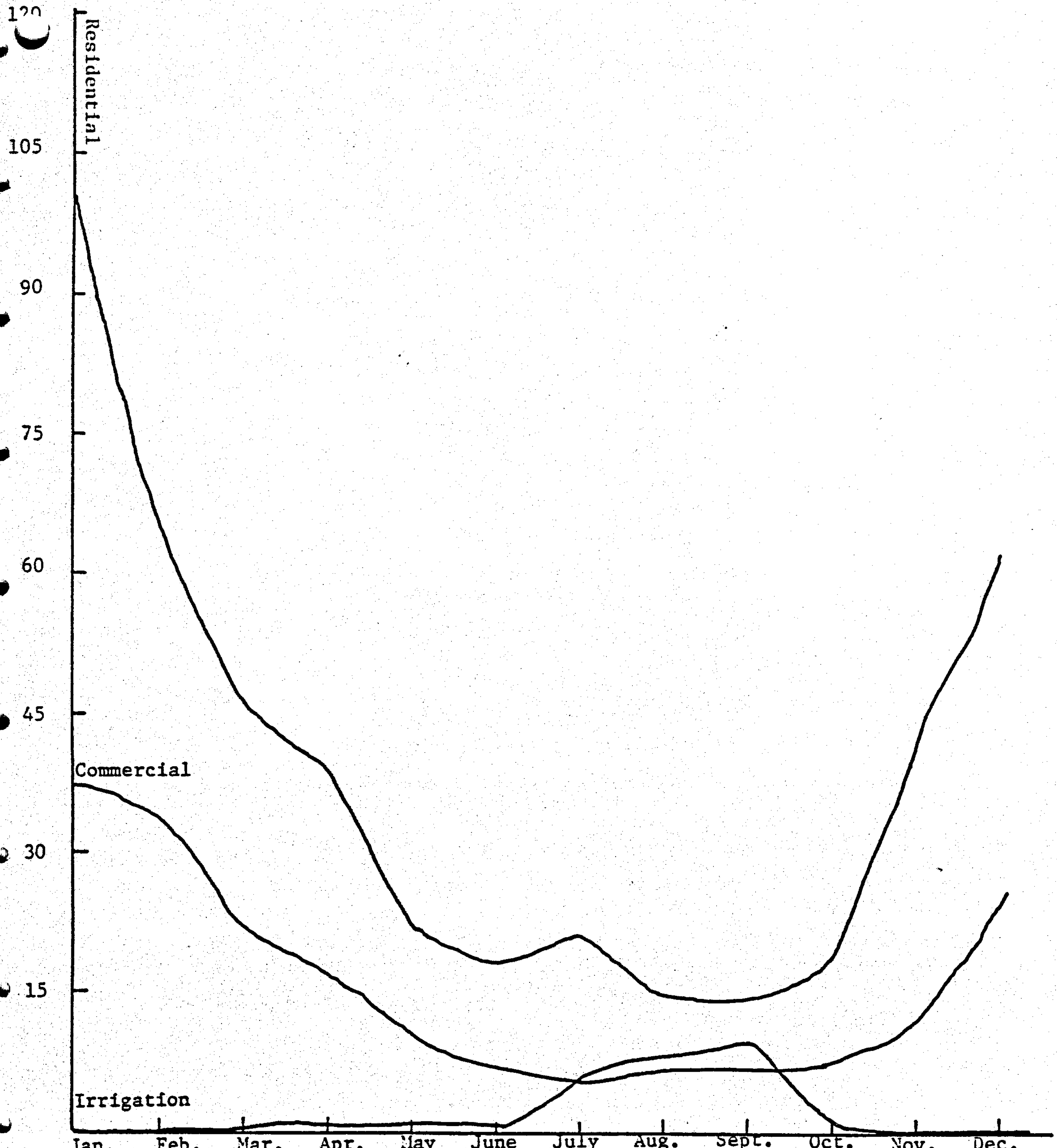


Figure 4-5: Estimated Gas Consumption By Month (1979) For Graham County

within Greenlee County. The mining sector continues to dominate the industrial employment composition. However, these trends are expected to change due to the recent effects of the depressed American copper industry upon the county's economy.

An updated list of industries in Greenlee County was compiled using the 1980 Arizona Directory of Manufacturers. However, no industries were found with process heat requirements of less than 125°C.

The agriculture sector in Graham County is an important economic base, dominated by livestock and livestock products, cotton, and sorghum.

The Safford area relies heavily on agriculture as a source of income. Safford farmers raise one-third of Arizona's swine. A hog kill plant was designated to be built. However, due to the poor bond market, financing was not feasible.

A new mining facility has been started in the Safford area. Employment in Safford is expected to increase significantly as a result.

The trade and service employment sectors grew the fastest of all sectors. The city of Safford is the center for retail sales in the region and retail sales has become the leading employment sector.

4) Pinal County

a) Energy Consumption

To date, data has not been received from Arizona Public Service Company or Southwest Gas Company for Pinal County. Both companies provide the bulk of gas and electricity to the county.

b) Industrial Process Heat Demand

As has been done in previous sections, industries which have process heat requirements of less than 105°C were identified in Pinal County and their annual energy consumption estimated. Table 4-4 presents additions to previously reported industries.

TABLE 4-4· PINAL COUNTY
ESTIMATED PROCESS HEAT ENERGY REQUIREMENTS NOT PREVIOUSLY REPORTED
ASSUMED RESERVOIR TEMPERATURE: 105°C.

SIC CODE	# of Firms	Description	Estimated Annual Energy Use (Btu x 10^{10})
2026	1	Fluid Milk	.435
2086	1	Soft Drinks	.566
3273	2	Ready Mix Concrete	.002
Subtotal			1.003
Previously estimated process heat demand			112.7
Total Process Heat Demand For Pima County Adaptable To Geothermal Energy			113.70

5) Yuma County

a) Geothermal Resources

To date, no work has been performed toward an evaluation of geothermal resource potential in the Yuma County area.

b) Economy

i) Population

The 1980 estimated population for Yuma County is 79,490. Total land area of the county is 9,991 square miles which results in a population density of 8 persons per square mile. However, over 50 percent of the population resides in the city of Yuma. Ethnic breakdown of the population is 65 percent White, 27 percent Hispanic, 4 percent Indian, and 3 percent Black.

ii) Growth

Between 1950 and 1960, the population of Yuma County increased at an average annual rate of 5.1 percent. This was slightly below the Arizona state annual average increase of 5.7 percent. From 1960 to 1970, the Yuma County population increase of 2.7 percent per year was again slightly below the state annual increase of 3.1 percent. Figure 4-6 presents future population projections to the year 2020. The implied annual growth rate over the next 40 years

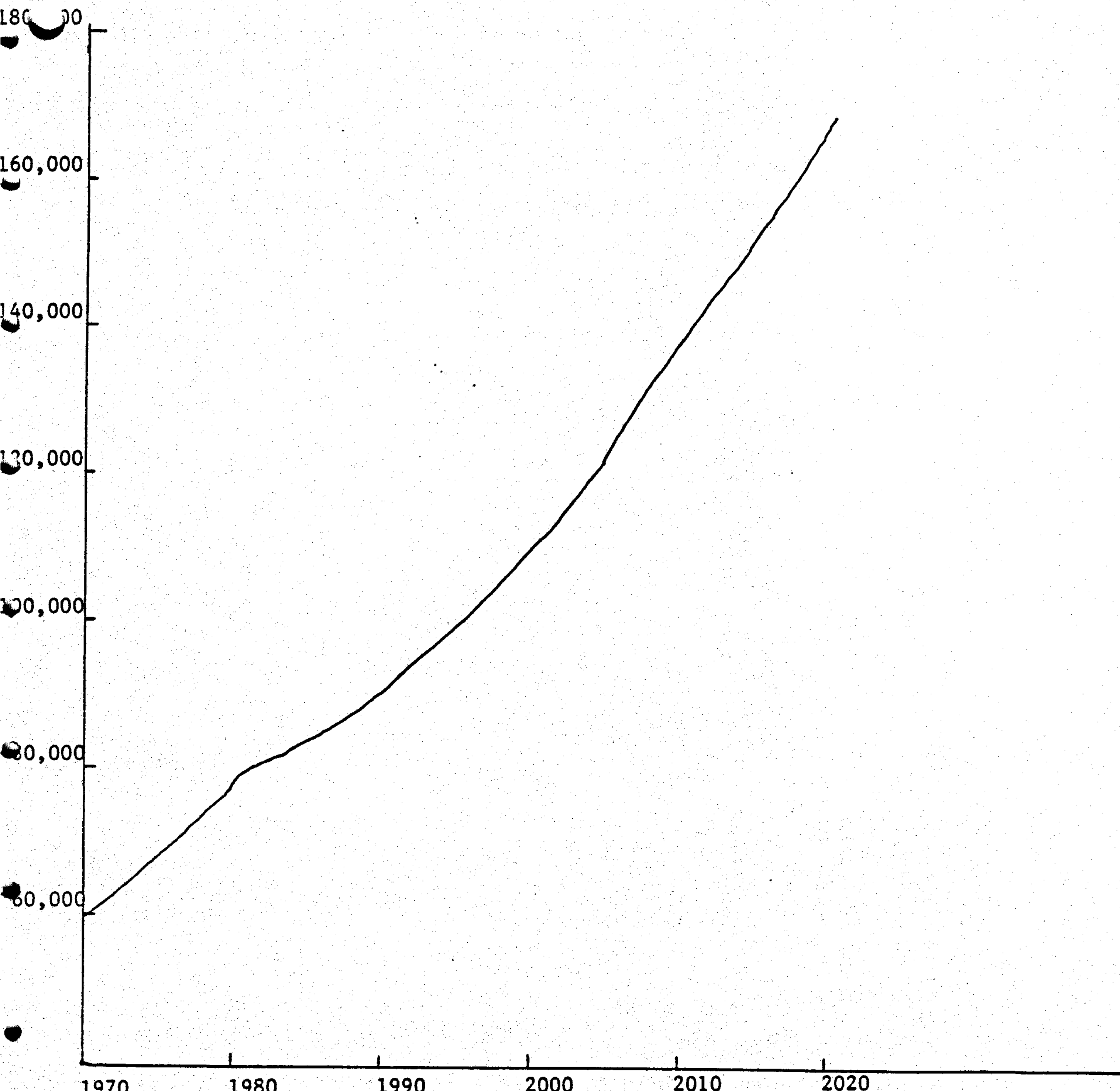


Figure 4-6: Population Projections For Yuma County To 2020 Source: Technical Advisory Committee (DES)

is almost 2 percent.

iii) Industry and Employment

Agriculture is the primary employment sector in Yuma County, accounting for 33 percent of the county's 1978 employment and 12 percent of its 1977 personal income.

Recently there has been a decline in the industry dollar value of agricultural marketing receipts. From 1976 to 1977, there was a decline of approximately 11.4 million dollars or 5.1 percent of total revenue from agriculture, The decrease is attributed to the decline in dollar receipts from livestock.

Yuma County accounted for 47.5 percent of the major citrus crops produced in Arizona during 1976-1977 season and for 45.0 percent of the citrus crops produced in the State during the 1977-1978 season.

Agricultural trends showed an overall downturn of total cash receipts for Yuma County agricultural products in 1977 compared to 1976, mainly attributable to the decline in livestock receipts. However, crops and citrus fruit receipts will continue to prosper in Yuma County. Principle crops in the county are cotton, hay, wheat, corn, barley, and sugarbeets.

Presently, Yuma County has several light industries. These include men's clothing, paper plates, photo processing equipment, and ceramic highway markers. Yuma County also serves as a distributional center for McDonnell-Douglas Corp, Hughes Helicopter, Broder Machinery, and Lipe Clutel Division of Lipe - Rollway.

Yuma County's Chamber of Commerce is actively seeking and encouraging new industry. Several new industries are projected for the county. However, this information is not available for public use.

c) Energy Use

Arizona Public Service Company serves both electric power and natural gas to Yuma County. The primary source of electrical power in the Yuma area is from the 2,085 MW Four Corners Generating Station which is interconnected with the 161 KV United States Bureau of Reclamation transmission network at Parker, Arizona. One-third of the 75 MW capacity at the Yucca Plant in Yuma is allocated to the immediate Yuma area. Two 2.5 MW and two 60 MW natural gas turbines are used for peaking. Additional information on energy consumption in Yuma County and projections on energy usage have been requested from Arizona Public Service but have not been received to date.

d) Water

Agriculture is the economic base of Yuma County and is the largest consumer of water. Rapid population growth is projected for Yuma County. However, water depletion associated with projected population increase is relatively insignificant when compared with depletions anticipated by agriculture. In Yuma County, urban use is projected to represent about two percent of total depletions while agriculture accounts for about 95 percent. Currently, only about 900 acre-feet per year is consumed for steam electric generations. Depletions for cooling steam electric power plants is projected to increase in Yuma County after 1990.

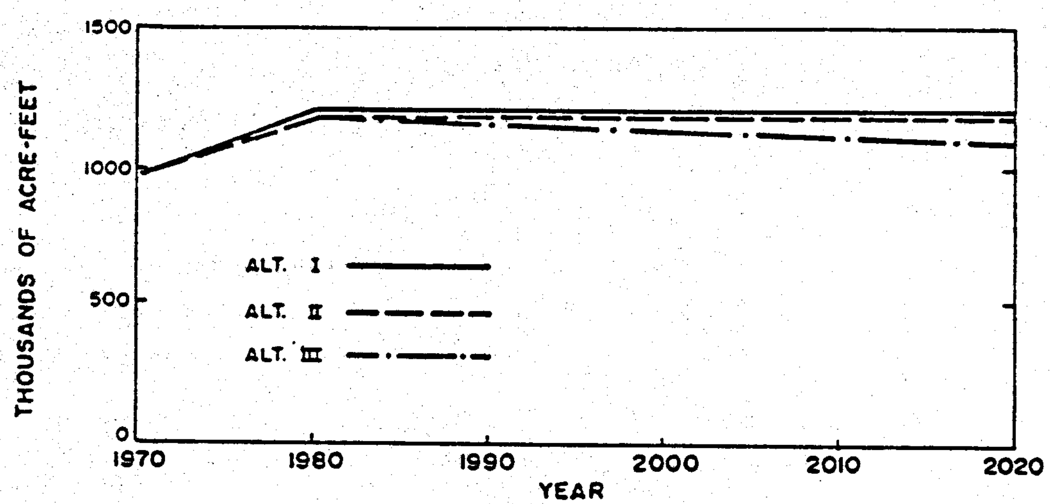
Future water use for mineral production under all alternative futures will be between 1000 and 2000 acre-feet per year and is expected to be associated with sand and gravel operation.

Irrigated average and associated water depletions are expected to increase in Yuma County. Most new developments will occur on Indian reservation lands.

Future dependable supplies along the Colorado River are reported to equal projected depletions. Although users along the river will have a dependable supply, other areas are experiencing groundwater overdraft. Thus, small deficiencies are projected for Alternatives I and II summarized in Figure 4-7 for Yuma County.

Work on the final two Area Development Plans has been undertaken and

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	60.8	118.0	200.0	96.1	136.0	96.1	136.0
HARVESTED ACRES	247.0	301.0	318.0	298.0	318.0	288.0	295.0
URBAN DEPLETIONS AF/YR	13.0	18.1	29.3	15.1	20.6	15.1	20.6
STEAM ELECTRIC DEPLETIONS AF/YR	0.9	0.7	26.9	0.5	11.6	0.5	11.6
MINERAL DEPLETIONS AF/YR	0	1.0	2.0	1.0	2.0	1.0	2.0
ARGICULTURAL DEPL. AF/YR	954.0	1170.0	1150.0	1160.0	1150.0	1120.0	1070.0
TOTAL WATER DEPL. AF/YR[1]	970	1219	1238	1206	1214	1166	1134
DEPENDABLE WATER AF/YR[2]	1086	1118	1127	1121	1127	1121	1127
SURPLUS SUPPLY (Def.)	116	(101)	(111)	(85)	(87)	(45)	(7)

[1]Includes 2,000 acre-feet depleted for fish and wildlife purposes in 1970 and 29,400 acre-feet in 1990 and 2020.
[2]Dependable supply from the Colorado River is equal to depletions for all alternatives. Off-river dependable supply was added to determine total county dependable supply. Deficiencies only occur from off-river uses. Dependable supply for 1970 includes unmeasured return flows.

Figure 4-7: Projected Future Water Availability And Use For Yuma County. Source: Arizona Water Commission (1977) results will be reported in the third quarterly progress report.

Task 2: Continuation of Site Specific Development Analyses (SSDA)

a) Space Cooling and Heating - Work under this task involves preliminary studies into the possibility of using geothermal energy to space cool and heat a residential district to be constructed at some future date. To date, preliminary discussions have occurred with a Phoenix home developer regarding a future subdevelopment on the west side of Phoenix. Relevant information has been obtained from the developer regarding home sizes, development size, heating loads and cooling loads for each home size. A preliminary study will be performed and future interactions will occur with this developer, hopefully leading to a demonstration project. To date, no specific work has been performed. This task also involves doing a preliminary study into the heating and cooling of a large commercial or industrial facility. However, to date, no company has expressed interest in contributing to such a study.

b) Geothermal Power Plants - No additional work has been performed on this task to date except for interactions with John Whipple, Water and Power Resource Services, Department of the Interior, Boulder City, Nevada. What is needed is a cost analysis 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. Therefore, it appears that this task will be conducted at a minimal level for the remainder of 1980. The work with Water and Power Resource Services involves mainly the generation of electric power using geothermal energy in the Willcox, Arizona, area to desalinate water.

c) Geothermal - Assisted Copper Dump Leaching - Work under this task involved studying the use of chelating agents for the recovery of copper from leach liquors using solvent extraction. In particular, the use of solvent extraction on more dilute solutions was investigated, along with the problem of organic loss in such extraction operations. Also, the effect of heating the solutions on reaction rate was investigated.

i) Copper

Today there are a large number of chelating agents commercially produced for use in solvent extraction of copper. Table 4-5 gives a list of chelating agents designed for use in hydrometallurgy and their applications. Of these, three are now being used in industry. They are : LIX 64N (General Mills/Henkel), 5ME 529 (Shell Chemical Co.), and Acorga P5100 (Acorga/ICI). General Mills (now owned by Henkel) was the first to develop chelating agents specifically for use in the processing of copper, and their LIX 64N is the most widely used reagent at this time.

In choosing which chelating agent to use; more information must be known about the specific makeup of the leach liquor. For example, the pH of the liquor, its Cu^{++} concentration, and the ratio of copper to iron in solution are all factors which will need to be taken into account.

At the present time, leach liquors as dilute as 1.0 g/l are being processed by industry. In the near future, the Cities Service Company, at Pinto Valley, AZ, will use liquors as dilute as 0.3 g/l. Pilot plant tests have used feed concentrations 80 mg/l from which nearly 95% of the copper was extracted. This demonstrates that the chelating agents will work on very dilute solutions. However, several problems are encountered as more dilute solutions are used. There are increased capital costs due to the large volume of liquor which must be processed. Also, more organic is lost as the aqueous flow rates increase and larger volumes of leachant are necessary to extract an equivalent amount of copper from the ore.

Barring a radical change of equipment design, not much can be done to reduce capital costs. Two proposals have been made to reduce organic loss: (1) enclose the system, and (2) recover the organic from the raffinate.

TABLE 4-5: Solvent Extraction Reagents For Hydrometallurgy

Class	Type	Examples	Manufacturers	Commercial Uses
Acid extractants	Carboxylic acids	Naphthenic acids	Shell Chemical Co	Copper nickel separation
		Versatic acids		Yttrium recovery
	Alkyl phosphoric acids	Di 2-ethylhexyl phosphoric acid (DEHPA)	Union Carbide	Uranium extraction, Europium extraction, Nickel, cobalt separation
Acid chelating extractants	Hydroxyoximes	LIX63, LIX64N, LIX65N, LIX70, LIX71, LIX73	General Mills Inc	Copper extraction and nickel extraction (LIX65N)
		SME 529	Shell Chemical Co	Copper extraction
		P5000 series	Acorga Ltd	Copper extraction
	Oxine derivatives	Kelex 100 and Kelex 120	Ashland Chemical Co	Proposed for copper extraction
	β-diketones and others	Hostarex DK 16	Farbwerke Hoechst AG	Proposed for copper extraction from ammoniacal solution
		LIX54	General Mills Inc	Proposed for copper extraction from ammoniacal solutions
		LIX34	General Mills Inc	Proposed for copper extraction from acidic leach liquors
Basic extractants	Primary amines	Primene JMT	Rohm & Haas	No known commercial use
	Secondary amines	LA-1 and LA-2	Rohm & Haas	Uranium extraction
		Adogen 283	Ashland Chemical Co	Proposed for vanadium and tungsten extraction
	Tertiary amines	Various Alamines, in particular Alamine 336	General Mills Inc	Widely used, uranium extraction, cobalt extraction, tungsten, vanadium etc
		Various Adogens, in particular Adogen 381	Ashland Chemical Co	Various uses, uranium, cobalt etc
	Quaternary amines	Aliquat 336	General Mills Inc	Vanadium, other possible uses for chromium, tungsten and uranium
		Adogen 464	Ashland Chemical Co	Similar to Aliquat 336
Solvating extractants	Phosphoric, phosphonic and phosphinic acid esters	Tributyl phosphate (TBP)	Union Carbide	Refining of U_3O_8, nuclear fuel reprocessing, Fe extraction, Zr/Hf separation, rare earth separation
		Phosphonic acid esters	Farbwerke Hoechst AG	No known commercial use
		Trioctyl phosphine oxide (TOPO)	General Mills Inc	Recovery of uranium from wet process phosphoric acid liquors (with DEHPA)
	Various alcohols, ketones, esters, ethers etc	Methyl isobutyl ketone (MIBK)	Various	Niobium, tantalum separation, Zr/Hf separation

Source: Chemistry and Industry
September 3, 1977

The organic solution is lost both by evaporation and entrainment in the raffinate, which, in industry is usually held to less than 0.1 gal per 1000 gallons of feed. Little or no reagent is lost by evaporation due to its very low vapor pressure. Therefore, if the system were enclosed, it would only serve to reduce kerosene loss, and may not be worth the added capital expense. Recovery of the organic from the raffinate is sometimes accomplished by allowing the solution to sit in a holding pond and then collect any organic which comes to the surface. No data was found on how much could be recovered this way. Usually, the raffinate is recycled to be used in leaching.

The kinetics of the extraction and stripping reaction of the chelating agents is fast. Therefore, heating the solutions would do little to increase the efficiency of the operation. However, heat is sometimes added to aid in phase disengagement of the organic from the aqueous.

To date, no meetings have been held with members of Arizona's copper mines. When data on copper dump leaching are more refined, interactions will occur.

d) In-Situ Leaching of Uranium, Zinc and Copper

i) Uranium

It has been found that tertiary amines serve as good chelating agents for the extraction of uranium from solution. One common reagent is Alamine 336 produced by General Mills/Henkel. Di (2-Ethylhexl) Phosphoric Acid (DEHPA), produced by Union Carbide, has also been used commercially to extract uranium from dilute and sulfate solutions.

There are a number of uranium mining operations throughout the world which use Solvent Ion Exchange. These use solutions as dilute as 100 to 200 ppm. Some of these operations in Texas are using in-situ solution mining on roll front sandstone deposits. Similar deposits have been found in Arizona.

Very little uranium mining is now being done in Arizona, and the depressed price of the metal is keeping others from getting into the business. However, Anamax is using a Solvent Ion Exchange circuit to extract uranium from a very dilute solution of approximately 10 ppm uranium. This is a by-product of the copper recovery setup which they have had in operation since 1975. Once the copper has been extracted from the leach liquor, the liquor is then run through the uranium extraction circuit. The solution is first run through an ion exchange column where the uranium is extracted by solid ion exchange resins. The uranium is then stripped from the resins giving a concentration in the range of approximately 10 ppm which is then processed using Solvent Ion Exchange. Since the uranium is already in solution in the circuit, it is economical to go ahead and extract it. However, it is doubtful that an operation designed solely for uranium recovery could be operated economically using such dilute solutions.

ii) Zinc

There are chelating agents which may be used on zinc, and a hydrometallurgical process has been proposed by General Mills Chemicals, but no one is using Solvent Ion Exchange for zinc in the U.S. Due to the depressed market for zinc, it is doubtful that it would be economical to start a zinc mining operation at this time.

e) Geothermal Steam Turbine Pumping

Work to date has involved identifying the various methods of irrigation currently in practice in Arizona and potential problems which may arise in these methods if spent geothermal brine were mixed with irrigation water in order to augment the water supply.

Currently three types of irrigation methods are in use in Arizona, trickle irrigation, sprinkler irrigation and ditch irrigation. Trickle irrigation using spent geothermal water would clog quite easily unless the geothermal water and the irrigation water were treated. Water treament would be a very costly approach to solving such a problem. Sprinkler irrigation using geothermal water would be less likely to clog than trickle systems, but the high salt content and relative acidity of the geothermal water would cause leaf-burn, with varying adverse effects on the plant. Ditch irrigation appears best suited for geothermal water. Clogging is not a serious problem, losses due to evaporation can be small, and large quantities of geothermal water can be used.

In addition to identifying irrigation methods within Arizona and the effects of using geothermal water in each type of system, a blended water chart was compiled for a 5 percent geothermal mix. Table 4-6 presents the salt values for various temperatures of geothermal water which may be used.

The general rule of thumb for the distribution of irrigation water is one horsepower for one acre to be irrigated. Irrigation patterns are somewhat site-specific, and the setup of a system also depends on the system currently in use. For example, a handmove system requires no pattern because of its mobility. Irrigation patterns will be optimized for drip, solid set and flood irrigation. Drip and solid set irrigation are permanent systems so the setup pattern will be identical. A radial distribution system (similar to a center pivot) with allowances for the geometry and land contours is currently being developed in the Paris basin and in New Zealand. A radial distribution system with allowances for plot shape appears to be the best available system.

Further information has also been collected on water irrigation districts in Arizona, water consumption by month for various crops, energy consumption for various crops and quantities of water required under various irrigation methods for popular crops in Arizona. This information will be correlated and reported at a later date.

TABLE 4-6: BLENDED WATER CHART

Tabulated values are capacity ppm values of the salts in a 5% geothermal 95% pure water mix

	60%	80%	100%
$Al_2(S)_4)_3$			49000
$BaCl_2$	17000	19000	22000
$BaCO_3$			3
$BaSO_4$			2
$Ba(NO)_2$			16000
$CaCl_2$			80000
$CaSO_4$			170
$MgCl_2$			35000
$MgCO_3$			5.5
$MgSO_4$			34000
KCl	23000	26000	28000
K_2CO_3			78000
K_2SO_4			12000
NaCl	19000	19000	20000
Na_2CO_3			23000
Na_2SO_4	23000	22000	21000

f) Direct Thermal Use for Food Processing - No new work has been performed on this task during the second quarter.

g) Geothermal Energy Utilization in Modern Cattle Feedlots

The major effort on cattle feedlots to date has been their integration with gasohol-alcohol plants, so that both operations can be made more economical by consuming the alcohol mash in the cattle feedlot. We determined that cattle feedlots are decreasing in Arizona due to their economic situation compared with California and Texas feedlots. The question is whether alcohol production and its new starch and cellulosic needs will change the situation.

h) Geothermal Assisted Coal Fired Power Plants

No new work has been performed on this task during the second quarter.

i) Satellite Urban Development

No new direct work has been performed on this task during the second quarter by the Arizona Team. However, it has continued interactions with city planners and has financially supported Dr. Mike Pasqualetti for work in the Phoenix area and for work in collecting data on how geothermal might be used.

j) Geothermal Assisted Aquaculture

No new work has been performed on this task; however, several inquiries have been received expressing interest in such an application and requesting further information.

k) Alcohol Production for Gasohol

As was stated earlier, members of the Arizona Geothermal Commercialization Team became involved in providing input and technical assistance to the Ethanol Task Force of the University of Arizona Cooperative Extension Service. The final result of those interactions will be a series of papers on ethanol production and economics. Input was provided on technical, economic and institutional aspects of alcohol production in Arizona. Results to date of that work are presented here.

i) Starch Feedstock

Starch is found in many types of grains including the most common, wheat and corn. To make starch chemically available, the grain is ground and mixed with water into a slurry. In the case of corn, the most commonly used process for this is called the corn wet-milling process for starch production.

In the corn wet-milling process, the corn is first steeped in aqueous 5 percent sulfur dioxide solution. This solution is sold as corn steep liquor (CSL). The grains are non-softened and can be coarse milled in order to loosen the oil-containing germ. The germ is then separated and processed to provide corn-oil and oil coke. The remaining slurry then goes through more milling, washing, and centrifugal separation to remove the fiber and gluten. These are saleable products. The remaining slurry is called the starch slurry and can be hydrolyzed and fermented by various methods discussed below.

In ethanol production there is no real need for the corn wet-milling process. By simply grinding and adding water, the corn is ready for hydrolysis. However, some people in the field believe with this extra processing, these minor by-products can make the ethanol process economical. On the other hand, others feel that the added cost of the wet-milling equipment offsets the benefits from the corn by-products. From the literature found, it is not now obvious which is the best way to go.

There are not many general differences between the processes for converting starch to ethanol. Basically, the difference lies in this acid hydrolysis vs. enzymatic hydrolysis. There are discussed below.

Acid hydrolysis of starch to glucose dates back to 1873. The Hamilin Plant of the American Glucose Company first produced glucose from wet-milled corn. Most pre-1950 glucose production used the acid process. Glucose was usually crystallized and used for food supplements. Since 1950, most glucose production has been enzymatic because the acid process is simply not thought to be economically competitive.

Enzymatic hydrolysis from starch feedstock can occur in two ways. First, a dual enzyme system can be employed to first use an alpha amylase system to reduce the starches to dextrins (complicated sugars). Then glucoamylase or amylglucosiclase can be used to break the dextrins down to glucose. The second way uses acid hydrolysis to convert the starch to dextrins while glucoamylase is used to convert the dextrins to glucose.

The major reason the enzymatic processes are competitive is the yield. The yield of acid hydrolysis is low compared to enzymes. On the other hand acid hydrolysis is fast and residence times are short. Enzymes have control problems. Depending on the enzyme the temperature and pH must remain within a specific range to avert serious consequences. With acid, temperature is not so critical.

ii) Cellulose Feedstock

The possibility of making sugars by hydrolyzing cellulosic materials has been around for 60 years. The early attempts during World War II (WW II) used acid hydrolysis of the cellulose. The following processes used acid hydrolysis.

Schallor

Improved and developed in Germany during WW II, this process uses high temperature and dilute H_2SO_4. The process was dropped for economic reasons after the war.

Madison Wood Sugar Process

Developed by USDA during WW II, this process used acid and was shut down after unsuccessful trial runs. Subsequent attempts by private industry also failed.

Bergius-Rheinau

Operated in Germany during WW II, this process utilized 40% HCl at room temperature and was used to grow tortula yeast. Later modifications proved unsuccessful.

Other processes that have been unsuccessful as far as commercialization are ones from Japan, USDA Northern Research Laboratory, and EPA projects. The only commercial scale wood hydrolysis practiced today is in the Soviet Union. They use modifications of the Rheinau process. However, little is known about the size, number, and location of these plants.

In recent years several innovations have taken place in the study of hydrolysis. Dr. George Tsao at Purdue University has shown that cellulose hydrolysis can be improved with the use of solvents, cadoxen, CMCS (EMNN) and sulfuric acid. The Solar Energy Research Institute has done a study on Dr. Tsao's process. A study was also done for DOE on enzymatic hydrolysis of wheat straw. The wheat straw process applies work done by C.R. Wilke at Berkeley, and the U.S. Army Natick Development Center. The Natick Center has developed an enzyme system utilizing the enzyme produced by Trichoderma Viride. The Army has been studying these enzymes for years.

iii) Fractionation Methods

One method used to produce anhydrous alcohol is to absorb the 4 percent to 5 percent water present in 95 percent to 96 percent industrial alcohol using guide lime, with subsequent distillation. This process is expensive even though it produces a high quality of absolute alcohol. It has been superceded by improved chemical engineering unit operations of distillation and extraction involving a third component. This has led to a lower cost of dehydrating operations. This second method involves azeotropic and extractive distillation. Contemporary commercial schemes for the dehydration of ethyl alcohol are based upon azeotropic distillation utilizing an entrainor such as benzene, cyclohexane or even gasoline. The water is removed by vaporization as a portion of the overhead vapor and the bulk of the ethyl alcohol is removed as bottoms. In extractive distillation, on the other hand, all of the ethyl alcohol is vaporized as an overhead vapor with the water being removed in a solution with an extracting agent. The water is then vaporized in a second column.

A third method involves fractionation at two pressures to separate the azeotrope. The azeotrope (water-ethanol system) increases in alcohol content as the pressure is reduced. Thus, by operating at reduced pressure, an overhead product can be produce which contains a higher percentage of alcohol than corresponds to the azeotrope at some higher pressure.

A fourth method involves the use of molecular sieves. Molecular sieves are crystalline metal alumino-silicates with a three dimensional inter-connecting network structure of silica and alumina tetrahedra. Molecular sieves generally behave as physical absorbents. An advantage of molecular sieves is that they have an extremely high equilibrium absorption capacity for water and polar compounds at very low concentration of these compounds in the fluid phase.

A fifth method involves membrane separation. By the use of a reverse osmosis type membrane selectively permeable to water, one can dehydrate the ethanol to 99.5 percent. The energy requirements are low compared with distillation but membrane life and capital cost is very high.

iv) Institutional Requirements

The Bureau of Alcohol, Tobacco and Firearms (ATF) of the Department of the Treasury, is responsible for administering the laws in the Internal Revenue Code that relate to distilled spirts (alcohol).

Due to provisions in the recently passed Windfall Profit Tax Bill, ATF has streamlined the permitting procedures for alcohol fuel producers. Currently, those interested in producing alcohol for fuel purposes must first obtain an Alcohol Fuel Producer's Permit from ATF. An applicant for an Alcohol Fuel Producer's Permit may not engage in operations until the permit has been issued by the ATF Regional Regulatory Administrator. The application (Form 5110.74) must be completed by a person who would like to establish a plant to produce, process, and store, and use or distribute distilled spirits to be used exclusively for fuel use. The completed application must be submitted to the appropriate Regional Regulatory Administrator of ATF. Estimated minimum time involved in obtaining an Alcohol Fuel Producer's Permit is 60 days.

The type of permit needed, small, medium or large, depends on how many gallons of distilled spirits one intends to produce and receive by transfers from other plants during one calendar year. Proof gallons may be calculated by taking the proof of the spirits multiplied by the number of gallons and dividing by 100. The following permit categories (all determined on a proof gallons per calendar year basis) now exist:

Small - 10,000 proof gallons or less during one calendar year.

Medium - More than 10,000 proof gallons but not more than 500,000.

Large - More than 500,000 proof gallons.

Applicants for a medium or large plant permit must file a distilled spirits bond with ATF. This bond is based on yearly production figures. Bond rates for medium plant permits range from $2000 (for production of 10,000 to 20,000 proof gallons) to $50,000 (for production of up to 500,000 proof gallons). The bond rates for large plant permits range from $52,000 to a maximum of $200,000. The application for an Alcohol Fuel Producer's Permit calls for the following information:

- Information about applicant, individual owners, or corporations involved.

- Capacity of stills in proof gallons

- Sample diagram of premises

- A statement of the maximum quantity of distilled spirits to be produced and received from other plants during a calendar year.

- A statement as to whether the applicant or any person required to be listed on the application has been previously convicted of any Federal or State law (other than minor traffic violations).

- Basic materials to be used in production of spirits.

ATF will require each alcohol fuel producer to maintain records of production and disposition of the alcohol. At regular intervals, the alcohol fuel producer will provide information to ATF for verification and auditing. Producers must maintain records of:

- The quantity and proof of alcohol produced.

- The quantities and types of materials added to the alcohol to destroy the beverage character of the alcohol.

- The disposition of the denatured alcohol.

The law requires denaturing (destroying its beverage character) of alcohol for fuel use. ATF has several different formulas for the denaturing of alcohol. Alcohol must be denatured before it leaves the premises on which the production facilities are located.

For additional information contact:

Regional Regulatory Administrator
Bureau of Alcohol, Tobacco and Firearms
515 Market Street
San Francisco, California 94105
800-227-3072 (Toll Free)

v) Arizona Regulatory Requirements

The Arizona Department of Health Services (DHS) requires that a gasohol plant meet air quality regulations. The DHS requires that an industrial plant emitting measurable pollutants, obtain an operating permit.

The Arizona State Industrial Commission administers regulations in three areas pertaining to the distillation of alcohol. These include: Workmen's Compensation, Federal OSHA regulations, and State Fire Code.

The Motor Transportation Division of the Arizona Corporation Commission (ACC) has regulatory jurisdiction over the intrastate shipment and transportation of flammable liquids (including ethanol and gasohol). All flammable liquids must be transported in U.S. Department of Transportation approved specification containers. Permits must be obtained from the ACC if the flammable liquid is to be transported by common carrier.

Registration of an operating alcohol distilling facility is necessary through the Arizona Department of Liquor Licenses and Control. This is not a lengthy permitting process but merely a formality. Information needed by the department includes:

- Name, address, and telephone number of operator
- Location of distilling apparatus
- Brief description of distilling apparatus
- Copy of Federal Alcohol, Tobacco and Firearms permit

Local Regulations

It would appear that local regulations such as fire restrictions, building codes, and zoning would play a part in the location of a gasohol facility. These, however, seem to pose no problems or time lags in the development of gasohol facilities.

List of Contacts - Federal and State

1. Regional Regulatory Administrator, Bureau of Alcohol, Tobacco and Firearms
   525 Market Street, 34th Floor
   San Francisco, CA 94105

   Phone: (415) 556-0226

2. Arizona Department of Health Services
   1740 W. Adams
   Phoenix, AZ 85007

   Phone: (602) 255-1140

3. Arizona State Industrial Commission
   1601 W. Jefferson
   Phoenix, AZ 85007

   Phone: (602) 255-4411

4. Arizona Corporation Commission
   Motor Transportation Division
   2222 W. Encanto
   Phoenix, AZ 85009

   Jack Vaugn
   Phone: (602) 255-3316

5. Arizona Department of Liquor Licenses and Control
   1645 W. Jefferson
   Room 227
   Phoenix, AZ 85007

   Phone: 602) 255-5141

vi) Government Incentives

The first major boost for the U.S. alcohol fuel program came with the National Energy Act of 1978, which removed the Federal gasoline tax of 4¢ on every gallon of gasohol containing alcohol from nonpetroleum sources. Effective January 1, 1979, this law exempted a ten-gallon mixture, containing one gallon of ethanol and nine gallons of gasoline, from the Federal tax of 4¢ per gallon, thus providing an actual subsidy of 40¢ on each gallon of alcohol used as fuel. As early as 1980, 16 states also exempted gasohol from state gasoline tax. To date, the Arizona Legislature has failed to follow the lead taken by these states.

A second major boost for the U.S. alcohol fuel program was when the White House announced in January 1980 a program for the next decade with specific goals set for 1981 and the mid-eighties (see the discussion above). All told, it is proposed that somewhere between $8.5 to $13 billion dollars be committed to encouraging the alcohol fuel industry. Many of the incentives of this multi-billion dollar package are already in effect, including the 4¢-a-gallon Federal gasoline tax exemption. In order to provide investors in alcohol fuel distilleries a long-term market and profitability for their product, the President proposed that the gasohol tax exemption be made permanent.

A major new component in this program was $3 billion in proposed new Federal loans and in loan guarantees for those investing in alcohol distilleries. The figure includes about $300 million to assist small scale producers such as individual farmers who wish to produce their own farm fuel supplies.

In addition to the above program, the Department of Energy is already looking at a way to use sweet sorghum to produce ethanol. This crop is attractive because of its high potential alcohol yield per acre (381 gallons).

The Crude Oil Windfall Profit Tax Act of 1980, signed into law on April 2, 1980, contains several provisions which will affect persons or firms producing, blending, marketing, or using alcohol fuels. These include:

1. Continuation from 1984 through 1992 of the exemption from the 4¢ per gallon Federal excise tax on alcohol-gasoline blends containing at least 10 percent alcohol. The alcohol must be at least 190 proof and produced from sources other than petroleum, natural gas and coal.
2. Refunds for excise taxes paid on gasoline blended with at least 10 percent alcohol.
3. Income tax credits for blenders of alcohol-gasoline blends, and for users of straight alcohol fuel.
4. Continuation through 1985 of the energy investment tax credit for alcohol fuel production equipment.
5. Authority for simplification of Bureau of Alcohol, Tobacco and Firearms regulation of alcohol fuel producers.
6. Tax-exempt status for certain industrial development bonds for financing alcohol fuel production facilities.

For the period October 1, 1980 through December 31, 1992, a person who blends alcohol fuel with gasoline or any other liquid fuel suitable for use in an internal combustion engine may claim an income tax credit. To qualify, the blender must sell the blended fuel for use as a fuel or use it as a fuel himself. For example, a farmer who blends his own alcohol-gasoline fuel would qualify for an income tax credit.

The tax credit amounts to 40¢ per gallon of alcohol of at least 190 proof, and 30¢ per gallon of alcohol of at least 150 proof but less than 190 proof. Alcohol is defined as ethanol and methanol, but does not include alcohol produced from petroleum, natural gas, or coal. The tax credit is reduced by the amount of Federal excise tax exemption applicable to the blended fuel. The following table illustrates calculation of the income tax credit according to the alcohol content of the blend:

Gasoline (gallons)	Alcohol (gallons)	Tax Credit #	
		Gross[1/]	Net
			.40[a/]
99	1	$0.40	2.00[a/]
95	5	2.00	0.00
90	10	4.00	2.00
85	15	6.00	8.00
70	30	12.00	16.00
50	50	20.00	24.00
30	70	28.00	36.00
0	100	40.00	

1/ Gross tax credit equals 40¢ times the gallons of alcohol in the blend. The gross tax credit for blends containing 10 percent or more alcohol is reduced by the value of the excise tax exemption ($4 per 100 gallons of blend) to obtain the net tax credit.

2/ Blends that contain less than 10 percent alcohol are not exempt from the 4¢ per gallon Federal motor fuels excise taxes; therefore, the gross tax credit is not reduced in these cases. The Federal excise tax of 4¢ must be paid on each gallon of this motor fuel.

If the alcohol-gasoline blends or straight alcohol fuel are sold to certain purchasers exempt from all Federal motor fuel excise taxes, the gross tax credit is not reduced by the value of the excise taxes exemption. Such exempt purchasers are farmers who use fuel for on-farm use, and units of local government.

Any person considering alcohol fuel production, blending, or marketing, and who believes that he may qualify for the tax provisions under this law, should seek professional tax counsel.

The Windfall Profit Tax Act retains through 1982 the 10 percent Energy Investment Tax Credit for "alternative energy property", and creates for the period January 1, 1983 through December 31, 1985, a new eligibility section for "biomass property". Both of these sections apply to equipment that converts biomass into alcohol fuel provided that the equipment producing the alcohol uses a primary source of energy (i.e., more than 50 percent of the fuel energy requirement) other than oil, natural gas, or a product of oil or natural gas. Biomass is defined as any organic substance other than oil, or natural gas. Biomass includes waste, sewage, sludge, grain, wood, oceanic and terrestrial crops, and crop residues. Beginning January 1, 1983, coal may not be used as a feedstock if the 10 percent Energy Investment Tax Credit is claimed.

The recently passed Energy Security Act authorizes the USDA to insure and guarantee loans for ethanol facilities up to 15 million gallons annual capacity and certain categories of projects (those which use forestry feedstocks or which are sponsored by cooperatives) larger than 15 million gallons annual capacity. This new Biomass Energy Financial Assistance Program will involve the close cooperation of the Department of Energy and the Department of Agriculture. Credit assistance is expected to be available under the act by October 1, 1980. The Secretary of Agriculture has consolidated all USDA financial assistance for commercial biomass energy projects in the Farmers Home Administration. Within the FmHA an office of Renewable Resources has been established to participate in the development and direction of alcohol fuel and other biomass energy financial assistance programs. Processing and servicing of insured loans and loan guarantees will occur primarily through existing personnel of the Farmers Home Administration and through the existing state, district and county offices of the agency.

In providing financial assistance, USDA recognizes the need to encourage smaller and intermediate size ethanol production facilities, including on-farm units. A promising approach would be to target financial assistance to cooperatively-owned, "community" sized plants which have excessive anhydrous production capacity which could upgrade farm produced lower-proof alcohol as well as produce anhydrous alcohol directly from locally-grown unprocessed feedstocks.

vii) Environmental Effects

There are three main areas to examine for potentially hazardous environmental effects in the gasohol fuel cycle. These include the growing and harvesting of the ethanol feedstocks, the ethanol production process, and the use of ethanol as vehicular fuel. Environmental aspects of alcohol fuels production and use are the responsibility of the Environmental Protection Agency.

In the growing and harvesting of ethanol feedstocks, the feedstock crops are limited. A commitment to produce large quantities of gasohol would involve additional crop production through more intense cultivation of present cropland and developing "potential" croplands such as forests, range, or pasture. The detrimental environmental effects of such intense cultivation would include accelerated erosion and sedimentation, loss of topsoil, increase in pesticide and fertilizer use, and replacing unmanaged with managed ecosystems. Another environmental impact would result with the removal of crop residues. Crop residues are important because they help control soil erosion through their cover and provide nutrients, minerals and fiberous material which help maintain soil quality. To alleviate some of these environmental effects, farmers may use a number of environmental protection measures such as integrated pest management procedures, soil analysis to minimize fertilizer applications, crop rotation, and the development of disease resistant crops.

All phases of ethanol production would be subject to Federal EPA, State and local environmental regulations. Some EPA regulations which may affect alcohol plants include the following:

- Regulations for the Prevention of Significant Deterioration (PSD) under the Clean Air Act and its amendments call for industries to prepare an ambient air increment analysis and a control technology review which requires the best available control technology for a major source of pollution. A major source of pollution is classified as emitting 250 tons per year or more of any air pollutant regulated by the Clean Air Act.

- Regulations regarding the discharge of pollutants into U.S. waterways are covered under the Federal Water Pollution Act Amendments of 1972. If an alcohol plant would discharge pollutants into water, it must obtain a National Pollutant Discharge Elimination System Permit (NPDES) from EPA.
- Regulations regarding solid waste disposal are covered under the Resource Conservation and Recovery Act which requires any hazardous waste to be disposed of in either a solid waste facility which has been certified by the state or a treatment, storage, or disposal facility permitted by the EPA.

Other standards which may affect alcohol plants are the following:

- General emission standards for particulate matter and sulfur dioxide.
- The National Ambient Air Quality Standards.

Other significant environmental effects of alcohol production are associated with the disposal of distillation wastes such as stillage. Stillage, the effluent from the initial distillation step, is composed of very small solid particles and solubles. Stillage is very high in chemical and biological oxygen demand and must be kept from entering surface waters without treatment. Its logical use is in cattle feedlots. If such is not available, then two kinds of problems can result from applying thin stillage to the land; odor and acidity. Possible solutions include the use of a sludge plow or possible recycling of the thin stillage within the alcohol plant.

The EPA and the Department of Energy have conducted tests to obtain environmental impact data on the use of gasohol as vehicular fuel. The results of gasohol use include:

- a slight decrease in hydrocarbon emissions;

- a significant decrease in carbon monoxide emissions;
- a slight increase in nitrogen oxide emissions;
- a substantial increase in evaporative hydrocarbon emissions.

In 1978, the EPA approved the use of gasohol under the Clean Air Act of 1977 and determined that there was no significant environmental risk associated with the continued use of gasohol.

viii) Other Government Programs

DEPARTMENT OF COMMERCE

Public Works and Business Assistance Programs

The Economic Development Administration (EDA) of the Department of Commerce offers grants to state or local government entities, Indian tribes and nonprofit organizations for proposed small-scale alcohol fuel plants to be located in EDA "designated areas." These grants are for alcohol plants designed to produce less than one million gallons of ethanol per year. A key consideration will be the local economic development effects of the project in the EDA designated area.

EDA also offers direct loans and loan guarantees for the private sector under the Business Development Assistance Program. The purpose of this program is to increase employment and income, increase crop markets, and increase the supply of transportation fuel. Loan guarantees to support loans made by private lending institutions are made for up to 90% of capital costs. For additional information, contact:

Assistant Secretary
Economic Development Administration
Washington, D.C. 20230
(202) 377-5081

COMMUNITY SERVICES ADMINISTRATION

Rural and Small Farm Energy Program

This program provides technical assistance and limited grants for the construction and operation of demonstration fuel alcohol plants. The purpose of the program is to develop and disseminate efficient technologies for small-scale fuel alcohol production. Financial assistance for construction and operation is restricted to plants serving the energy needs of rural, low-income residents. For further information, contact:

Energy Program Director
Office of Community Action
Community Services Administration
1200 19th Street, N.W.
Washington, D.C. 20506
(202) 632-6503

DEPARTMENT OF ENERGY

Biomass Energy Systems

This program provides technical assistance and competitive awards for converting biomass to alcohol fuels. The purpose of the project is research and development for on-farm systems, advanced energy crops, collection and harvesting improvements, and advanced conversion technologies. For further information, contact:

Dr. Beverly Berger
U.S. Department of Energy
600 E Street, N.W.
Washington, D.C. 20545
(202) 376-9739

Small Scale Technology Program

This program provides grants for developing small-scale renewable energy sources. The purpose of the program is to develop innovative small-scale renewable energy technologies. Individuals and small institutions are eligible. Maximum award is $50,000. For further information, contact:

Office of Consumer Affairs
U.S. Department of Energy
1000 Independence Ave. S.W.
Room 8G066
Washington, D.C. 20585
(202) 252-5877

Task 3: Continued Evaluation of Geothermal Resources

No leasing activity occurred in Arizona during the second quarter. However, the Commercialization Team is continuing to monitor such activities. In addition, the team members are continuing to interact with the resource assessment team of the Arizona Bureau of Geology and Mineral Technology - Geothermal Group regarding occurrences of resources for various site-specific applications. J.C. Witcher of the Geothermal Group has provided the following resource appraisal for the Safford-Willcox area in conjunction with local interest in alcohol production.

THE GEOTHERMAL POTENTIAL OF THE WILLCOX AND SAFFORD AREAS FOR USE IN ETHANOL PRODUCTION

The Willcox and Safford area has a favorable pairing of the required ingredients for ethanol production, biomass and a heat source. Biomass is provided by the agriculture in the area and a potential heat source is available from the earth as geothermal hot water. This report investigates the potential geothermal resources for use in ethanol production.

The Willcox and Safford area lie in the Basin and Range physiographic province of southern Arizona (Figure 1). Here, agricultural areas are situated over sediment filled structural troughs trending north and northwest. Structural troughs (basins) filled with sediments derived from surrounding mountains form the Gila-San Simon Valley and the Sulphur Springs Valley. If all the sediments in these valleys were removed, the terrain would appear as a series of interconnected basins formed by crustal blocks displaced downward along faults (Figure 2). Crustal blocks displaced upward by faults form the mountains. In many places, the sediments filling the structural basins are porous and permeable; thus, providing the aquifers supplying water for the area's irrigation wells. Several of the irrigation wells drilled into these sediments encounter hot water. Temperatures between 138^{o}F (58^{o}C) and 100^{o}F (37^{o}C) are observed in the hot wells at depths between 500 feet and 3500 feet. Most of the wells deeper than 1000 feet flow naturally at the surface (artesian wells). The chemical quality of the hot wells is generally good except for wells adjacent to the Willcox Playa or in the axis of the Gila Valley. Chemically poor quality hot water may contain more than 3,000 mg/l (milligrams per liter) of sodium chloride (salt). Salty water is not useful for irrigation or domestic use; therefore, water of this type would have to be reinjected after it is used for geothermal purposes.

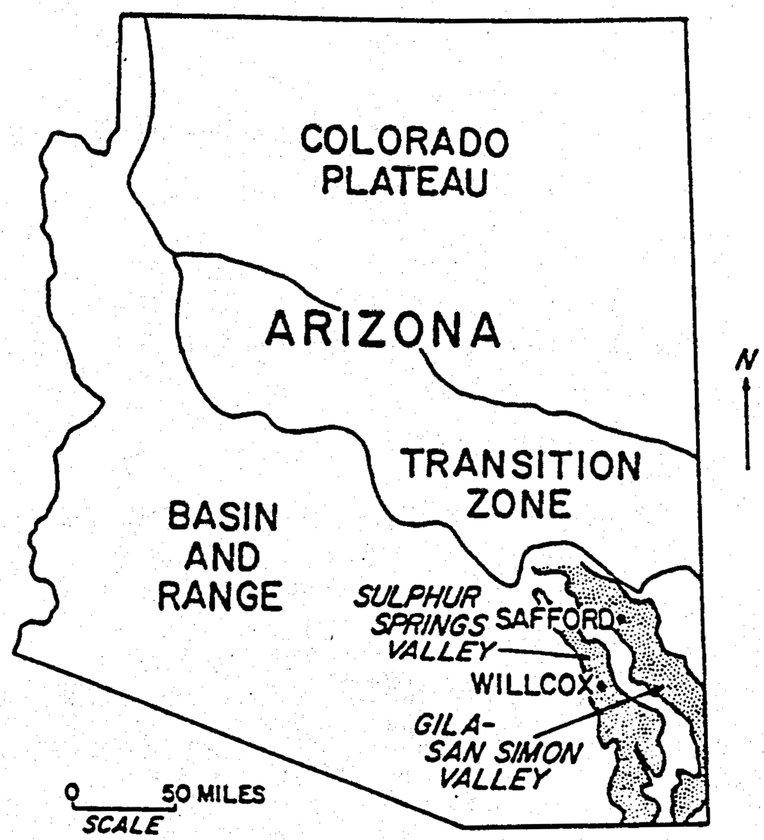
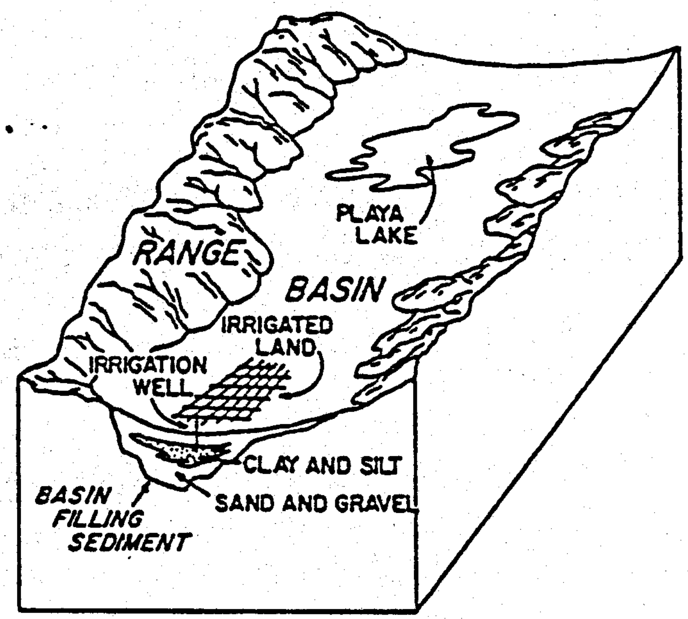
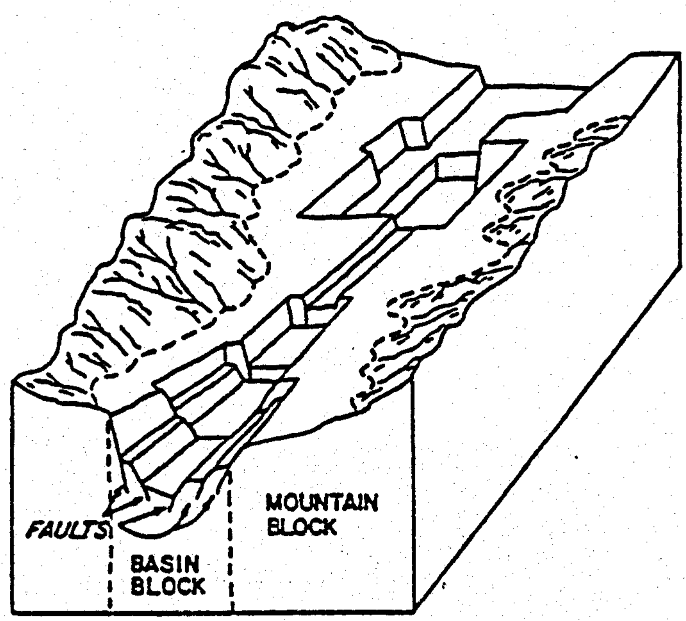


FIGURE I

MAP OF ARIZONA SHOWING LOCATION OF THE BASIN AND RANGE PHYSIOGRAPHIC PROVINCE AND THE SULPHUR SPRINGS AND GILA-SAN SIMON BASINS.



a. BLOCK DIAGRAM OF A BASIN



b. BLOCK DIAGRAM OF A BASIN WITH BASIN FILLING SEDIMENTS REMOVED

FIGURE 2

CONCEPTUAL GEOLOGIC MODEL OF THE SULPHUR SPRINGS AND GILA-SAN SIMON VALLEYS.

Since there is no evidence of young volcanism (less than 1 million years old) in these areas, it must be assumed the hot water results from meteoric water circulating to depth and heated by heat flowing (conducting) vertically through the basement rocks.

Average heat flow or the average quantity of heat in calories flowing through a square surface area per unit of time, is known for the Willcox and Safford areas. The average area heat flow is 1.9 HFU [(1)] (Reiter, M. and Shearer C., 1979). The average heat flow for the United States is 1.5 HFU; therefore a 1.9 HFU is considered above normal.

Heat flow is obtained by multiplying the temperature gradient (change in temperature with depth) and the rock thermal conductivity (ability of the rock to conduct heat). The following equation is used to determine the subsurface temperature gradient (G) when the heat flow (Q) and the thermal conductivity (K) are known:

$$\frac{Q}{K} = G$$

An average heat conductivity for clayey quartz-deficient sediment is 4 TCU [(2)] (Robertson, 1979). Using the 1.9 HFU and the 4 TCU in the equation, an average temperature gradient of 47.5°C/kilometer is obtained; therefore, a well 1 kilometer deep (3000 feet) could tap water that is 47°C hotter than the average surface temperature. If the mean annual air temperature is 17°C, the predictable bottom hole temperature in a 1 kilometer deep well is 64°C and in a 2 kilometer deep well it is 101°C. In special circumstances water may be moving (convecting) upward from depth along a fault zone or other vertically permeable geologic structure. If the water moves rapidly upward from 2 kilometers and does not mix with shallower water it may be close to boiling (100°C) at 1 kilometer depth.

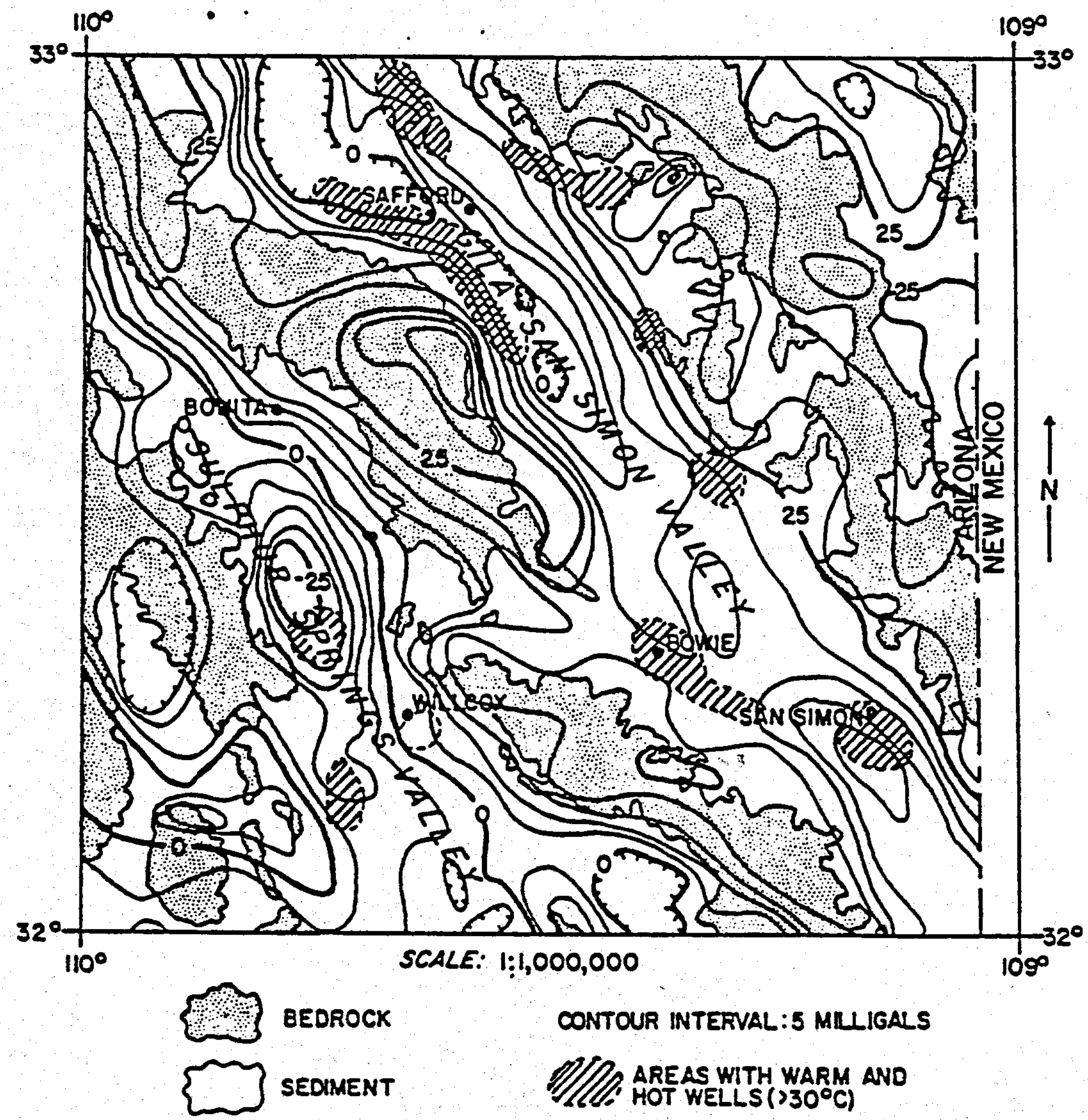
(1) HFU - Heat Flow Unit
10^{-6} cal/cm^2-sec (41.84 mw/m^2)

(2) TCU - Rock Thermal Conductivity Unit
10^{-3} cal/cm-sec °C (0.4184 w/mk)

The object of geothermal exploration is to locate and explore these upward moving flows of hot water since they transport heat to shallow and more economic depth. Hot springs are manifestations of similiar systems which reach to the earth's surface. Where convection systems exist in the subsurface, rocks overlying the system are heated more than the surrounding rock. Shallow temperature gradient holes over a convection system may detect abnormally heated rock capping the system; but only if shallow cold water flows do not obscure the deep heat flow. Thus, shallow temperature gradient holes (called heat flow holes if cores are measured for thermal conductivity) may be used to detect geothermal convection systems.

Where drill hole data are sparse, gravity survey data are the best means to determine the gross subsurface structure of the basins. Gravity data may be interpreted to delineate major fault zones and to determine the thickness of sediment filling the basins because sediment fill has a lower density than most rocks comprising the basin basement and mountain ranges. Gravitational acceleration (quantity measured in a gravity survey) is directly proportional to the mass (density and volume) of anomalous material beneath the gravimeter and inversely proportional to the square of the distance from the center of the anomalous volume that is beneath the gravimeter. A residual gravity map is shown in Map 1. Very steep gravity gradients occur south, east and north of the Pinaleno Mountains. These steep gravity gradients flank deep gravity lows within the Safford Basin and Willcox Basin. Steep gradients define areas of lateral density contrasts possibly caused by low density sediment in vertical contact with more dense rock comprising the mountain blocks. Major faults or fault zones frequently occur along the vertical contacts of basin fill sediments and mountain blocks.

Faults sometimes provide very good vertical permeability for upward directed flows of water which were heated at depth by the earth's outward conducting



Gravity after Lysonski and others, 1980.
Geology after Cooley, 1972.

Figure 3

RESIDUAL BOUGUER GRAVITY MAP SHOWING AREAS WITH HOT WELLS IN THE SAFFORD-WILLCOX REGION.

heat. Also, deep sediment filled basins are capable of providing very deep and permeable aquifers which act as the source for geothermally heated water in upward movement along faults or basin margins.

Figure 3 shows known or former hot wells in the Safford and Willcox areas. Additional hot wells are possible on the basin margins where gravity gradients are steep and indicative of possible faults.

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Table 1

Wells With Measured Temperatures >30°C In The Safford-San Simon Basin

Location	Temperature (°C)	Depth (Meters)	Temperature Gradient (°C/km)	Source
D-5-24-16 CB	48.3	183	166	1,4
D-5-24-17 AD	48.3	183	166	4, 12
D-6-24-4 CBB	47.8	18	1655	4, 12
D-6-24-13 AB	58.9	1148	36	4, 5, 6
D-6-25-36 CBB	46.0	660	42	4, 9, 10, 12
D-7-24-17 BD	30.6	11	1145	4
D-7-25-22 DDD	43.3	416	61	7
D-7-27-1 BBA	37.8	76	260	9
D-7-27-2 AAA	37.2	122	157	9
D-7-27-2 ACD	38.0	122	164	8, 10
D-7-27-2 ADD	41.0	122	188	9, 12
D-7-27-2 CC	35.6	91	193	5, 9
D-7-27-11 BBB	43.5	122	209	10
D-7-27-11 BBB	49.0	133	233	14
D-8-25-1 DDD	36.0	213	85	5, 6
D-8-25-12 AA	30.6	305	41	6
D-8-25-12 AA	36.7	320	58	4, 5
D-8-25-12 AAA	39.0	366	57	9, 10, 14
D-8-25-12 ABA	30.0	180	67	7
D-8-25-12 AC	34.4	320	51	4
D-8-25-12 AD	32.2	244	58	6
D-8-25-12 AD	32.2	274	52	6
D-8-25-12 AD	34.4	122	134	5,9

Table 1 cont.

Wells With Measured Temperatures >30°C In The Safford-San Simon Basin

Location	Temperature (°C)	Depth (Meters)	Temperature Gradient (°C/km)	Source
D-8-26-7 DA	41.5	488	48	9, 10
D-8-26-7 DDA	39.0	421	50	9, 14
D-8-26-7 DDB	35.0	381	45	9, 14
D-8-26-7 DDB	38.0	387	52	9, 14
D-8-26-8 BDC	39.4	195	110	10, 16
D-8-26-18 AC	33.9	274	58	6
D-8-26-18 DDA	42.0	463	52	9, 10
D-8-26-20 AB	30.6	213	59	6
D-8-26-20 DBC	45.0	390	69	10, 6
D-8-26-28 ABC	31	244	53	7
D-8-26-32 CB	32.2	110	129	6
D-8-26-32 DB	32.2	122	116	6
D-8-26-32 DC	32.8	122	121	6
D-8-26-33 AC	32.8	226	65	6
D-8-26-33 CA	32.8	122	121	6
D-8-26-33 CA	33.3	152	100	6
D-8-26-33 CCC	31.0	132	99	9, 14
D-8-26-6 CCB	31.0	227	57	9
D-9-30-11 DD	72.2	98	553	4
D-10-28-25 DD	36.0	474	38	4, 6, 12
D-10-28-36 AAC	41.1	587	39	1, 4, 5, 6, 10, 12, 13
D-10-29-20 AC	34.1	160	101	10, 15
D-11-29-36 CBB	32.2	207	69	2, 10, 13

Table 1 cont.

Wells With Measured Temperatures $>30^{o}C$ In The Safford-San Simon Basin

Location	Temperature (^{o}C)	Depth (Meters)	Temperature Gradient ($^{o}C/km$)	Source
D-8-25-12 DA	31.4	161	83	6, 9
D-8-25-12 DBD	30	213	56	7
D-8-26-7 ABA	42.0	467	51	7
D-8-26-7 AB	30.0	253	47	6
D-8-26-7 ACC	30.0	274	44	7
D-8-26-7 AC	35.0	329	52	6
D-8-26-7 AC	30.0	213	56	6
D-8-26-7 ADD	34	305	52	7
D-8-26-7 AD	30.6	274	46	6
D-8-26-7 ADC	32.0	243	58	9, 10, 14
D-8-26-7 BAA	41.5	463	51	9, 10
D-8-26-7 BA	35.6	344	51	6
D-8-26-7 BBB	34	262	61	6, 10
D-8-26-7 BB	35.8	320	56	6
D-8-26-7 BDB	32.0	335	42	7
D-8-26-7 BDB	38.0	476	55	7
D-8-26-7 BDB	34.4	464	35	9
D-8-26-7 BDB	32.0	415	34	7
D-8-26-7 BD	33.3	396	39	6
D-8-26-7 BD	35	366	46	6
D-8-26-7 BD	33.9	299	53	6
D-8-26-7 CA	37.0	244	78	6, 10
D-8-26-7 CD	33.9	290	55	6

Table 1 cont.

Wells With Measured Temperatures >30°C In The Safford-San Simon Basin

Location	Temperature ($^{\circ}$C)	Depth (Meters)	Temperature Gradient ($^{\circ}$C/km)	Source
D-12-28-10 CCC	35.5	305	58	10, 14, 15
D-12-28-22 CDC	31.5	200	68	2, 4, 12
D-12-28-23 CCC	32.2	305	47	9
D-13-28-1 BB	30.0	218	55	12
D-13-28-3 C	37.2	244	79	2, 4
D-13-28-4 DDB	37.2	253	76	12, 13
D-13-28-9 BCC	31.0	213	61	12, 13
D-13-28-10 BC	36.0	305	59	9, 10
D-13-28-15 CCC	31.7	139	99	9
D-13-29-6 CCC	31.1	255	51	12
D-13-29-6 CC	31.1	214	61	4
D-13-29-24 CD	40.6	293	77	5
D-13-29-24 DCC	40.6	293	77	2, 8, 12, 13
D-13-29-27 ACC	33.3	311	49	3
D-13-29-36 AD	43.3	305	83	11
D-13-29-36 ACC	35.6	305	58	11
D-13-29-36 ADC	36.7	229	82	11
D-13-30-3 B	42.8	262	95	8
D-13-30-3 BCC	33.5	262	59	12
D-13-30-3 BDC	33.3	262	58	13
D-13-30-9 ACD	34.0	274	58	5, 8, 9, 12
D-13-30-11 BCC	32.2	290	49	5, 8, 12, 13
D-13-30-13 A	31.1	232	56	8

Table 1 cont.

Wells With Measured Temperatures >30^{o}C In The Safford-San Simon Basin

Location	Temperature (^{o}C)	Depth (Meters)	Temperature Gradient (^{o}C/km)	Source
D-13-30-14 DDD	32.2	284	50	5, 8, 9, 12, 13
D-13-30-15 DAA	35.0	397	43	5, 8, 12, 13
D-13-30-23 ACC	30.6	274	46	12, 13
D-13-30-23 B	33.3	274	56	4, 8
D-13-30-25 ACD	30.5	268	47	5, 12
D-13-30-27 AD	134.4	1952	60	4
D-13-30-30 B	40.6	284	80	8
D-13-30-30 BCB	40	293	75	5, 13
D-14-30-36 AA	75.6	2312	25	4
D-13-30-36 DDD	41.7	610	39	3
D-14-30-12 ADB	30.6	279	45	9, 12, 13
D-14-31-16 DCC	31.6	610	22	2, 9, 12, 13
D-14-31-21 BCC	32.2	217	65	9, 12, 13
D-16-31-10 AA	54.4	1657	22	1, 4

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(15) Wilson, R.P., and White, N.D., 1976
(16) Witcher, 1979

Table 2

Wells With Measured Temperatures >30°C In The Willcox Basin

Location	Temperature (°C)	Depth (Meters)	Temperature Gradient (°C/km)	Source
D-12-23-31 CB	54.5	136	267	3
D-12-24-20 BA	37.9	460	43.3	19
D-13-22-33 DA	61.1	1612	26.7	4
D-13-24-5 BA	47.8	204	146	3
D-13-24-11 AB	40.6	412	54.8	3
D-13-24-23 DC	86.7	2028	33.9	4
D-13-25-5	31.1	762	17.2	17
D-13-25-31 CA	31.7	229	59.8	12
D-13-25-31 CA	32.8	577	25.6	4
D-14-25-6 AA	36.7	235	79.6	18
D-14-25-6 CB	35.0	214	79.4	12
D-14-24-6 DB	35.0	214	79.4	12
D-15-26-19	43.3	980	25.8	20
D-16-24-10 AC	40.4	415	53.9	19
D-16-24-10 DB	35.6	350	50.2	19

Table 2. (Continued)

Wells with Temperatures > 30°C in the Willcox Basin

Sources

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Task 4: Engineering and Economic Analyses

Work began in the final days of the second quarter on a preliminary design of a 30 million gallon alcohol production plant to be located in the Willcox-Safford area. Work is being performed in conjunction with Water and Power Resource Services (WRPS) of Boulder City, Nevada. WRPS 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.

Task 5: Technical Assistance in the State of Arizona

During the second quarter, limited technical assistance was provided to several interested parties within the state. First, technical assistance related to space cooling for district type systems was provided to John F. Long, a Phoenix land developer. Further detailed work has been undertaken for a subdevelopment on the west side of Phoenix. Second, Western Electric Corporation of Phoenix expressed interest in utilizing geothermal energy for space heating and cooling for a large cable manufacturing facility. Informal meetings were held to discuss technical aspects for utilizing geothermal energy for space heating and cooling. Third, 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. Finally, resource and technical information have been provided to several engineering firms in the Tucson and Phoenix areas.

Task 6: 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.

Task 7: Outreach Programs

Outreach during the quarter consisted of telephone contacts and personal discussions with various persons within the State. Persons contacted included several city planners within Phoenix and Tucson, every Chamber of Commerce within Arizona, every council of government in the State and several engineering firms in Tucson and Phoenix. Speaking engagements included the Casa Grande Rotary Club, a special course at the University of Arizona related to alternative energies, and a teacher's group in Phoenix. Personal contacts included Western Electric, John F. Long, John Whipple of Water and Power Resource Services, and Bill Nelson of the Bureau of Land Management. In addition, the geothermal display was exhibited during the Southern Arizona Energy Fair and an alternative energy fair on the University of Arizona campus.

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