MASTER

DOE/ID/12015-1

ARIZONA GEOTHERMAL COMMERCIALIZATION PLANNING

SEMI-ANNUAL PROGRESS REPORT

January 1, 1979 - June 30, 1979

Prepared by: R. Hahman Sr., F. Mancini, D. White, M. Chehab, L. Goldstone, B. Weibel

Specific Task Contributors: D. Astrom, I. Khan, D. Linkhart, L. Malysa, A. Qaheri, X. Suarez, C. Tabet, S. Unguran

Arizona Solar Energy Commission
1700 West Washington
Phoenix, Airzona 85007

Work Performed Under Contract No. DE-FC07-79ID12015
U.S. Department of Energy
Idaho Operations Office

DISCLAIMER

DISCLAIMER

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0: INTRODUCTION

The Department of Energy (DOE) through its Idaho Operations Office has contracted for the planning of geothermal energy commercialization in Arizona with the Arizona Solar Energy Commission (ASEC) via a cooperative agreement. This agreement was signed on April 5, 1979, to be effective January 1, 1979. From August 13, 1978 to April 5, 1979 work consisted of low level planning until the direct contract was signed, subsequently, work activity increased.

The ASEC assumed authority for monitoring the progress of the project through its director James Warnock and its associate director Frank Mancini. The ASEC in turn subcontracted the planning activities to the University of Arizona.

1.1: Purpose of Proposal

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

1.2: Objectives

The project objectives include:

1) The provision of a State Institutional Handbook, enabling potential geothermal developers in Arizona to be in possession of institutional information concerning procedures to be followed and the agencies involved in geothermal development.
2) The identification and delineation of geothermal prospects, and the updating and classification of resources according to set definitions. Also, leasing and exploration activities are to be reported.
3) The comparison of conventional energy use patterns, both current and projected, with geothermal energy sources in order to determine a realistic projection of geothermal energy-on-line in Arizona.

4) The compilation of detailed economic data for each Area Development Plan (ADP) to help determine where geothermal energy will have the most effective uses in Arizona. A matching of potential resources and applications in each geothermal area will result in development plans for commercialization of geothermal energy, projected to the year 2020.
5) The preparation of development plans for specific locations where a geothermal prospect coincides with a potential application. These development plans will detail in time the evolution of specific electric and/or direct thermal applications.
6) The interaction of the State Geothermal Team with the private and public sectors of Arizona to help promote the commercial development of the state's geothermal resources.

1.3: Technical Approach and Team Members

The main emphasis for this project is upon producing plans for geothermal energy commercialization. The technical approach for achieving this goal is to characterize geothermal resources and possible users, resulting in a detailed appraisal of each ADP. Pertinent information on currently active and pending legislation will also provide input to the ADPs. In places where specific proven or potential geothermal resources correspond with specific applications, commercialization possibilities are to be designated Site-Specific Development Plans (SSDPs). Additionally, a program of direct interaction with business and community leaders will be undertaken. The procedure for this "outreach" program consists of contacting local industries to induce awareness of geothermal resources and to provide proposals for its use, as well as advice and assistance. This will also involve contacting state legislators to present specific suggestions and to enhance their understanding of geothermal energy potential in Arizona, hoping to expedite the commercialization of this resource.

The Arizona Team consists of three key personnel, two senior level advisors, three support personnel and eight additional temporary personnel. Key personnel are: 1) Dr. Frank Mancini, Project Monitor. His responsibilities include: a) monitoring the progress of the project, b) serving as a liason between the Arizona Geothermal Team and the DOE.

2) Dr. Don H. White, Team Leader. His responsibilities include: a) coordinating and monitoring all the efforts of workers on the project, b) suggesting and analyzing ADPs, c) suggesting and analyzing geothermal applications, d) editing all reports written for this project. 3) Richard Hahman, Sr., Resource Advisor and Director of Outreach. His responsibilities include: a) providing geothermal resource advice, b) suggesting and analyzing ADPs, c) suggesting and analyzing geothermal applications, d) directing outreach activities. The senior level advisors are: 1) Dr. Helmut Frank, Energy and Economics Advisor. His responsibilities include: a) providing energy and economic data on Arizona, b) advising on energy and economic planning. 2) Dr. David Wolf, Technical Advisor. His responsibilities include: a) advising on and analysis of the ADPs, b) advising and analyzing the geothermal applications.

The support personnel are: 1) Mohamad N. Chehab, Project Coordinator. His responsibilities include: a) coordination of the efforts of all the workers on the project, b) technical analysis of ADPs and SSDPs, c) preparation of SSDPs. 2) Larry Goldstone, Group Leader. His responsibilities include: a) Arizona energy and economic analysis, b) economic compilation and analysis of ADPs and SSDPs, c) providing energy and economic data to New Mexico Energy Institute (NMEI), d) analysis of institutional procedures, e) coordinating efforts of workers on the above-mentioned tasks. 3) William Weibel, Group Leader. His responsibilities include: a) identifying and analyzing geothermal resource data, b) monitoring leasing and drilling activities, c) appraising the Arizona water situation, d) evaluating geothermal resource quality of ADPs and SSDPs, e) coordinating efforts of workers on the above-mentioned areas.

There are eight additional temporary personnel and their names and tasks are listed in the organization chart of the Arizona Geothermal Team in Fig. 1-1.

A schedule of actual, proposed and projected expenditures for the Arizona Geothermal Team is shown in Fig. 1-2. As can be seen in this figure, work progressed somewhat slowly from August 13, 1978 to March 31, 1979. In part expenditures in this time frame signify the initial planning phase of the project plus the time lag due to a delay in the finalization of the DOE contract. In April, 1979, an intensive effort began in order

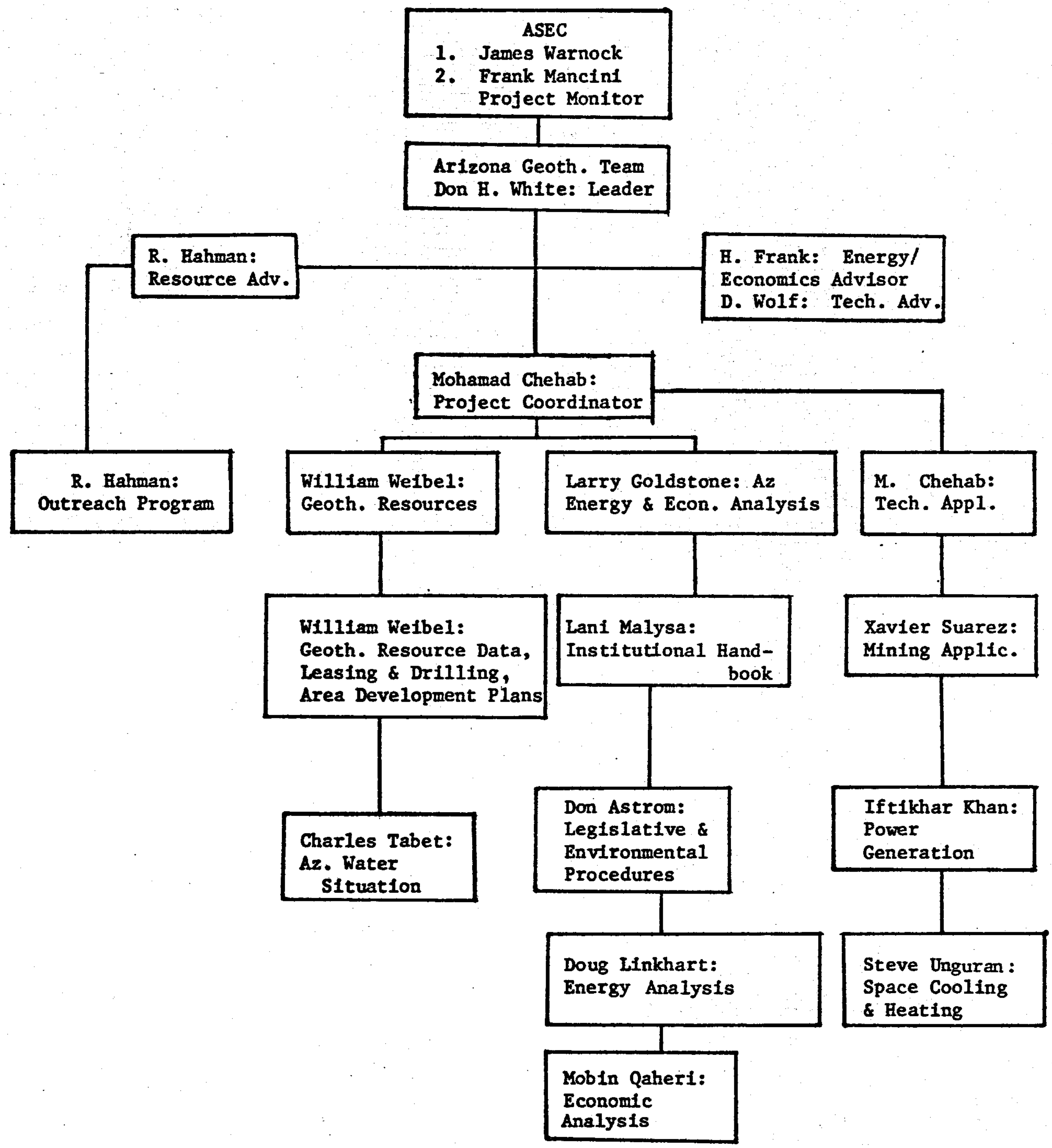


FIGURE 1-1: ORGANIZATION CHART OF THE ARIZONA GEOTHERMAL TEAM.

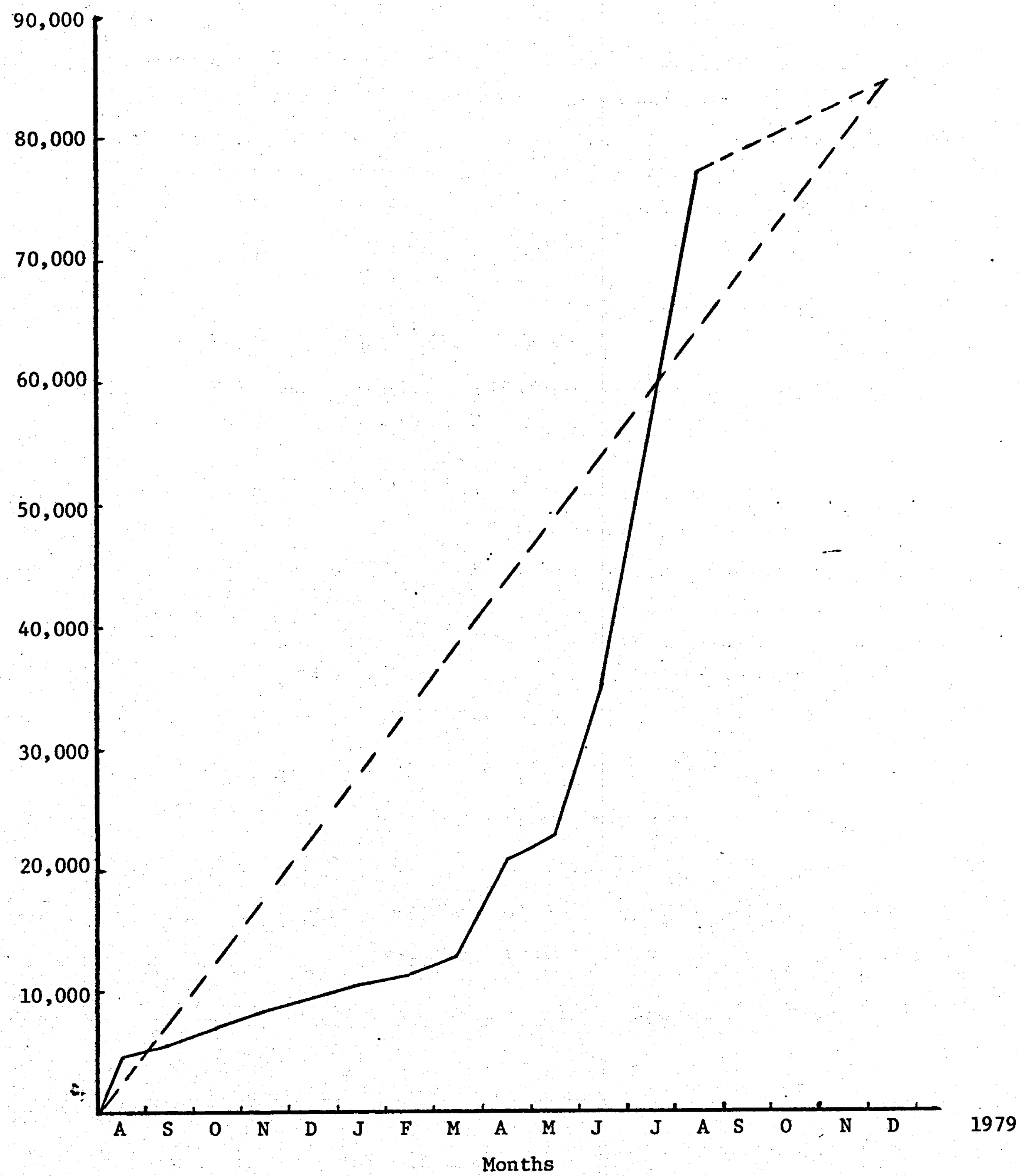


FIGURE 1-2: SCHEDULE OF EXPENDITURES FOR THE ARIZONA GEOTHERMAL TEAM.

to meet our contractual obligations in a timely manner. Expenditures increased rapidly during the summer months due to the addition of eight temporary personnel. After August 13, 1979, personnel on the project will reduce to the pre-summer level, with work output and expenditures reduced accordingly.

1.4: Benefits of Project of State and DOE

The goal of energy independence for the U.S. can only be achieved by bringing energy on line from alternative sources. The intent of this project is to plan for the commercialization of geothermal energy in Arizona. There has been a lack of both awareness and development of geothermal energy in Arizona; planning should provide a base from which interested developers of geothermal energy can build in the future. This planning effort will clearly benefit both the state and the U.S. as a whole in that an important step will have been taken toward providing energy to the state. The result will expedite institutional procedures, expand understanding of the geothermal resource base, and eventually lead to the commercialization of geothermal energy in Arizona.

2.0: SUMMARY OF STATE PROJECT TASKS AND ACCOMPLISHED WORK

The major project tasks for the State of Arizona are:
1) The provision of a State Institutional Handbook. This handbook should assist prospective geothermal developers by providing institutional information and defining the roles of agencies that govern the development of geothermal resources in Arizona. The handbook shall chart and describe the agencies, regulatory procedures, time requirements, and the costs for all necessary procedures. This task involves compiling the required information and presenting it in a handbook, the format of which has been specified by the DOE.

The results for this task include: a) State land leasing. All state land to be leased for geothermal development purposes is leased on a competitive bid basis by the State Land Department. A minimum time period of 5-6 months can be expected when leasing state land, due to both lease advertisement and processing. b) Indian lands leasing. Ultimate approval in leasing Indian land rests with the Secretary of the Department of the Interior. The Bureau of Indian Affairs and U.S. Geological Survey provide technical, administrative and environmental assistance. The individual Indian tribes set the terms and conditions of each lease. If an environmental impact statement is deemed necessary, a time period in excess of two years can be expected for obtaining an Indian land lease. c) Drilling procedures. The Arizona Oil and Gas Conservation Commission has jurisdiction over the drilling of wells for geothermal development on State, Federal, Indian and private land. Permits to drill can be obtained in a relatively short period of time (1-2 weeks) and the costs involved are: (i) $25 filing fee per well and (ii) $5000 surety bond per well or a blanket sum of $25,000 for all wells. d) Environmental Results. Arizona does not require that an environmental assessment or an environmental impact statement be written on the state level. e) Geothermal's status with water laws. Arizona's geothermal resources are largely exempt from the State's water laws due to statutory and administrative interpretation.

2) The provision of in-depth geothermal resource data. This task will consist of the identification and characterization of geothermal prospects. Moreover, present data on potential site-specific geothermal resources will be constantly updated and augmented. Geothermal leasing and exploration activity will be reported and documented.

The basic resource data has been provided by the Arizona Bureau of Geology and Mineral Technology. All other available information relevant to the delineation of hydrothermal resources in Maricopa County has been gathered to aid in the estimation of:

a) attainable subsurface temperature
b) approximate volume of geothermal reservoirs
c) depth to top of geothermal reservoirs
d) salinity of reservoir water.

Additional inferences concerning the bedrock configuration of the basin and range province have been made based upon published reports of Cenozoic stratigraphy in Arizona. Commercialization of high-temperature geothermal reservoirs has the most potential where deep Cenozoic basins contain hot-water convection cells above the geologic basement.

Areas where moderate-temperature geothermal development could be favorable have been appraised to the extent possible from available well data and warm spring flows. Arizona's geothermal potential seems more prospective for this class of temperature (i.e. non-electric) as a whole, but data not yet generated may show otherwise in the future.

Recently, leasing activity has been prolific. Since April, 1979, 14,393.64 acres of Federal land and 1844.36 acres of State land have been granted for geothermal development leases. This newly leased land all lies within the first ADP or Maricopa County. Geothermal development in these leased lands and any further leasing will be watched closely.

3) The comparison of energy sources and uses. This task involves the compilation of current and projected energy data so as to determine which energy sources might be replaced by geothermal energy. Furthermore, the current and projected use patterns for all conventional fuels shall be identified by user class. The availability of resources shall also be

addressed, including the present capacity for power generation and all current costs. In addition, this task will involve the interaction with NMEI to forecast energy supply and demand to the year 2020. The result shall be a realistic current and projected future geothermal utilization.

The purpose of addressing such issues are, first, to determine Arizona's energy future as viewed by the utility companies. The data presented represents the most accurate data available from a primary source. Second, geothermal energy's place in Arizona must be determined in order to properly plan for its commercialization. By analyzing Arizona's electric production capability in the present and in the future, later consumption projections will define whether geothermal energy has a good chance of realizing commercialization over the next forty years. Essentially, this provides an analysis of electric supply as viewed by utilities and electric demand as projected by NMEI. Such results will provide a picture of the future electrical energy situation in Arizona, and presumably will provide a visible niche for geothermal energy.

To date, the major emphasis has been on Arizona's electrical energy production. Within this category, two primary questions were addressed. The first was to assess Arizona's present capacity for production of electricity. The second was to assess the resource requirements necessary to support such production. Both of these questions were addressed in terms of current and future resource requirements and production capabilities.

As stated earlier, the accomplished work and results to date fall mainly on the supply analysis. Presently, Arizona is capable of generating 8187 MW of electricity, 44% of which is generated using gas and oil, 44% using coal and 11% using hydroelectric sources. By the year 2000, utility sources anticipate an additional capacity of 6868 MW to be on line, thus Arizona's total capacity will be 15,055 MW. If all planned power plants were on line by the year 2000, 48% of the electricity generated would be produced from coal. The remaining percentages are as follows: 24% gas and oil, 21% nuclear, and 6% from hydroelectric sources. Further, of these 6868 MW of additional capacity, 53% will use coal and 46% will use nuclear fuels. Clearly, the results show that coal is the predominant fuel between now and the year 2000 (the year 2000 is used because utility planning horizons have not gone beyond 2000 as of 1979). Detailed results of this work are presented in Appendix B.

4) Economic data compilation for ADPs. Since Arizona is the fastest growing state in the U.S., it is necessary to compile detailed economic data on the State in order to integrate geothermal applications into the rapidly growing economy and rising demand for energy. This section will provide a detailed analysis and breakdown of current Arizona GNP on a county-by-county basis using available information. Economic sectors including mining, agriculture, manufacturing, commerce, banking and tourism shall be considered. The Arizona water situation will also be taken into account. When combined with the data in Task 3, correlations can be made between energy consumption patterns and economic growth. These correlations will then be used to determine where geothermal applications will have the most profound impact in Arizona. This shall be done by dividing Arizona into geothermally quantifiable areas and matching the potential geothermal prospects with the potential applications in each geological area. This will provide one or more development plans for energy on line as a function of time between now and the year 2020.

Overall, the ADPs shall integrate the available information on geothermal resources, existing and projected energy consumption activity, and prospective utilization of geothermal energy by the residential, commercial, and industrial/agricultural sectors into plans for potential commercialization for geothermal energy in Arizona. The resource, energy and economic data will also be made available to NMEI for their resource information and economic analysis.

To date, population, income and labor growth trends have been identified and projections of these variables have been provided for each county to the year 2000. This information was provided by the Department of Economic Security's growth model, the standard planning model for Arizona. Furthermore, a detailed analysis of the agricultural sector on a county level has been completed. Labor employment has also been projected to the year 2000 for this sector, and the results show a marked decline in agricultural employment in the state. This reflects the critical water situation, anticipated technological improvements and replacement of agricultural land with higher value uses. Finally, work is progressing on the remaining sectors of Arizona's economy on a county-by-county basis.

Arizona's water availability has also been evaluated. It has been estimated that 80,000,000 acre feet of precipitation falls over Arizona each year. Of this amount approximately ninety to ninety-five percent is lost to evaporation and plant transpiration. It has also been estimated that 3,000,000 acre feet of surface water are diverted each year. Further estimates have been made about the amount of groundwater in Arizona. As estimated by the Arizona Water Commission, 1.2 billion acre feet of water remains in storage although its availability is limited by location, depth and quality. Work is now being focused on water uses and sources on a County level.

5) The preparation of site-specific development plans, which will detail in time the evolution of specific geothermal applications using specific geothermal resources. This task will emphasize the production of realistic time-specified development plans for potential site-specific geothermal applications. The plan shall characterize geothermal resources and identify technological, institutional, environmental and economic factors involved in the implementation of each application. Since this is mainly a planning project, reporting will focus on results rather than procedures.

The summaries of the results for this task are: a) the site-specific developments of two geothermal power plants are under consideration. One power plant has been located in the Clifton area. The capacity of this power plant is to be 50 MW. Also a 700 MW geothermal/coal hybrid power plant in the San Bernardino Valley is being considered. b) Progress on the SSDP for copper dump leaching has so far embodied the identification of the locations of potential and existing copper dumps in Arizona. Moreover, a preliminary assessment of copper dump leaching in Pima County as a potential application for geothermal energy has been conducted and the results are presented in Appendix C. c) Progress on the site-specific development for space air-conditioning included compilation of data on commercially available systems that can use geothermal energy. Also, information on the demand for cooling in Arizona is being accumulated and interaction with potential users in Pima and Maricopa Counties has started. d) Progress on in-situ solution mining consisted of the acquisition of data about, i) low grade ores of zinc, uranium and copper that can use geothermal energy, ii) potential mining operations in Arizona.

Interaction with potential users has begun in order to acquire more data. e) Progress on the food processing application and direct thermal utilization consisted of assessing the geothermal prospects in the Yuma area, the determination of the energy demand for the processing of citrus, the acquisition of pumping and irrigation requirements in the area, and information on growth of the citrus agriculture in that area. f) Progress on irrigation pumping included the characterization of the geothermal resources and the determination of the irrigation requirements. g) Progress on Central Arizona project pumping stations consisted of locating the planned future pumping stations and characterizing the geothermal resources in the Picacho Mountains area where two pumping stations are planned by the year 1986. More information on the amount of water that will be pumped and the pumping requirements will be collected. h) Progress on coal-fired/ geothermal power plant application included the identification of the coal-fired plants that are planned for construction in the Willcox and Springerville areas, and the characterization of the geothermal resources in the two areas.

6) The outreach program began by compiling realistic geothermal resource data, site specific analysis, cost-effective analysis, and viable proposals in preparation for interaction with local industry and community leaders to arouse their interest in geothermal applications and development. The program's initial purpose will be to inform local leaders about the usefulness of naturally-occurring hot water deposits. This will be followed by a presentation of specific proposals for application of geothermal resources in certain areas of the state, and assisting prospective developers of geothermal energy.

Outreach activities were continuous throughout the year and the outreach consisted of correspondence by mail and phone and sometimes by trips to talk with potential users. Some potential users were in the food processing industry, agricultural industry, power production industry and the mining industry. Also, a novel approach to outreach is being conducted by the Arizona Team. A public relations person has been hired in June to contact prospective users and to publicize geothermal energy in Arizona and thus the full-fledged outreach program has started in early July.

3.0: SPECIFIC TASK DESCRIPTIONS AND RESULTS

The efforts on each task varied during this past project period. The progress and results are herein reported in proportion to the efforts devoted to each task.

3.1: Geothermal Prospect Identification

Arizona's geothermal resources occur due to the relative nearness in depth (5-15 km) of very high temperature (575°C) rock (3-1) from which heat is both conductively and convectively transferred upward through geologic processes. Most prospective in the state are the Transition Zone and Basin & Range Physiographic Province, shown in Fig. 3-1. Evidence such as high heat flow (3-2), hot (up to 82°C) springs, relatively young (less than 3 million years) volcanic rocks, and hot bottom-hole temperatures in deep tests (3-3) make the conditions for geothermal exploration in Arizona most promising. More information has been obtained as a result of groundwater exploration, normally providing information on only the shallowest 350 meters below the land surface.

Of key importance to Arizona's geothermal development outlook is the availability of water in the deeper subsurface layers of rock, beneath the shallow section experiencing groundwater withdrawal. Between this 350 meter shallow section and geologic basement an extreme paucity of information precludes the certainty of water occurrence, which is necessary for hydrothermal production and development. However, water-bearing continentally-deposited sediments are expected to be often interbedded with volcanics just above the basement, which is of variable depth and composed of hard dense rock. These water-bearing sediments may contain the most attractive hydrothermal resources in the Basin and Range Zone.

Geophysical surveys and geochemical sampling have enabled inferences to be made concerning probable geothermal reservoir location and temperature in some specific cases, but in many areas subsurface conditions are not known. More exploration needs to be directed toward prospective areas with little or no known subsurface data near population centers that can use geothermal energy. The Preliminary Map of Geothermal Resources in Arizona appears in Fig. 3-2.

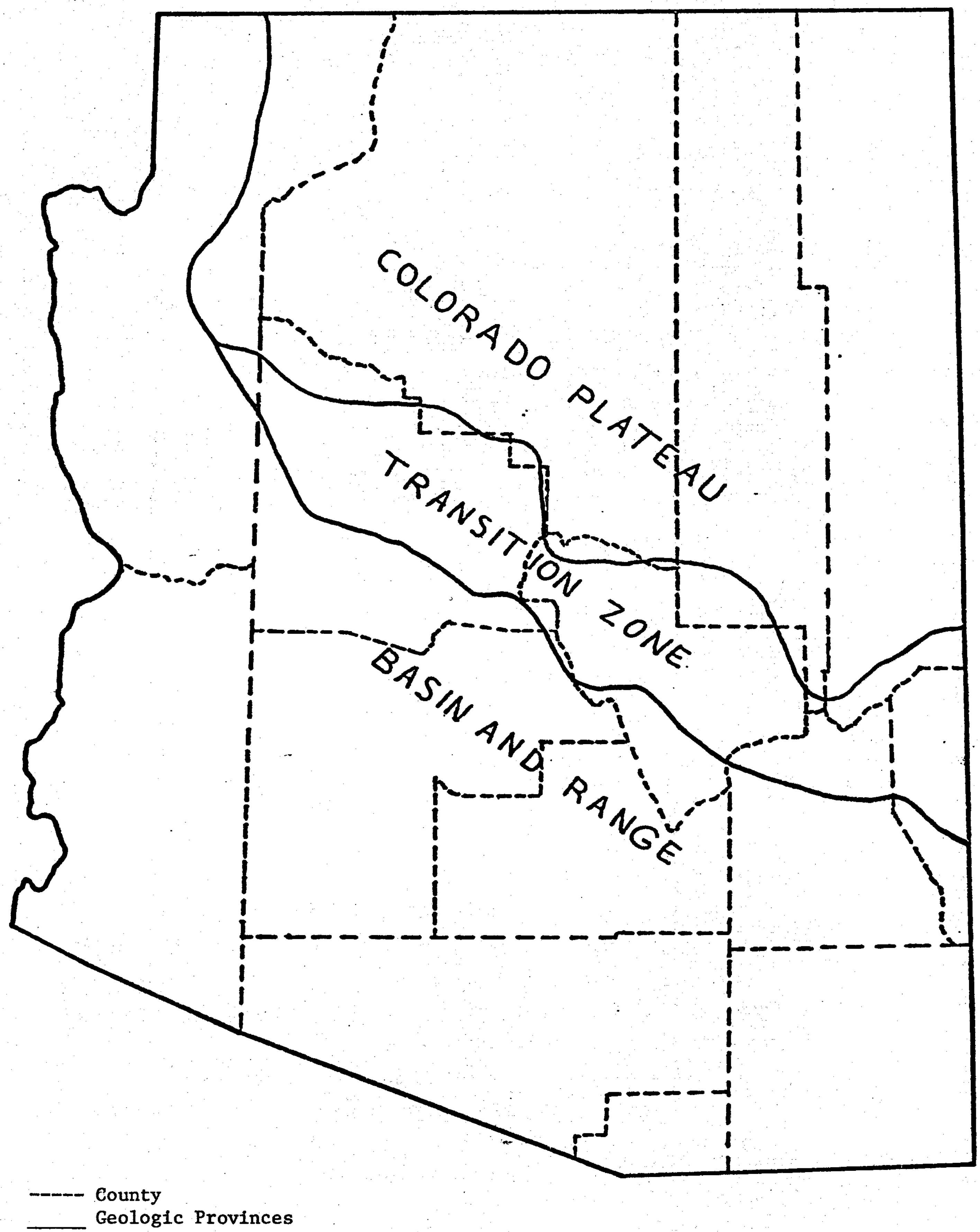


FIG. 3-1. GEOLOGIC PROVINCES IN ARIZONA

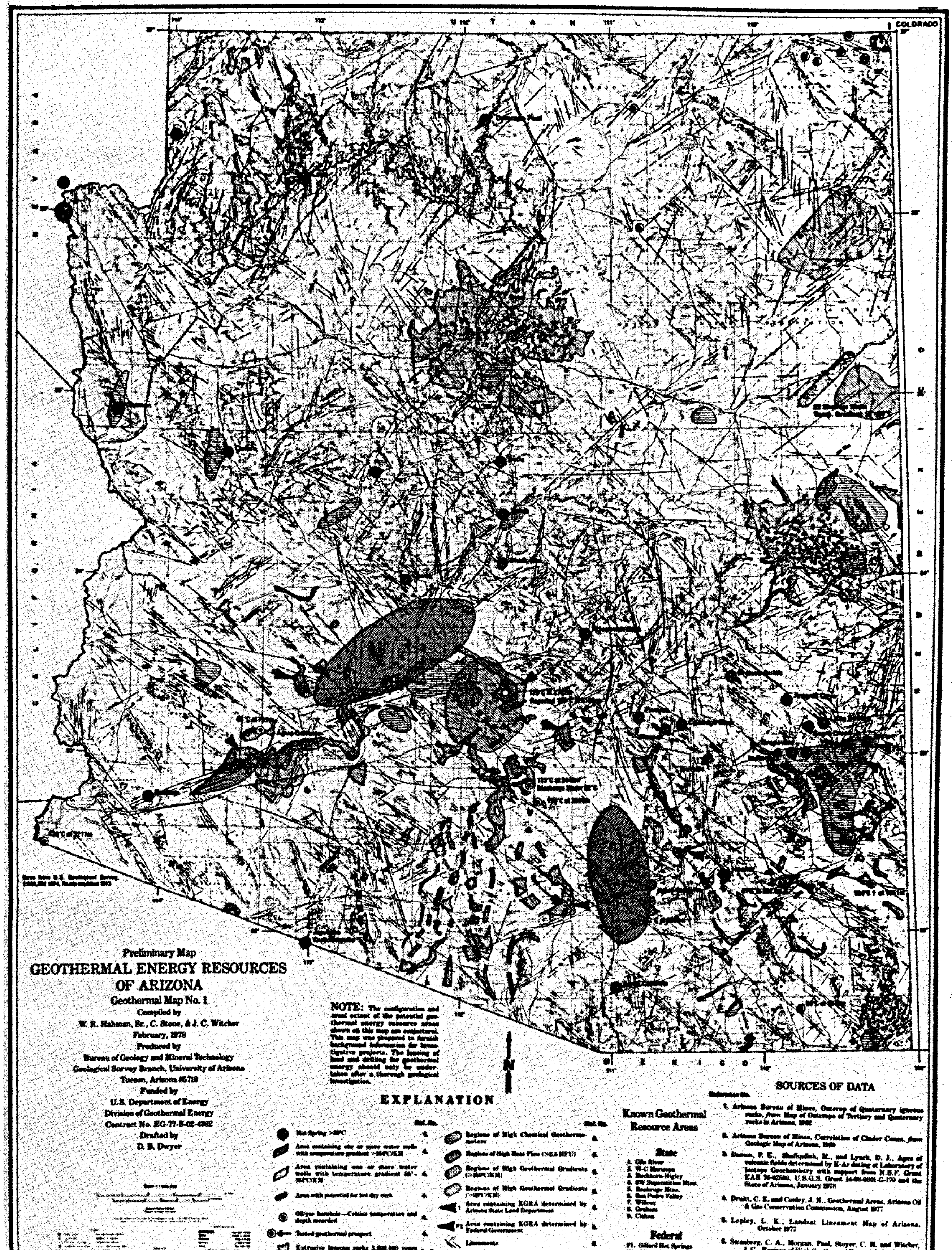


FIG. 3-2: REDUCED COPY. FOR LARGE COLORED MAP REFER TO BUREAU OF GEOLOGY AND MINERAL TECHNOLOGY. GEOLOGICAL SURVEY BRANCH, UNIVERSITY OF ARIZONA

Recent efforts have been directed toward realistic estimates of Arizona's geothermal resource quality for electrical and direct thermal uses. Table 3-1 is a classification of high temperature geothermal resources for the entire State of Arizona. The only proven resource for electric power generation is the Power Ranch area located in Higley Basin southeast of Phoenix. A temperature of 184°C was measured at a depth of 3186 meters. As listed in this table, there are also four areas classified as potential high temperature resources. Table 3-2 lists all proven, potential, and inferred resources with direct thermal possibilities. Clearly, there is an abundance of proven moderate temperature resources throughout the state.

Recent efforts have also been directed toward estimating the potentially usable geothermal energy for Maricopa and Pima Counties. Table 3-3 presents the results of these estimates. Notice that Maricopa County was estimated to have 1.46 quads of potentially usable geothermal energy while the Pima County estimate was .81 quads.

3.2: Area Development Plans

3.2.1 State Geothermal Planning Areas

Area Development Plans (ADPs) consist of seven distinct intrastate subdivisions for which geothermal commercialization plans are to be prepared. Each geothermal resource prospect and all potential geothermal uses in a given single or multicounty planning area are to be considered in the compilation of a table showing the projected timing of significant development events. A map of Arizona, presented in Fig. 3-3, shows ADPs numbered in order of planning priority. Principal consideration in choosing ADP priorities has been given to quantifiable geothermal resource and economic criteria. Each ADP is described below in order of priority.

TABLE 3-1: CLASSIFICATION OF GEOTHERMAL RESOURCES THAT ARE SUITABLE FOR POWER GENERATION (>150°C)

CLASS	LOCATION OF SITE	ESTIMATED SUBSURFACE TEMPERATURE	MEASURED SUBSURFACE TEMPERATURE	TEMPERATURE OF SURFACE SPRINGS	FLOW
PROVEN	Power Ranch, T2S, R6E in Higley Basin, T1-2S, R4-7E		184°C at 3,186 m[c]		83.6 gpm below 2 km[c]
POTENTIAL	Clifton Hot Springs T.4S, R30E, Sec. 18	164°(4)[c]-188°C(5)[f]		61°C[g]	About 8.5 cm^3/sec[g]
	Gillard Hot Springs T5S, R29E	134°(1)-169°C(6)[f]		82°C[g]	100-400 gpm[g]
	Hyder Valley, Whitewing Ranch T5S, R12W., Sec 4,5	140°-153°C (3)[b]		--	
	Verde Hot Springs T11N, R6E	122°(1)-153°C(3)[e]		41°C[g]	10 gpm[g]
INFERRED:	San Bernardino Valley Springerville - Alpine Pinacate Volcanic Field Flagstaff				

TABLE 3-2: CLASSIFICATION OF GEOTHERMAL RESOURCES THAT ARE SUITABLE FOR DIRECT THERMAL USE (<150°C)

CLASS	LOCATION OF SITE	ESTIMATED SUBSURFACE TEMPERATURE	MEASURED SUBSURFACE TEMPERATURE	TEMPERATURE OF SURFACE SPRINGS	FLOW
PROVEN	Buckhorn Mineral Bath (well) T1N, R6E	89°C(1)[e]	48.5°C[e]		
	Safford Area Mineral Baths (wells) T8S, R26E	71°C(2)[e]	41.5°C[e]		
	Springerville South T9N, R29E,	85°C(1)[e,d]			
	San Bernardino Ranch T24S, R30E, Sec 15	89°(1) - 99°C(3)[e]			
	Hyder Valley T4-5S, R10-11W	97°C(2)[e]			
	Avra Valley T10-12S, R10-11E	50°-150°C (1)[c]	35°C at 30.5 meters[a]		
	Safford East T7S, R27E	101°(3)-116°C(2)[e]			
	Castle Hot Springs T8N, R1W, Sec. 34	85°(3)-113°C(1)[e]		50°C[g]	280 gpm[g]
	Coolidge Dam Hot Sp. T3S, R18E, Sec 17	100°(1)-157°C(3)[e]		36.6°C[g]	165 gpm[g]
	Coffers Hot Springs T16N, R13W, Sec 36.	110°C(1)-152°C(3)[e]		36.0°C[g]	70 gpm[g]
	Rainbow Valley T2-3S, R1-2W	98°-139°C(3)[e]	37°C at 246,287,314m[a]		
	Willcox T13S, R24E		87°C at 2027 meters[a]		
	Tucson South T15S, R14E	72°-86°C(1)[f]	52.2°C at 763 meters[a]		
	San Simon 14S, R30-31E	93°C(1)[e]	134°C at 1951 m		
	Kingman-Aquarius Region T15-21N, R12-17W	83°-121°(4) 90°C(2)[i]	44.5°C at 395m 37°C at 400m[i]	37°C[i] (Kaiser HS)	Spring: 160 gpm[i] Wells: 0-718 gpm[i]
	Hualapai Valley T26N, R16W, Sec 28		50°C at 651 m[a]		

TABLE 3-2 Cont

CLASS	LOCATION OF SITE	ESTIMATED SUBSURFACE TEMPERATURE	MEASURED SUBSURFACE TEMPERATURE	TEMPERATURE OF SURFACE SPRINGS	FLOW
PROVEN	Picacho Reservoir T7S, R8E		113° at 2440m $71.7^{\circ}C$ at 824m[a]		
	Papago Farms, T19S, R1E Sec 5,7	$107^{\circ}C$(1)[d]	$46.6^{\circ}C$ at 128m $45.5^{\circ}C$ at 218m		
	Sells, T17S, R4E, Sec 25	70°- $90^{\circ}C$(1)[c]	$41.7^{\circ}C$ at 35.7m[a]		
	Yuma T11S, R24W		$138^{\circ}C$ at 3217m[a]		
	Coolidge T5S, R7-8E		$52^{\circ}C$ at 61m $54^{\circ}C$ at 156m $54.4^{\circ}C$ at 592m[a]		
	McMullen Valley T6N, R12W		$36^{\circ}C$ at 279m $37.7^{\circ}C$ at 365m[a]		
	Mesa - Buckhorn Area, T1N, R4-6E		$54.4^{\circ}C$ at 305m $42.2^{\circ}C$ at 92.4m $36.0^{\circ}C$ at 320m[a]		
	Glenbar - Ashurst T5-6S, R24E		$59^{\circ}C$ at 1150m $47.7^{\circ}C$ at 18m[a] $48.3^{\circ}C$ at 183m[a]	47.7°- $50^{\circ}C$[g]	200-300 gpm[g]
	Goodyear - Phoenix West T2N, R1W		$53.9^{\circ}C$ at 707 $48.8^{\circ}C$ at 318m[a]		
	Hoover Dam T30N, R23W			$42.2^{\circ}C$[g]	
	Hooker's Hot Sp.			$54.5^{\circ}C$[g]	40 gpm[g]
	Harquahala Plains T5-6N, R12-13W	$77^{\circ}C$(2)[e]	$34^{\circ}C$ at 251m		
	Friendly Corners T9S, R8E		$37.2^{\circ}C$ at 153m[a]		
	Mammoth-San Manuel T9S, R16-17E		$38^{\circ}C$ at 397m $32^{\circ}C$ at $25.7^{\circ}C$[a]		
	San Simon Valley T10-12S, R28-29E		$72.2^{\circ}C$ at 82.9m $42.2^{\circ}C$ at 418m[a]		
	Gila Bend T5S, R4W, Sec 31		$48.5^{\circ}C$ at 534m[a]		

TABLE 3-2 Cont

POTENTIAL AND INFERRED:	The entire basin and range has an average ground water temperature of 26°C; thus it is inferred to be a low temperature resource wherever water may be found by conventional methods.

Key to aqueous geothermometry methods for estimating subsurface reservoir temperature:

1) SiO_2
2) Average of SiO_2 estimates
3) Na-K-Ca
4) Na-K-Ca, Mg-corrected
5) SiO_2 mixing model
6) SO_4 water isotope

SOURCES OF DATA FOR TABLES 3-1 AND 3-2 OF GEOTHERMAL RESOURCES IN ARIZONA

a. Giardinia, S., and Conley, J.N., 1978, Thermal Gradient Anomalies: Az. Oil & Gas Conservation Commission Report of Investigations 6.

b. Jones, N.O. and Campbell, A., 1979, Preliminary Assessment of the Geothermal Potential of the Hyder Area, Arizona: Arizona Bureau of Geology, in press.

c. Muffler, L.J.P., 1978, Assessment of Geothermal Resources of the U.S., USGS Circ. 790, p. 62-63

d. Stone, C., oral communication, July 1979.

e. Swanberg, C.A., et al, 1977, An Appraisal Study of the Geothermal Resources of Arizona and Adjacent Areas and Their Value for Desalination and other Uses: NMEI Rept. No. 6, p. 76.

f. Witcher, J.C., 1979, A Preliminary Study of the Geothermal Potential of the Tucson Metropolitan Area, Hahman, Sr., W.R., ed., Geothermal Reservoir Site Evaluation in Arizona, Semi annual Progress Report for the Period 7/15/78-1/15/79, pg. 73-90.

g. Witcher, J.C., written communication, December, 1978.

h. Witcher, J.C., 1979, A Progress Report of Geothermal Investigations in the Clifton Area, Hahman, Sr., W.R., ed., Geothermal Reservoir Site Evaluation in Arizona, Semi-annual Progress Report for the period 7/15/78-1/15/79: Az. Bur. of Geology, Geological Survey Branch, Tucson, p. 26-41.

i. Goff, Fraser E., 1979, "Wet" Geothermal Potential fo the Kingman-Williams Region, Arizona: Los Alamos Scientific Laboratory Informal Report LA-7757-MS, Los Alamos, N.M.

TABLE 3-3: POTENTIALLY USABLE ENERGY FOR ADPs

ADP	Basin	Reservoir Volume ($m^3 \times 10^9$)	Potentially Usable Energy (BTU $\times 10^{15}$)	Potentially Usable Energy (MWe, 30 Years)
Maricopa	Higley	5.0	0.30	334.0
	Rainbow	0.8	0.05	53.0
	Hyder	5.2	0.31	348.0
	Palo Verde	3.0	0.20	174.0
	Luke	4.2	0.25	281.0
	Harquahala	0.5	0.03	33.4
	Sentinel S.E.	2.6	0.16	173.7
	Paradise	1.3	0.08	86.8
	Verde	0.2	0.01	13.4
	Growler North	1.1	0.07	73.5
Totals		23.9	1.46	1570.8
Pima	Tucson	1.5	0.09	100.2
	Avra Valley	3.0	0.18	200.4
	Viopuli Valley	1.0	0.06	66.8
	Great Plain (Kom Vo)	4.1	0.25	274.0
	Growler South	1.3	0.08	87.0
	Childs-Ajo	1.1	0.07	73.5
	Gu Oidak	1.4	0.08	93.5
Totals		13.4	0.81	895.4

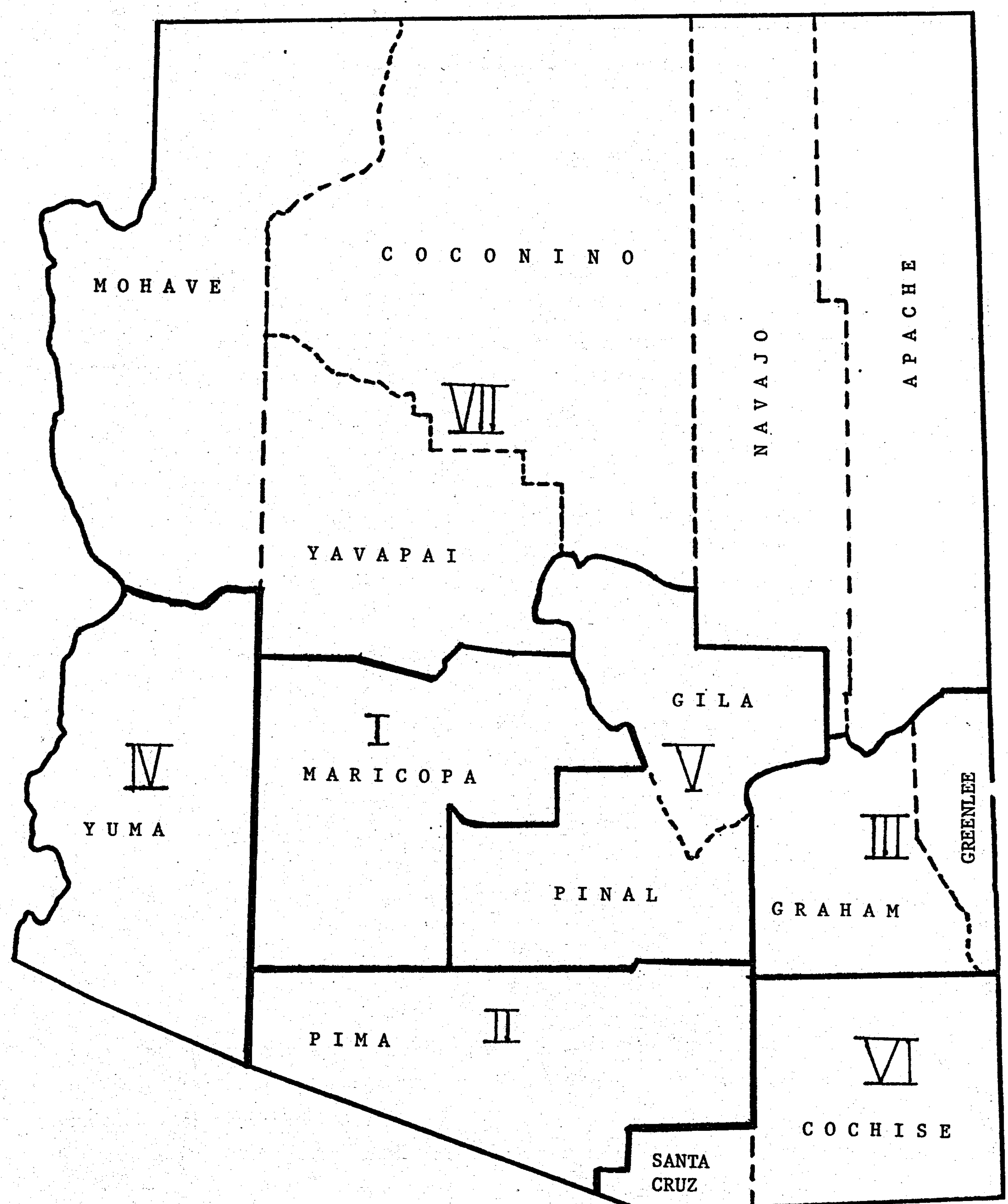


FIG. 3-3: AREA DEVELOPMENT PLANS FOR ARIZONA.

3.2.2 ADPs Completed or in Preparation

The following ADPs are under analysis:

1) Maricopa County

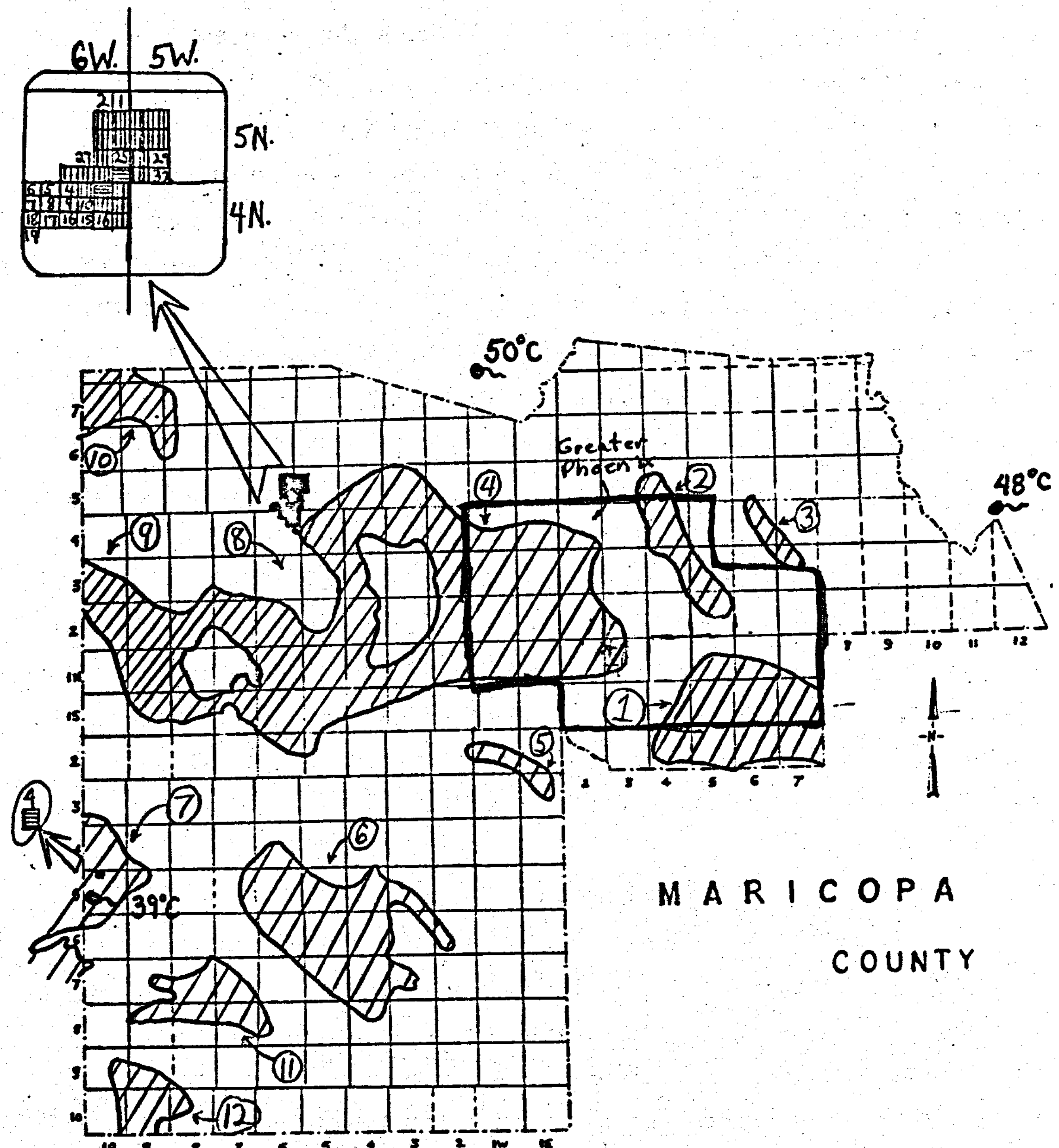
a) Geothermal Resources

Maricopa County lies entirely within the Basin and Range physiographic region, which is characterized by numerous mountain ranges rising abruptly from broad valleys or basins. Deep circulation of groundwater along basin-bounding faults and above normal heat flow result in the convective transfer of thermal water upward through basin-fill sediments and/or other faults. A deep (>3 km) 1974 geothermal test attained a fluid temperature of 184°C but produced water at a low flow rate. Drilled in Higley Basin 26 miles southeast of Phoenix, the hole penetrated 2020 meters of basin fill, including over 180 meters of chemically deposited anhydrite (3-4). Luke Basin, just northwest of Phoenix, also contains evaporite deposits at its center, inferred to be 2.0-2.5 km thick (3-5). High geothermal gradients (>50°C/km) have been encountered in about 25 water wells, most of which are deeper than 100 m (3-6) and are listed in Appendix A. Structural basins deeper than 365 meters are shown in Fig. 3-4 for Maricopa County. The locations of geothermal leases granted in the first half of 1979 are also shown, as well as the three thermal springs near the east (48°C), west (39°C), and north (50°C) boundaries of the county. The average temperature of groundwater in the Basin and Range is 26°C, the average air temperature about 20°C.

b) Economy

i. Population

Maricopa County ranks first in priority for ADPs for Arizona partly because it supports over half of the state's population. The 1979 estimate of population for Maricopa County is placed at 1,463,000 people (3-7). Its total land area is 9,226 square miles which gives it a population density of 145.9 persons per square mile. However this can be misleading in that over 90% of the total population of Maricopa County lies within a 20 mile radius of Phoenix. Ethnic breakdown of the population is 80% white, 15% hispanic, 3.5% black



-EXPLANATION-

- BASIN-FILL > 365 METERS
- GEOTHERMAL LEASES ISSUED 1-7/79
- FEDERAL LANDS
- STATE LANDS
- THERMAL SPRINGS

Basins

1.	Higley	7.	Hyder
2.	Paradise	8.	Palo Verde
3.	Verde	9.	Harquahala
4.	Luke	10.	McMullen
5.	Rainbow	11.	Sentinel S.E.
6.	Gila Bend	12.	Growler N.

Cooley, M.E., 1967, Thickness and distription of mid and late Cenozoic alluvial deposits: unpublished map, USGS, Water Resources Div., Tucson, Az.

FIG. 3-4: STRUCTURAL BASINS IN MARICOPA COUNTY and 1% Indian (3-8). Over the last 30 years the population of Maricopa County has grown at an implied annual rate of 5.7% (3-9). Future projections for Maricopa County place growth between 2% and 3% per year to the year 2000 with population growth slowing slightly after 2000. Fig. 3-5 shows projected population growth for the years 1970 to 2020, as approved by the Technical Advisory Committee of the Department of Economic Security on May 31, 1979. However, due to the energy situation in the northeast and midwest this rate of population growth could easily be exceeded as newcomers move to the sunbelt in search of a warmer climate. The largest towns in Maricopa County are listed in Table 3-4 with 1975 population and growth rates estimated to 2000, as provided by the Maricopa Association of Governments. The number of degree-heating-days were taken from the National Climatic Center reports for individual states, as provided by NMEI. Based on these growth rates and using a linear regression model, energy consumption for residential users was calculated for the year 2020 for each town. These results are reported later in this section.

ii. Industry and Employment

The principal contributor to the Maricopa County economy is manufacturing, specifically the manufacture of high technology products. Manufacturing accounted for an estimated 91,000 jobs in the county in 1979 (3-10) or about 17% of the labor force. Value added by manufacturing has been estimated at just over three billion dollars for 1979, or a 15% gain over 1978 (3-11). Most of this activity is concentrated in the Phoenix metropolitan area. The Department of Economic Security estimates that employment in the manufacturing sector will grow by 5% per year through the year 2000 (3-12). This 5% growth will occur mostly in the basic employment sector and come mostly from growth in the electronics and the aircraft industries. Because growth in the basic employment sector will be strong, the general economy of Maricopa County should remain healthy until the year 2000.

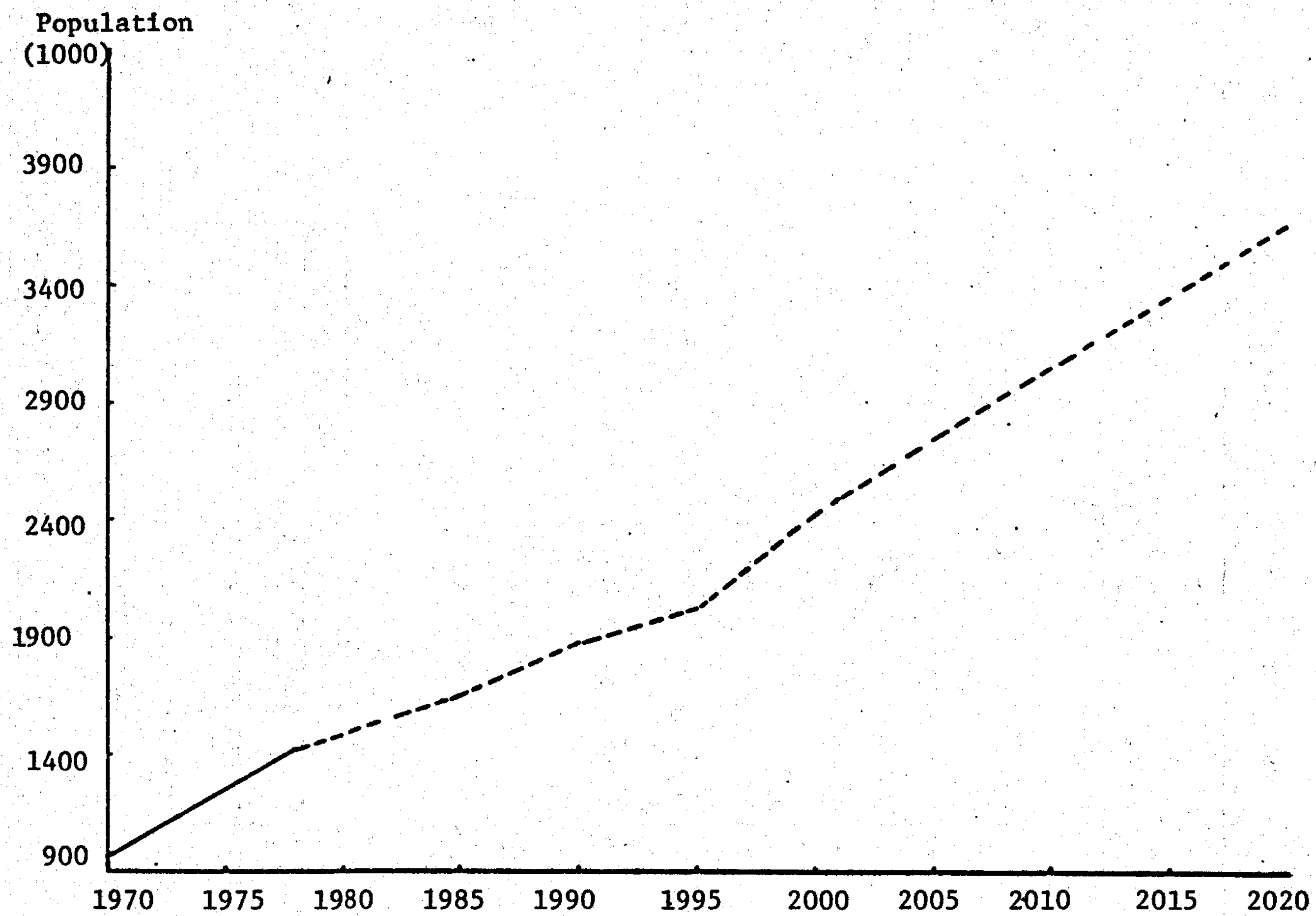


FIG. 3-5: POPULATION PROJECTIONS OF MARICOPA COUNTY TO 2020.
SOURCE: TECHNICAL ADVISORY COMMITTEE (DES)

TABLE 3-4: TOWNS IN MARICOPA COUNTY

City	Population (1975)	Growth Rate per year to 2000 (1)	Degree Cooling Days (2)	Degree Heating Days (3)
Avondale	11,405	10.5%		1550
Buckeye	2,675	8.3%		1450
Cashion	4,280(4)	5% (5)		1500
Cave Creek/ Carefree	2,150 (4)	5% (5)		1500
Chandler	22,496	12%		1750
El Mirage	3,827	10.6%		1750
Gila Bend	2,300	4.3%		1350
Gilbert	7,091	22%		1700
Glendale	71,292	4.25%		1750
Goodyear	3,187	29%		1600
Guadalupe	4,285	4.3%		1800
Litchfield Park	3,100(4)	5% (5)		1550
Mesa	117,099	2.5%		1710
Paradise Valley	11,532	2%		1800
Peoria	13,527	15.5%		1550
Phoenix	699,006	2%	4343	1550
Scottsdale	78,065	1.03%		1700
Sun City	43,500 (4)	5% (5)		1700
Surprise	3,400	4.85%		1750
Tempe	94,063	3.34%		1710
Tolleson	3,778	17.1%		1650
Wickenburg	2,908	5% (5)		2425
Youngstown	2,000	5%		1750

1. Maricopa Association of Governments.
2. Included for comparison purposes. 1978 figure.
3. National Climatic Center.
4. Valley National Bank (1977 data).
5. Estimated growth rate of 5% based on historic county growth.

The second largest contributor to the economy of Maricopa County is tourism and travel. Tourism showed a 22% gain in 1978 over 1977 and is expected to show a 10% gain in 1979. Latest reports show that the tourist industry realized $1.68 billion in revenue in 1978 (3-13) and provides about 180,000 jobs for Maricopa County residents. The reasons for such a strong tourist industry are numerous but certainly nice weather, a central location and major transportation networks help to contribute to this growth.

In dollar figures, agriculture is the third largest industry in Maricopa County. Approximately 510,000 acres of the county are used for agriculture (3-14), 50% of which was planted in cotton and the rest divided between wheat, hay, vegetables and fruits (mostly citrus) (3-15). Total value of crops and livestock exceeds one billion dollars annually.

The Department of Economic Security estimates that employment in agriculture will decline over the next 20 years at an average rate of 1.7% per year (3-16). This reflects the problems of water availability in the county since of all water used in the county, agriculture uses 90%. Also, the high value of land for non-agricultural purposes will serve to force the amount of agricultural acreage downward in the future.

In summary, Fig. 3-6 shows the projected growth of employment for all sectors of the economy through the year 2000. Total employment is projected to rise by 4% per year, with major contributions coming from the construction industry, manufacturing and civilian government (3-17). In addition, strong growth is anticipated in the basic employment sector which reflects a strong economy and provides a basis for other types of employment growth in the county.

iii. Income

Personal income and per capita income are considered by many to be strong indicators of economic health for a region. Income is not only a good indicator of economic health, but it also directly effects energy consumption in a positive manner. Thus, observing changes in personal income and per capita income should prove enlightening in terms of economic growth and energy consumption.

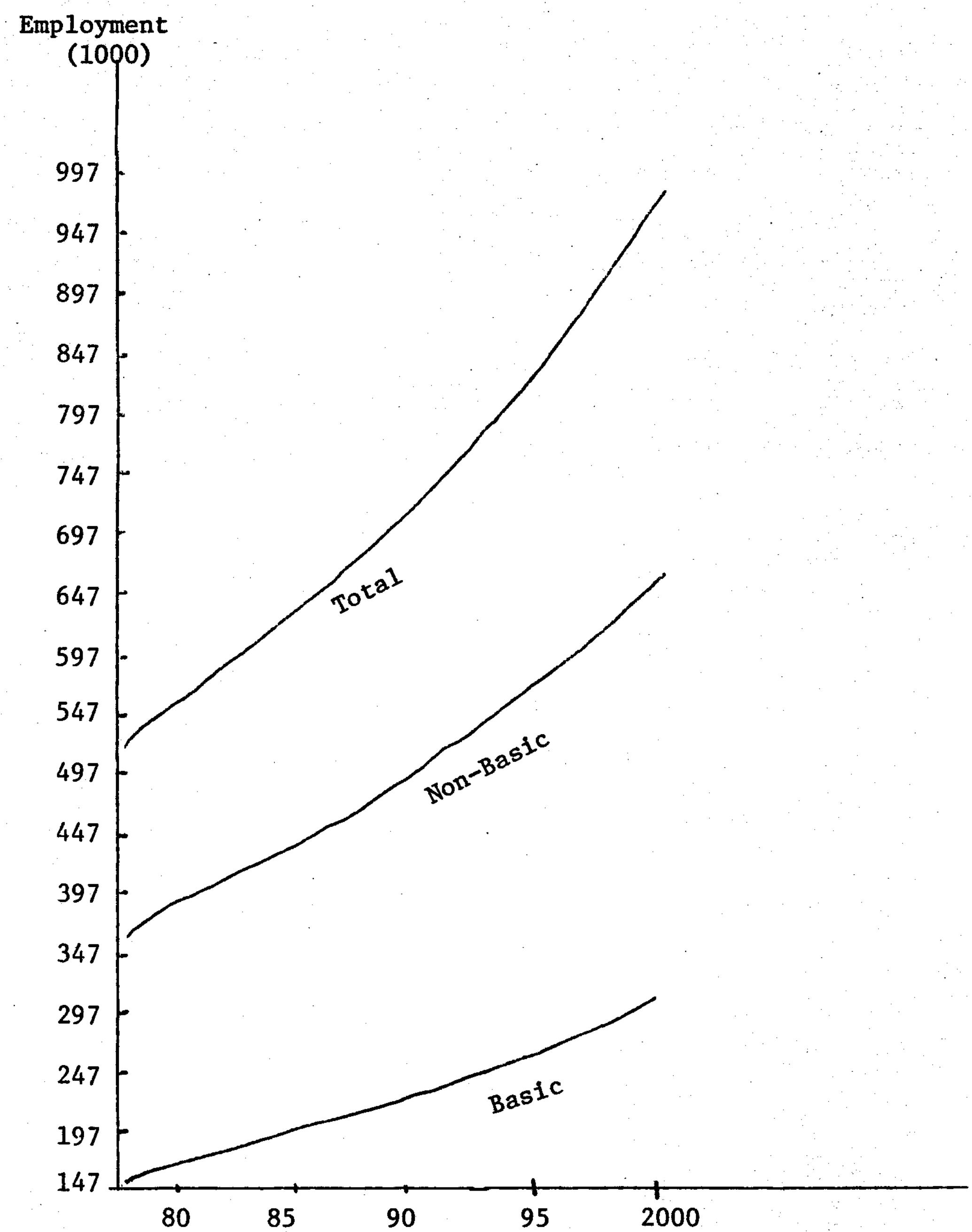


FIG. 3-6: EMPLOYMENT PROJECTIONS FOR MARICOPA COUNTY
SOURCE: EDPM MODEL - DEPT. OF ECONOMIC SECURITY

During the period 1970 to 1977, aggregate personal income in Maricopa County was increasing in real terms by 10% per year and as Fig. 3-7 shows, this trend is expected to continue to the year 2000 (3-18). This fact is not so surprising when one looks at the increasing importance of the construction industry, manufacturing and government employment in Maricopa County. These sectors tend to pay high wages to their employees which in turn fuels the regional economy.

Personal per capita income has also increased steadily in the last decade. Fig. 3-8 is a plot of the projected increase in real per capita income to the year 2000. The steady growth represents a real annual increase of 3.5% per year.

iv. Other Economic Indicators

Excepting the major economic indicators like population, employment and income, there are other indicators which help to illustrate the general welfare of the economy. One important indicator is retail sales. Between 1967 and 1977, retail sales in Maricopa County showed a total percentage increase of 245.4% or a simple 24.5% per year (3-19). Bank deposits also indicate well being and stability in the economy. Between 1967 and 1977, a 205% increase in bank deposits were experienced, which translates to a simple 20% annual rate of increase (3-20). Both of these indicators far exceed growth in other indicators and further bolster the strength of the economy.

In summary as a whole, Maricopa County, especially Phoenix, is one of the fastest growing areas in the state in terms of both industrial growth and population. Such facts provide a sound basis for the successful introduction of geothermal energy for several types of uses, from providing industrial process heat, to assisting agriculture and food processing, to heating and cooling of commercial buildings and private residences. Geothermal energy could provide a substantial input of energy to Maricopa County, which would aid in assuring its' growth and development well into the future.

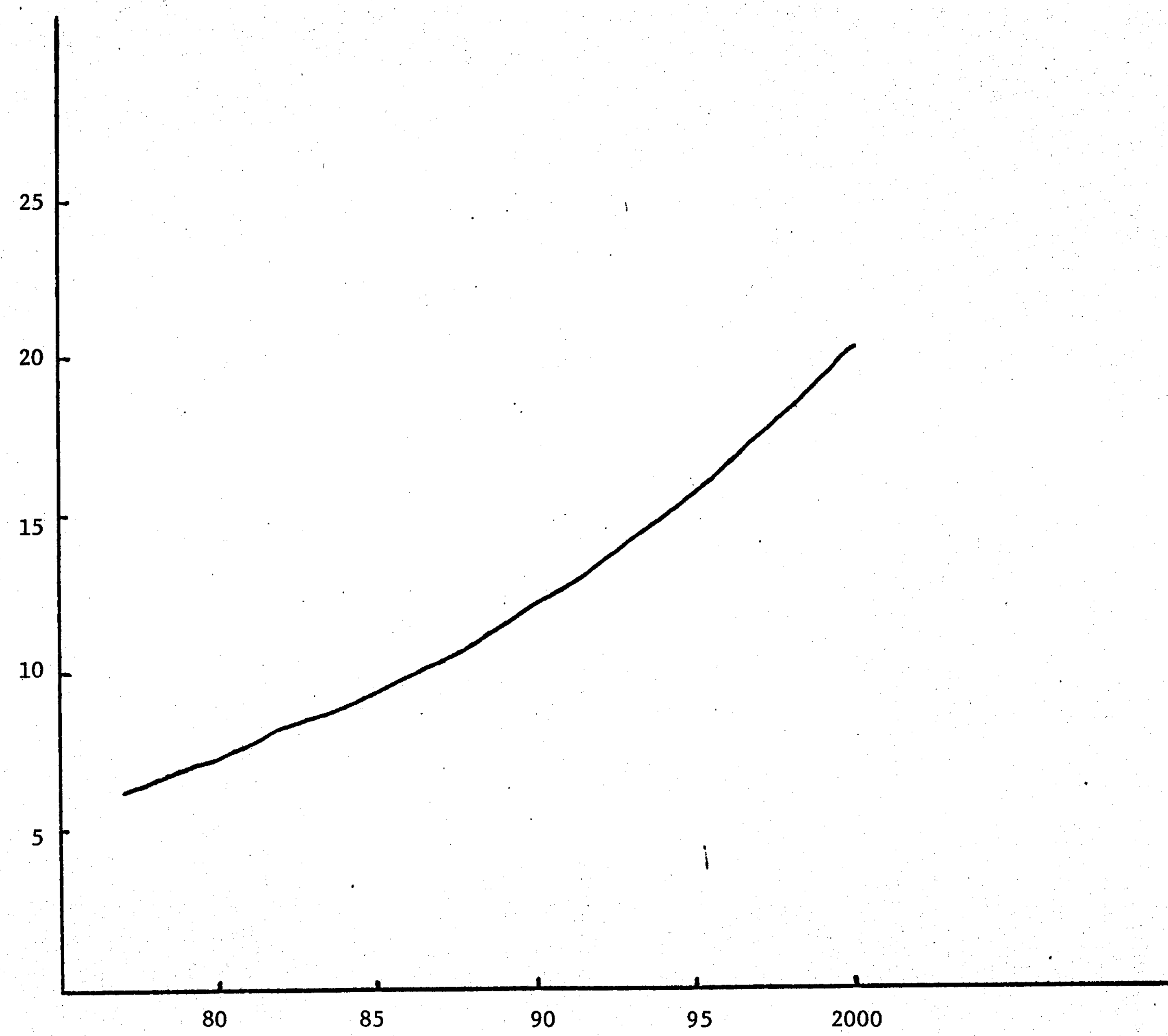


FIG. 3-7: PERSONAL INCOME FOR MARICOPA COUNTY TO 2000. (DES) 1972 DOLLARS

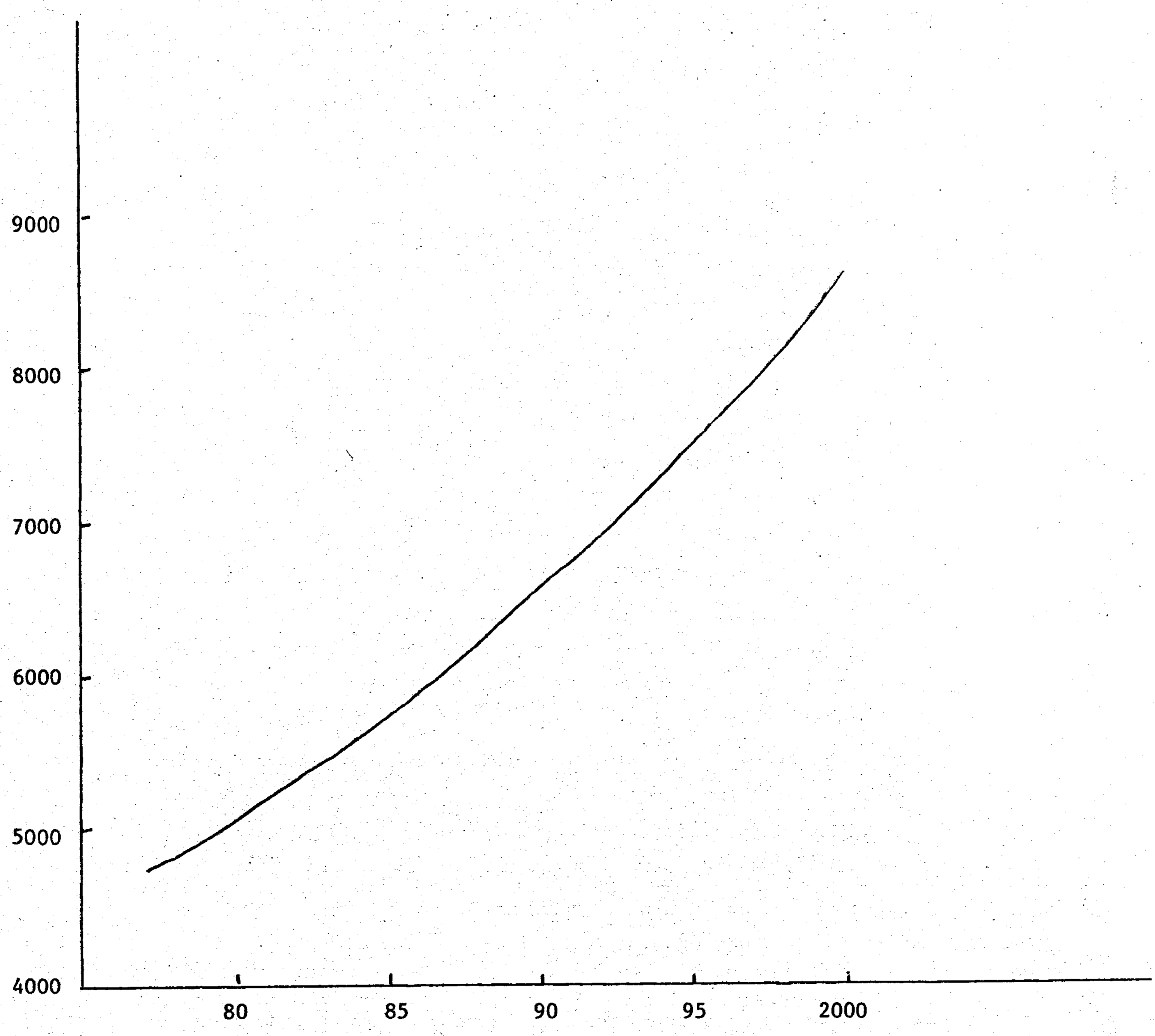


FIG. 3-8: PERSONAL PER CAPITA INCOME FOR MARICOPA COUNTY. 1972 DOLLARS (DES)

c) Land Ownership

Fig. 3-9 shows a general land ownership map for Maricopa County, divided between Federal, State, City, County, Indian and Private Lands. Percentages of land also are shown in Fig. 3-9. For clarification, a majority of the Federal land is owned by the Bureau of Land Management and the U.S. Forest Service.

d) Energy

In order to determine geothermal energy's potential contribution to Maricopa County's energy consumption, it is first necessary to estimate energy consumption for various user classes, then to estimate future energy consumption. To date, all that has been completed regarding this task is a preliminary estimate of residential consumption in 1979 and 2020 for the larger incorporated towns in Maricopa County. The results of this estimate are presented in Table 3-5.

The methodology used to generate these data is as follows. First, 1979 population was estimated for each town in Maricopa County. Using data on the number of persons per household gathered from Inside Phoenix 1979, the number of dwelling units in each town was estimated. Second, based on data derived from local utility company reports, average annual electricity and gas consumption per customer was estimated. These values were used to generate 1979 thermal energy consumption.

While estimating future thermal energy consumption, some simplifying assumptions were necessary. First, although population projections for each town were unavailable to the year 2020, based on population projections to 2000 a simple regression model was used to calculate future trends in individual town shares of total county population. A total population projection for Maricopa County was broken down to individual towns based on their percentage shares of total population. Second, it was assumed that electricity consumption and gas consumption per residential customer would remain at the same level in 2020 as it was in 1979. Even though this seems naive in light of the rapid growth in the U.S. energy consumption,

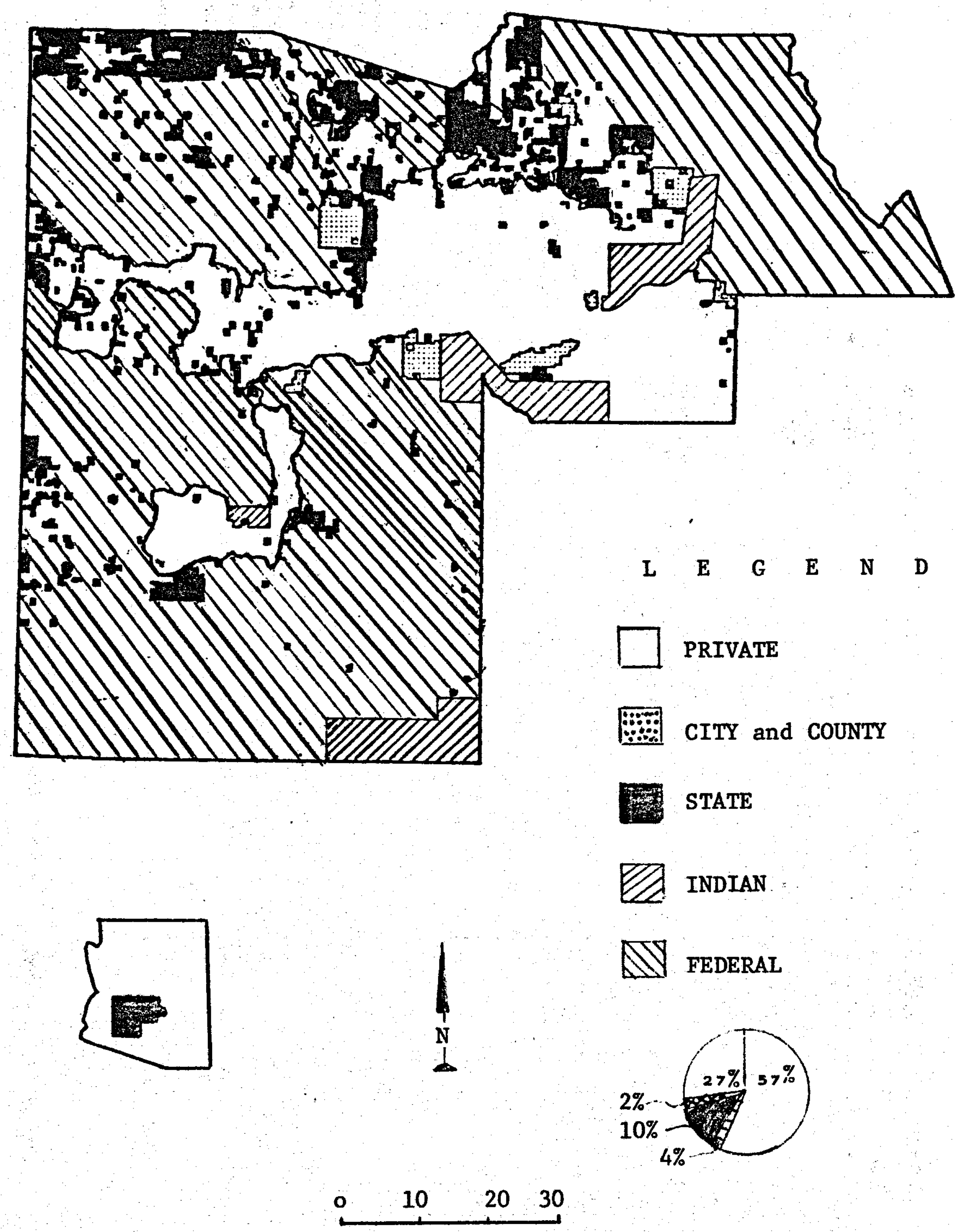


FIG. 3-9: LAND OWNERSHIP, MARICOPA COUNTY

SOURCE: ARIZONA WATER COMMISSION (1977)

TABLE 3-5: ESTIMATED THERMAL ENERGY CONSUMPTION FOR SELECTED COMMUNITIES IN MARICOPA COUNTY

Community	Estimated Population 1979	Estimated No. of Dwelling Units, 79	Estimated Residential Electricity Consumption 1979 BTUs x 10^{10}	Estimated Residential Natural Gas Consumption 1979 BTUs x 10^{10}	Estimated Total Residential Thermal Energy Consumption 1979 BTUs x 10^{10}	Forecast Population 2020	Forecast No. of Dwelling Units 2020	Forecast Residential Electricity Consumption 2020 BTUs x 10^{10}	Forecast Residential Natural Gas Consumption 2020 BTUs x 10^{10}	Forecast Total Residential Thermal Energy Consumption BTUs x 10^{10}
Avondale	11,800	3,933	15.247	22.457	37.704	84,553	28,184	109.26	160.94	270.20
Buckeye	2,930	977	3.788	5.579	9.367	16,837	5,612	21.76	32.05	53.81
Cashion	4,435	1,478	5.730	8.439	14.169					
Cave Creek/ CareFree	2,225	742	2.877	4.237	7.114					
Chandler	26,800	9,571	37.105	54.650	91.755	221,814	79,219	307.11	452.37	759.48
El Mirage	3,925	1,308	5.071	7.469	12.540	28,257	9,419	36.52	53.79	90.31
Gila Bend	2,535	845	3.276	4.825	8.101	8,565	2,855	11.07	16.30	27.37
Gilbert	8,275	2,955	11.456	16.873	28.329	122,620	43,793	169.77	250.07	419.84
Glendale	82,825	28,560	110.721	163.078	273.799	267,202	92,139	357.19	526.15	883.34
Goodyear	3,515	1,172	4.544	6.692	11.236	68,448	22,816	88.45	130.29	218.74
Guadalupe	4,300	1,483	5.749	8.468	14.217	13,543	4,670	18.10	26.67	44.77
LitchField Park	3,210	1,070	4.148	6.110	10.258					
Mesa	145,010	51,789	200.776	295.715	496.491	310,027	110,724	429.24	632.27	1,061.51
Paradise Valley	12,615	4,205	16.302	24.011	40.313	21,230	7,077	27.43	40.41	67.84
Peoria	16,465	8,666	33.596	49.483	83.079	176,060	92,663	359.23	529.14	888.37
Phoenix	755,145	269,695	1,045.554	1,540.000	2,585.554	1,307,459	466,950	1,810.22	2,666.44	4,476.66
Scottsdale	88,240	32,681	126.698	186.609	313.307	101,756	35,088	136.03	199.91	335.94
Sun City	45,060	23,716	91.942	135.418	227.360					
Surprise	3,440	1,147	4.447	6.549	10.996	12,079	4,032	15.63	23.02	38.65
Tempe	104,970	36,197	140.329	206.685	347.014	274,522	94,663	366.98	540.56	907.54
Tolleson	4,190	1,232	4.776	7.035	11.811	47,950	14,103	54.67	80.53	135.20
Wickenburg	3,750	1,250	4.846	7.138	11.984	14,641	4,880	18.92	27.87	46.79
YoungTown	2,000	1,053	4.082	6.013	10.095	2,197	1,156	4.48	6.60	11.08
TOTALS					4,656.593					10,737.44

electric consumption has risen only slightly over the past ten years while gas consumption has declined. The basic assumption used here is that the two trends would offset each other. The third basic assumption was that energy consumption is a function of population alone. Actually, energy consumption has been found to be dependent upon population, personal income, and per capita income. Later projections will be more detailed, but the results presented are illustrative of trends in future energy consumption.

At some future date, estimates for residential consumption will be updated and estimates will also be done for the industrial sector and commercial sector. The computer capabilities developed at NMEI should make the results much more reliable. As a check, actual consumption data is being collected from local utility companies. Unfortunately, these data are unavailable at present.

e) Water

Maricopa County is currently second to Yuma County in the availability of dependable water supply, and the proposed allocations of Central Arizona Project water will increase the County's supply to more than that of any other county. By 1986, the average dependable supply available is estimated to increase to about 1,452,000 acre feet per year from the current level of 971,000 acre feet per year (3-21).

Comparison of future water supplies and uses show that depletion will be 1.8 times greater than dependable supplies. The total water depletion is about 2.5 million acre feet per year, over 50 percent of which is used for irrigated agriculture (3-22). However, as a result of Central Arizona Project deliveries, the water supply deficiency would be reduced from a 1970 level of 902,000 to 427,000 acre feet per year in 1990 and 507,000 acre feet per year in 2020 (3-25). Agricultural depletions would represent about 45 percent of the total in the year 2020 (3-24).

Electric power generation in Maricopa County is projected to increase substantially in the future. The scheduled completion of the Palo Verde nuclear generating station west of Phoenix will also contribute to the County's water use through requirements for cooling steam power plants. Thus Maricopa County will continue to be the largest user of water in Arizona.

In Fig. 3-10, future projections are referred to as Alternatives I, II and III. Each was developed by summing compatible projections of individual water using categories.

2) Pima County

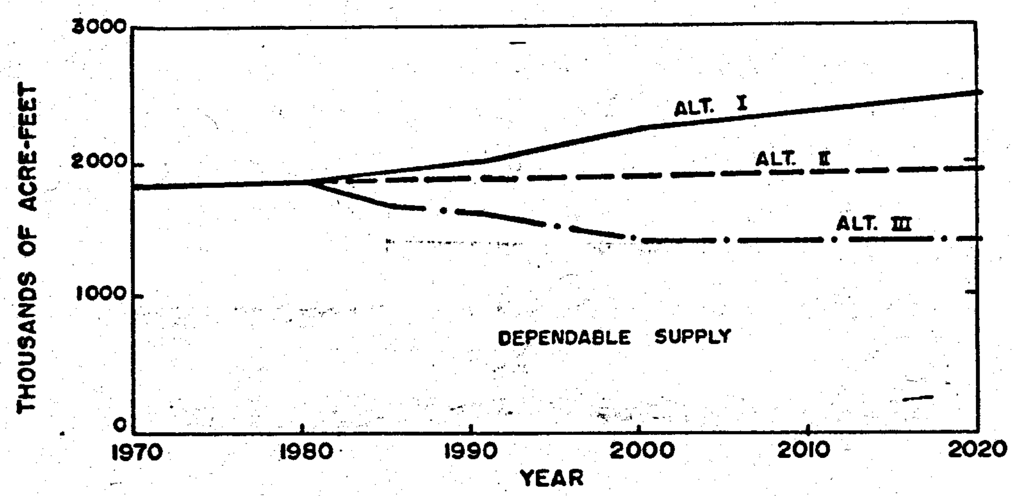
a) Geothermal Resources

Pima County also lies completely within the Basin and Range Province. Thermal waters rising along faults from deep basins probably reflect regionally high heat flow for the Tucson area (3-25). A deep oil test near the center of the Tucson Basin reached geologic basement at 3600 meters, and attained a 147°C temperature at its bottom, with possible thermal disturbance from cooler drilling mud. Five miles northeast of the well are water wells in which high temperatures have been encountered relative to their depth. The highest temperature measured is 52.2°C at 762 meters depth. Other water wells in the Tucson area have high thermal gradients although they are usually shallower than 300 meters (3-26).

Because of an observed inverse relationship between depth and thermal gradient in this area, Witcher (3-27) has tabulated this phenomenon and used quartz geothermometry to estimate the water temperature in the Tucson subsurface. The estimated temperatures range from about 72°C to 86°C (3-28). This suggests an energy resource in the correct temperature range for space heating and possibly cooling in the Tucson area.

Elsewhere in Pima County evidence of low-to-moderate geothermal potential is manifested in warm water from wells on the Papago Indian Reservation. Much of this vast area is unexplored in the subsurface, but two water wells in the Great Plain encountered 45-47°C water at shallow (<200 m) depths. Nearby, other water wells have normal to moderately high thermal gradients. However, this water is presently suitable for soil warming, fermentation, and fish farming without further well investment.

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	969.0	2350.0	4670.0	1920.0	3180.0	1920.0	3180.0
HARVESTED ACRES	470.0	418.0	382.0	412.0	332.0	342.0	184.0
URBAN DEPLETIONS AF/YR	183.0	380.0	638.0	331.0	478.0	331.0	478.0
STEAM ELECTRIC DEPLETIONS AF/YR	7.8	107.0	534.0	77.5	279.0	77.5	279.0
MINERAL DEPLETIONS AF/YR	1.0	3.0	5.0	3.0	5.0	3.0	5.0
AGRICULTURAL DEPL. AF/YR	1681.0	1480.0	1310.0	1460.0	1140.0	1210.0	633.0
TOTAL WATER DEPL. AF/YR[1]	1873	1977	2494	1879	1909	1629	1402
DEPENDABLE WATER AF/YR	971	1452	1402	1452	1402	1452	1402
SURPLUS SUPPLY (Def.)	(902)	(525)	(1092)	(427)	(507)	(177)	0

[1]Projections include 7,300 AF/YR for fish and wildlife depletions.

FIG. 3-10: FUTURE PROJECTED ALTERNATIVES
SOURCE: ARIZONA WATER COMMISSION (1977)

b) Economy

i. Population

Pima County has been chosen as the second Area Development Plan because it has the second largest population center in Arizona, namely Tucson. Elevations in the county range from 1200 ft to 9185 ft. The terrain is mostly desert with a few large mountain ranges.

The 1979 estimated population of Pima County is 506,100 (3-29). The size of the county is 9,240 square miles which leads to a population density of 51.3 persons per square mile. Again, like Maricopa County, the majority of people live in the Tucson area, rather than uniformly distributed throughout the county. In the last 10 years, Pima county population has grown by 43% and the trend is expected to continue into the future. Of the 506,100 persons in Pima County, 69.4% are white, 3% Indian, 3% black and 24% are hispanics.

As was stated before, the major city is Tucson with a 1979 estimated urban area population of 467,200 (3-30), and a population density of 1335 persons per square mile. Other leading towns in the county are South Tucson, Ajo, Green Valley/Continental and Catalina.

ii. Employment and Industry

The major industry in Pima County is mining, the highest production being from copper. The mining industry in Pima County accounted for about 40% of the production of copper in Arizona in 1970. Further descriptions of this industry in Pima County is given in Appendix C. The second largest contributor to the Pima County economy is manufacturing, which accounted for 12,400 jobs and 295,000,000 dollars of output in the Tucson area in 1975 (3-31). The third major contributor is tourism. It contributed 658,516,344 dollars to the economy in 1977 (3-32). Total employment in the county in 1978 was 172,800, leading to a seasonally adjusted unemployment rate of 5.8% (3-33).

iii. Land Ownership

Land ownership in the county is divided between Federal, State, Indian and Private. Of the land in Pima County, 42% is designated Papago Indian land, 13% is Federal (split BLM and USFS), 16% is State land and the rest is private.

3) Graham/Greenlee Counties

The third Area Development Plan will be completed for at least Graham and Greenlee counties combined, but might also include Cochise County and Santa Cruz County. The nature and arrangement of energy data from this area of the state will determine how these counties are grouped. Currently, preliminary work has begun on this ADP, but data collected so far are not sufficient to justify a final decision regarding boundaries.

3.3: Site Specific Development Plans

Based on the recommendations of last year's preliminary study, eight site-specific development plans were chosen from the twenty-two proposed uses. These eight applications were chosen for further study during this current year because they proved to have more potential of being implemented in the future. It is important to note that none of these proposed applications are under development at the present time.

3.3.1 Candidate Geothermal Site-Specific Applications

The following candidate geothermal site-specific applications are being evaluated with respect to their technical, financial, environmental, and institutional aspects. A description of these SSDPs follows:

1) Space Air Conditioning

The very hot climate in the south half of Arizona necessitates the allocation of great amounts of electricity to provide comfort cooling, especially in the summer months. The more populated areas of Arizona, namely the Phoenix and Tucson areas demand a considerable amount of space cooling and a smaller amount of space heating. Geothermal energy could augment the energy supply by using the available technology of absorption cooling, which uses less electricity than centrifugal air-conditioning. The overall result would be to reduce the electric peak load of the utilities by harnessing the geothermal resources and using this geothermal energy to power absorption cooling system. A great interest in this application exists in the state. A government establishment is assessing this application and might start plans to implement this use in the greater Phoenix area. Also a large industrial firm in the greater Tucson area is considering the use of geothermal energy for space cooling. This government establishment and private firm asked to remain anonymous at the present time. Finally plans are being considered to study the possibility of using geothermal energy for district cooling for a community like Sun City. Members of the Arizona Geothermal Team are involved in some stages of the studies mentioned above and this SSDP will evaluate this promising application.

2) Geothermal Power Plants

The demand for electricity is increasing constantly due to the increase in the State's population, and the price of fossil fuels is constantly rising. Thus, it is of paramount importance to utilize the State's energy resources to meet this rising demand. Geologic studies have shown that some geothermal prospects in Arizona are likely to have fluid temperature above 150°C and might be suitable for use in power production. Two possible locations that seem to have potential for power production are the San Bernardino Valley, where there is the possibility that a large geothermal reservoir exists, and the Clifton Hot Springs area where there might be good geothermal prospects. These two locations are currently under consideration. Preliminary work has been done and based on this first iteration, San Bernardino was chosen to be the site for a 700 MW geothermal/coal hybrid power plant. San Bernardino might have a large reservoir that could sustain such a power plant. One SSDP will be prepared to compare the cost per KW of this geothermal power plant with the cost of coal-fired and nuclear power plants of the same size. The other SSDP will consider a 50 MW power plant in Clifton as a candidate for a PON (Program Opportunity Notice) especially after it has been learned that the Greenlee County Manager, Mr. Dave Perkins, is considering the use of geothermal energy for a small power plant in the Clifton area.

3) Geothermal Assisted Copper Dump Leaching

Arizona has several copper mining locations where some form of leaching is practiced. Moreover, many potential or inactive dumps are present in the state. Theoretical studies have shown that the rate of copper extraction is enhanced by increasing the temperature of the leaching fluid. Several areas exist in Arizona where geothermal prospects overlap mining locations. A large portion of these locations occur in Pima and Greenlee counties. Thus the use of geothermal energy to heat the leaching fluid may cause substantial savings in fossil fuels as well as an increase in the copper recovery. Due to convenience, preliminary efforts focused on the analysis of geothermal prospects that overlap mining locations in Pima County; but there are locations in Morenci/Clifton and Globe where mining areas coincide with significant geothermal anomalies and these prospects will be evaluated.

4) Geothermal Assisted In-situ Solution Mining

Arizona has large reserves of copper, as well as considerable deposits of uranium and zinc. Many geothermal anomalies overlap ore deposits of zinc, uranium and copper, thus it would be considerably advantageous to use geothermal energy in in-place solution mining. Some of these advantages are, a) an increase in the copper recovery due to the increase in the temperature of the leaching fluid; b) the increase of copper recovery per unit time will increase the production of copper and at the same time reduce pumping cost and overall operating cost; c) some less brackish geothermal brines could be used directly in the leaching process and thus will help replace the more potable water that is currently used. This will lead to conservation of the water table and allow the use of this water for other purposes like agricultural and domestic uses; d) geothermal brine could be used for some other use such as providing process heat and the waste geothermal brine could be used in in-place mining, since leaching does not require a high temperature and can use the waste heat of another process; e) there might be no need for re-injection wells if the mining process involves leaching one area and then moving to another area and thus the previous location could be used as a dump for the waste brine.

5) Direct Thermal Use for Food Processing/Power Production

Geothermal energy could be used to provide steam for the food processing industry. Most food processing industries use steam at a temperature of about 100^{o}C which makes it a good potential user of moderate-temperature geothermal resources. This site-specific application will consider the use of geothermal energy for a citrus juice concentrate plant in Yuma. The plant uses process steam at a maximum temperature of about 97.5^{o}C for reducing the water content of the citrus juice. The plant also requires a great amount of refrigeration to freeze and store the citrus juice concentrate. This plant is located in an agricultural area where a great amount of irrigation is needed due to the arid climate. Thus this SSDP will consider the possibility of an integrated use geothermal system. Geothermal energy could provide process steam, and may be used to power a small power plant that will provide electricity to be used for, a) providing refrigeration and other electrical uses in the plant; b) helping alleviate the demand for electricity by selling electricity to the utilities during peak periods; c) providing electricity for irrigation pumping. This SSDP will also consider the future of the citrus industry in Arizona.

6) Geothermal Assisted Coal-Fired Power Plants

There are a few coal-fired power plants under construction in the areas of Springerville and Willcox. More units will be constructed in the next ten years in these and other areas in the state. Geothermal brine can be used to wash and preheat the coal and also to preheat the make-up water that will be converted to steam. This SSDP will consider the possibility of implementing this application in the Springerville area where geothermal exploration is presently being conducted. A similar application was evaluated by TRW systems corporation to be applied in the City of Burbank in California. Efforts were made to get information on this study but these attempts were met with failure. Nevertheless, more attempts will be made to acquire the needed information.

7) Geothermal Steam Turbine Pumping

A large portion of Arizona is agricultural land. Since most of the state has a semi-arid climate about 90% of the rain is lost by evapo -transpiration. Most of the remaining rain infiltrates into the ground. A considerable amount of this underground water is being pumped up to the surface and used for irrigation, thus causing a large demand for pumping and electricity. Geothermal energy might be used to produce the electricity needed by the pumping stations. It is recognized that irrigation pumping normally consists of a large number of small pumps. The use of alternate sources of energy like solar and geothermal energy have been studied in New Mexico and Arizona. This SSDP will include a review of these studies to assess the feasibility of geothermal irrigation pumping and the possibility of using the less brackish geothermal brine for irrigation.

8) Geothermal Pumping for Central Arizona Project (CAP)

Geothermal energy might be used to produce the electricity needed by the CAP pumping stations. Pumping stations to be constructed within the next six years are mainly between Phoenix and Tucson. One of these planned stations is in the Picacho area where good geothermal prospects exist. This SSDP will compare the cost of geothermal pumping stations with the cost of transferring the electricity from the Navajo Power Plant in Page, Arizona.

3.4: Institutional Analysis

3.4.1 Overview of State Laws and Regulations

Arizona State Law broadly defines a geothermal resource to include hot water, hot brines, indigenous steam, heat found in geothermal formations and minerals exclusive of fossil fuels and helium gas which may be present in solutions or in association with geothermal steam.

The State Land Department has statutory authority to designate "known geothermal resource areas" (KGRA), and to lease State lands for geothermal development purposes through competitive bidding. The Arizona Oil and Gas Conservation Commission regulates the drilling of wells for geothermal development on State, Federal, Indian and Private Land.

Several key points have arisen from our studies. First, the State of Arizona does not require environmental assessments and environmental impact statements. This will definitely aid in providing a shorter time span for leasing of state land. Second, geothermal resources are exempt from state water laws due to statute 27-667 and administrative rulings. Lastly, the state offers a number of tax incentives to potential developers of geothermal resources, thus adding an incentive to the commercialization of a potential future energy source.

3.4.2 Detailed State Institutional Procedures

1) State Land Leasing

Sole authority to lease state land for geothermal development purposes rests within the jurisdiction of the Arizona State Land

Department. The statutes pertaining to such land leasing are incorporated in A.R.S. sections 27-667 through 27-676. The agency regulations are incorporated into Arizona Administrative Rules and Regulations, sections R12-5-850 through R12-5-865. These laws define "geothermal resource" as:

(a) All products of geothermal processes embracing indigenous steam, hot water and hot brines.

(b) Steam and other gases, hot water and hot brines resulting from water, other fluids or gas artificially introduced into geothermal formations.

(c) Heat or other associated energy found in geothermal formations, including any artificial stimulation or induction thereof.

(d) Any mineral or minerals, exclusive of fossil fuels and helium gas, which may be present in solution or in association with geothermal steam, water or brines. (A.R.S. 27-651).

The State Land Department has statutory authority to designate "known geothermal resource areas" (KGRAs) and to lease State lands for geothermal development purposes through competitive bidding. Leases are sold for a primary term of ten years and as long thereafter as geothermal resources are being produced in paying quantities. If drilling operations are being "diligently prosecuted" and the primary lease term expires, then the lease term shall continue for a period of two more years, and so long after that as geothermal resources are produced from the leased lands. If geothermal resources in paying quantities are discovered on the lands while the lease is in full force, but the lessee is unable to produce any geothermal product (lack of transportation, processing or generating facilities) the lease shall be extended beyond the primary ten year term on a year to year basis (but not to exceed three years) by payment of a shut-in geothermal resource royalty of two dollars per acre per year. This royalty would be payable in advance annually on the anniversary date of the lease. The acreage allowed is limited to 2,560 acres per lease. A minimum royalty rate is set at 12.5 percent of the gross value of the resource at the well head. The annual rent is one dollar per acre for each year the lease is in effect.

Any person eighteen years or older or any firm, association, or corporation which has complied with the state laws shall be qualified to lease state land.

2) Procedures for Leasing State Land

Geothermal leases on State land can be initiated by either of two methods:

(a) The Land Department can designate likely resource areas that it wishes to lease, or

(b) an individual or company may apply for a lease on a given tract or state land.

Upon receipt of a lease application (along with a $25 filing fee), the Land Department shall offer the tracts of land for leasing purposes to the "highest and best bidder" based on the highest first year's bonus bid. The bonus bid is the excess bid above the standard one dollar per acre rental rate for the first year. Thereafter the annual rate is one dollar per acre. The Land Department then publishes a call for bids for a period of ten weeks in Arizona newspapers of general circulation (Arizona Weekly Gazette and the newspaper distributed nearest to where the lease land is located), the cost of which is to be paid by the successful bidder. This notice will specify the day and hour the bids will be opened, give description of the lands up for bid, specify the royalty to be demanded, and give full information on how and where the bids are to be accepted. A certified check in the amount of the bid must be enclosed with all sealed bids.

Following the opening of the sealed bids, the department will return all unsuccessful bid payments and will notify all interested parties of the outcome. By law, the State Land Department has the right to reject any and all bids. If a lease is offered, two copies of the lease will be sent to the successful bidder. The bidder will then have thirty days to execute and return the lease to the department. At such time, the first year's rent, the cost of publishing the notice, and any reasonable expenses of the sale must be paid. According to the sales division of the Land Department, the newspaper notices run anywhere from $250 - $400 per lease. To this point, no successful bidder has had to pay the reasonable expenses of the sale). If a successful bidder fails to execute and return the lease within the thirty day period, the lease will become invalid and all payments will be forfeited.

Mr. A.K. Doss of the State Land Department estimated that it would take a minimum of 5-6 months to obtain a lease for State land.

3) Indian Land Leasing

Actions that relate to trust resources on Federal lands ultimately rest with the Secretary of the Department of the Interior. Accordingly, the leasing of Indian lands for geothermal development has been assigned to the Bureau of Indian Affairs (BIA) and the U.S. Geological Survey (USGS). The BIA provides technical and administrative assistance to the Indian Tribe in bid publication, lease contract review, and operations monitoring. USGS evaluates any environmental assessment or impact statement and also provides similar technical assistance. In addition, USGS has enforcement authority in operation compliance of resource development. The individual Indian Tribes maintain a fair degree of flexibility in that they determine the terms of the lease, for instance, rents, royalties, period of lease and whether a lease will be sold by competitive or non-competitive bidding process. The time periods involved in obtaining an Indian land lease for geothermal development purposes depend on whether the BIA or other Federal agencies determine that an environmental impact statement (EIS) is necessary. In such cases, periods of 2 years or more would be realistic in obtaining a lease.

It is possible to do pre-lease exploratory work on Indian lands. This would require obtaining an exploration permit from the individual tribes involved. The terms of the permit (cost, length of permit, extent of exploration work, etc) would be determined by the tribe.

4) Private Land Leasing

There are no state regulations pertaining to the leasing of private land in Arizona for geothermal development. Private land leases can be obtained by direct negotiation with the owner of the land on which the geothermal resources are located. Once the lease is negotiated, a copy of the lease must be filed with the County Recorder for the county or counties in which the land is located. There is a $3.00 recording fee in Arizona's fourteen counties and leases are generally recorded on the day they are received by the recorder's office. Fig. 3-10 is a land ownership map for Arizona.

5) Arizona Well Drilling Regulations

The Arizona state agency involved in regulating and enforcing the drilling of wells for geothermal development on State, Federal, Indian or private land is the Arizona Oil and Gas Conservation Commission. The statutes pertaining to the commission's jurisdiction over geothermal development are incorporated in A.R.S. sections 27-651 through 27-666. The agency regulations are incorporated into Arizona Administrative Rules and Regulations, sections R12-7-201 through R12-7-294. The commission has jurisdiction and authority over such persons and property deemed necessary to administer and enforce the statutes relating to the conservation of geothermal resources. In so doing, the commission shall:

> Supervise the drilling, operation maintenance and abandonment of geothermal resource wells as to encourage the greatest ultimate economic recovery of geothermal resources, to prevent damage to the waste from underground geothermal reservoirs, to prevent damage to or contamination of any waters or the state or any formation productive or potentially productive of fossil fuels or helium gas, and to prevent the discharge of any fluids or gases or disposition of substances harmful to the environment by reasons of drilling, operation, maintenance, or abandonment of geothermal resource wells (A.R.S. 27-652).

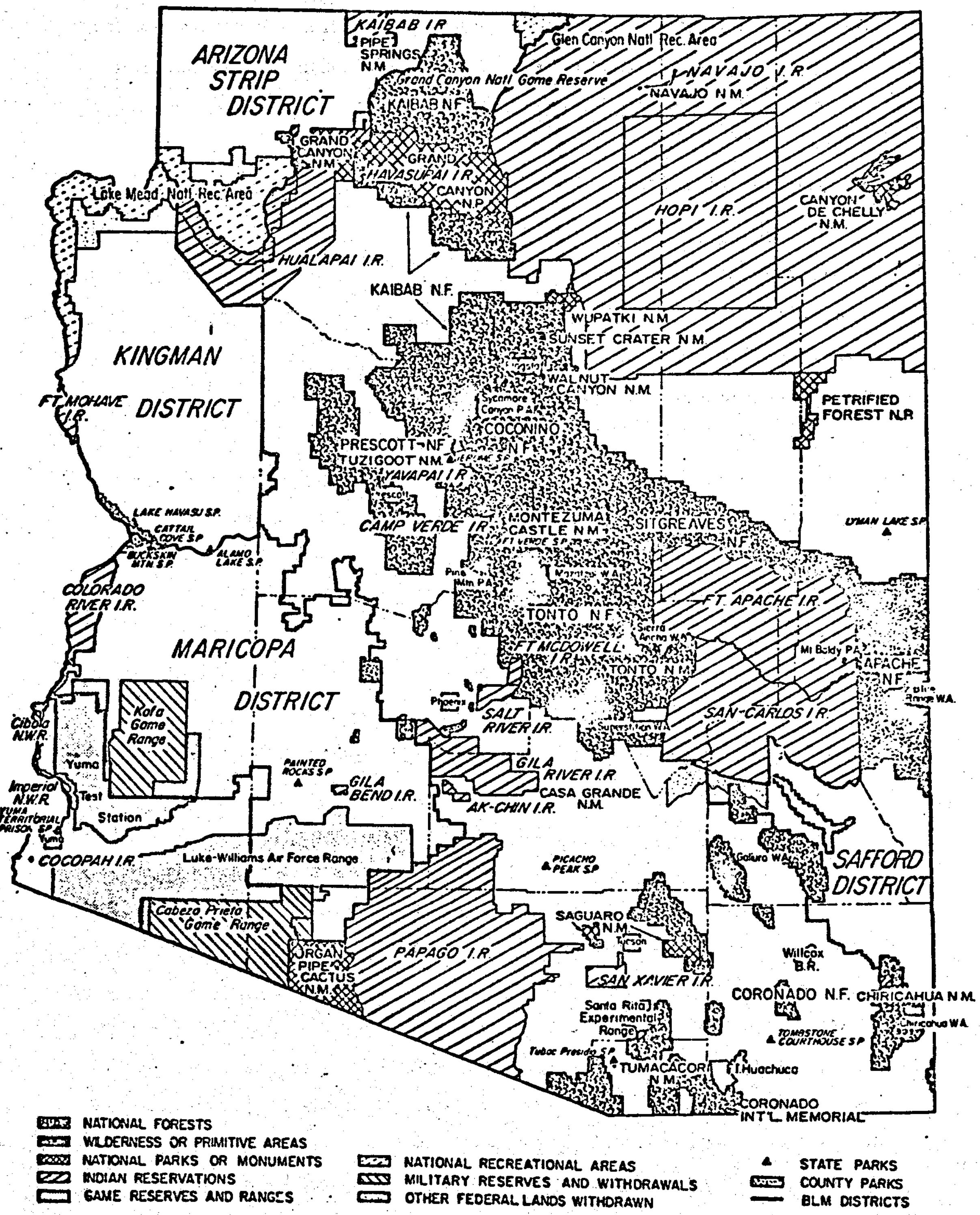


FIG. 3-11: LAND OWNERSHIP IN ARIZONA.

The Oil and Gas Conservation Commission consists of six members of which five are appointed by the Governor with Senate consent. The State Land Commissioner serves as an ex-officio member.

6) Application Procedures

Before engaging in drilling or producing a well on State, Federal, Indian or Private land, such person must file with the commission a surety bond in the amount of $5000 for each well or $25,000 as a blanket sum for all wells. This surety bond would be conditioned as to the following:

a) Compliance with all statutes and rules and regulations
b) Plugging and abandoning the well as approved by the commission.

In addition to the bond, the following three items must be filed with the commission in order to obtain a permit to drill:

i. an application (form G-3)
ii. a $25 filing fee for each well
iii. a surveyor certified plat which shows the exact acreage or legal subdivisions allotted to the well.

Once the above procedures are carried out in compliance with the laws, a permit to drill is issued by the commission. According to Mr. William E. Allen, Director of Enforcement Section of the Oil and Gas Conservation Commission, it would take only one to two weeks for the commission to issue this permit. Drilling operations must commence within ninety days of the issuance of the permit or the permit becomes null and void (unless an extension in writing is granted by the commission). If violations occur on the part of the permit holder, the commission may order the holder to cease further work and after a notice and a hearing, the permit holder may be ordered to plug and abandon the well. Only after certain requirements have been complied with, will the commission authorize a change in location of the well.

7) Drilling of the Well

In drilling the well, the parties involved must comply with all technical and environmental conditions and restrictions as set forth by law. Every person drilling or operating a well must post in a conspicuous place (not more than 20 feet from the well) a sign stating the following:

a) name of well;
b) location of well by quarter-quarter-quarter section township and range;
c) the state's drilling permit number.

8) Reports

The following types of reports pertaining to geothermal wells must be filed with the Oil and Gas Conservation Commission:

a) Well Completion Report (form G-4)
   Report must be filed with the commission within 30 days after completion of the well.
b) Injection Project Report (form G-8)
   Report would contain information on amount of geothermal resources produced, volumes of substances injected and other information as called for by the commission. Report must be filed on or before the 20th day of the next succeeding month.
c) Monthly Producer's Report (form G-6)
   Such report must be filed on each producing lease within the state for each calendar month. Report must be filed on or before the 25th day of the next succeeding month.
d) Geothermal Purchasers Monthly Report (form G-7)
   Each purchaser or taker of a geothermal resource must file this report detailing acquisition and disposition of all geothermal resources taken by such person during that month. Report must be filed on or before the 20th day of the next succeeding month.
e) Processor's Report (form G-7)
   Each plant operator processing a geothermal resource must file a report of the geothermal resource's procedes during the preceding month. The report must detail:

-- Particulars of the geothermal resources received at the plant

-- Particulars of the products derived from such geothermal resources and the disposition thereof.

Report must be filed not later than 20th day of each month.

f) Organization Reports (form G-1)

Every person acting as principal or as agent for another or who is independently engaged in the drilling, operation, production, storage, transportation, refining, reclamation, treating, marketing, processing of, or scientific exploration for geothermal resources must file an Organization Report immediately with the commission. The report must contain the following information:

--Names and addresses of the business, the directors, and principal officers.

--State where incorporated. If a foreign corporation, name of its Arizona agent, and date of permit to do business in Arizona.

--The plan or organization.

If any of the above information changes, a supplementary report must be filed immediately.

9) Technical and Environmental Drilling Conditions - Oil and Gas Conservation Commission

a) Spacing of Wells

The Commission must approve all well-spacing programs or prescribe modifications to programs.

b) Pit for Clay, Shale and Drill Cuttings

An earthen or portable pit must be provided (prior to drilling operations) in order to assure a supply of mud-laden fluid to confine oil, gas, water, etc. to its natural stream.

c) Sealing off Strata

Any oil, gas and water above the producing horizon shall be confined to their respective stratum and shall be sealed or separated in order to prevent their contents from passing into another stratum.

d) Surface Casing Requirements

In areas where pressure and formations are unknown, sufficient surface casing shall be run to reach a depth below all reasonably known estimated fresh water levels, to prevent blow-outs or uncontrolled flows. Surface casing shall be set in through an impervious formation and shall be cemented by the pump and plug or displacement method.

e) Defective Casing or Cementing

The operator shall notify the commission if any well appears to have defective casing, faulty cementing or corroded casing that will permit or create underground waste.

f) Blow-out Prevention

Any person drilling a well for geothermal resources in an area where fluids, gases or steam under high pressure are known to exist, shall case (in a watertight manner) the bore hole to a depth sufficient to protect against surface cratering in the event of a blow-out.

g) Pulling Outside Strings of Casings

When pulling outside strings or casing from the well, the space outside the casing left in the hole shall be left full of mud-laden fluid or cement to seal off each fresh and salt water stratum.

h) Deviation of a Hole

Unless the operator receives permission from the commission, no drilling well may be directionally deviated from its normal course except where necessary to straighten the hole, sidetrack junk or correct other mechanical difficulties.

i) Shooting and Chemical Treatment of Wells

The commission shall be notified if injury results to the producing formation, casing or casing seat as a result of shooting or treating a well.

j) Noise Abatement

The operator shall minimize noise when conducting air drilling operations or when the well is allowed to produce while drilling.

k) Fires, Leaks and Blow-outs

The commission shall be immediately notified of all fires breaks or leaks in the well.

l) Casing and Cementing of Injection Wells
Wells used for injection shall be cased with safe and adequate casing or tubing in order to prevent leakage.

m) Pollution and Surface Damage
The owner or operator shall take all precautions to avoid polluting streams, polluting underground water, and damaging soil. If any deleterious substances cannot be treated or destroyed by the usual methods, then other methods of disposal (approved by the commission) shall be used.

n) Disposal of Brines and Salt Water
Commission regulations must be followed in the disposal (either by injection or disposal in earthen pits) or brines and salt water.

o) Environmental Protection
The commission shall require operations to be conducted so as not to pollute land, water or air, pollute streams, damage the surface or pollute the underground water of the land, or of neighboring lands. Federal and state air and water quality standards will be followed unless more stringent requirements are stipulated by the commission. Plans for disposal of well effluents must take into account the effect on groundwaters, streams, plants, fish and wildlife and their populations, atmosphere, or any other effects which may contribute to pollution.

10) Environmental Studies and Approvals

The State of Arizona does not require environmental assessments nor does it require environmental impact statements.

11) Water Rights, Appropriations and Usage

An operator of a geothermal well must notify the Arizona Water Commission of any well which is drilled or abandoned. The permits and precautionary measures required are detailed under the Arizona Well Drilling Regulations in this report.

Geothermal resources have been given special exemptions from Arizona water laws. Arizona Revised Statutes 27-667 reads:

a) Geothermal resources and their development shall be exempt from the water laws of this state unless:
   i) Such resources are comingled with surface waters or groundwaters of this state; or
   ii) such development causes impairment of or damage to the groundwaters supply.

b) In the development of geothermal resources, any well drilled to obtain and use groundwater, as defined in 45-301, shall be subject to the water laws of this state.

Examining 45-301 one discovers the following broad and ambiguous definition for groundwater: "Groundwater means water under the surface of the earth regardless of the geologic structure in which it is standing or moving. It does not include water flowing in underground streams with ascertainable beds and banks." This definition if interpreted strictly could invalidate geothermal's exemption from Arizona water law, since geothermal energy normally occurs below the zone of groundwater production.

This eventuality fortunately remains latent. William Allen of the Oil and Gas Conservation Commission has indicated that the three geothermal wells drilled in Arizona had no difficulties with water laws. The Water Commission passed their applications without attempting to hold them to the water laws of the state. It must be noted that this is an administrative decision.

Reason for further optimism on this issue is provided by information received from the Arizona Groundwater Management Study Commission. The Groundwater Commission was created by the Legislature with instructions to draft new water laws by the end of 1979. If the Legislature fails to act on the proposal within a year, the Commission's version automatically becomes law in 1981. The Commission has decided to continue the policy of exempting geothermal resources from water law. If the Commission's recommendations become law, this would provide a firmer foundation for geothermal's exemption from water law. Fig. 3-11 is the general organization chart of the Arizona State Legislature.

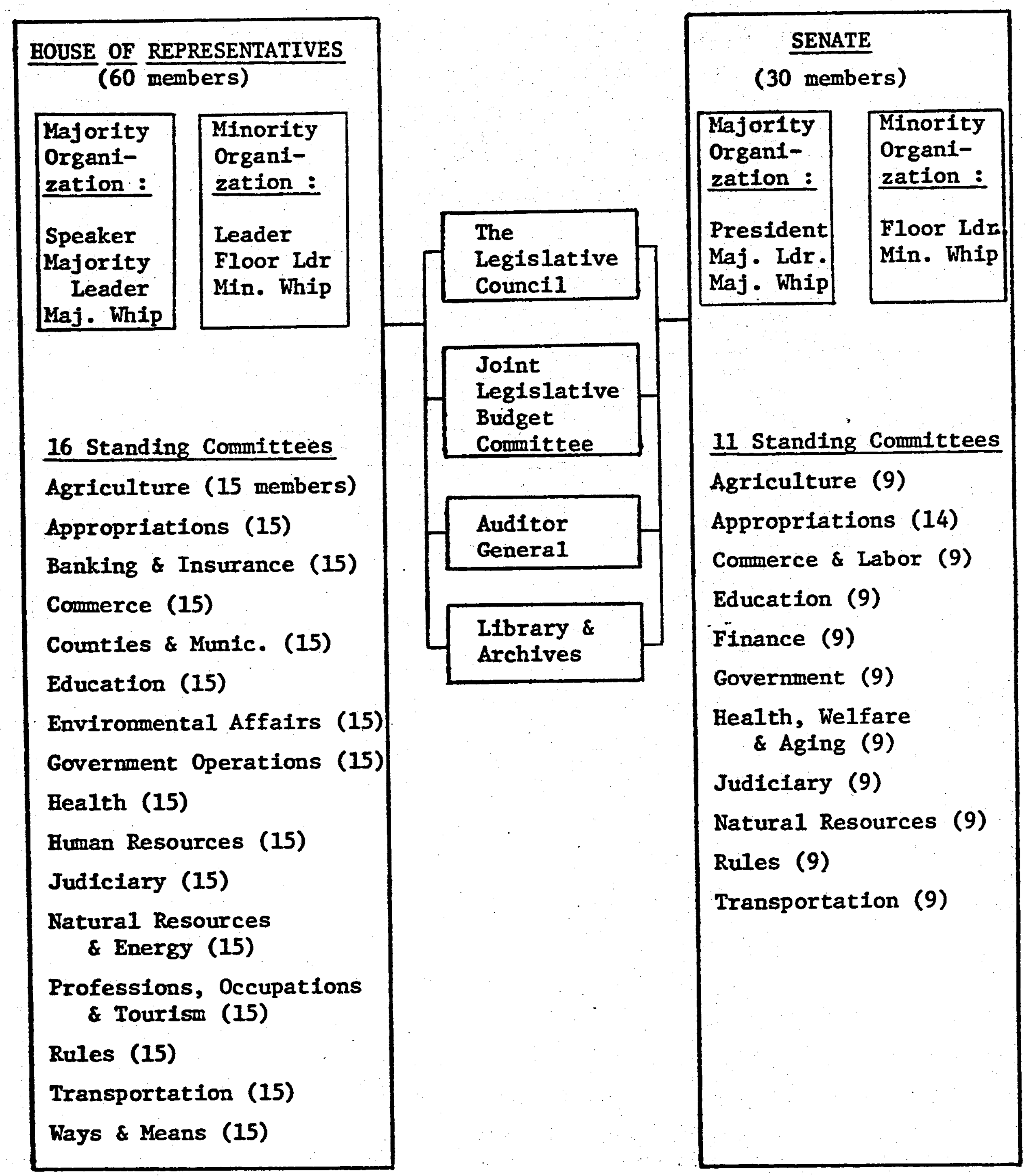


FIG. 3-12: GENERAL ORGANIZATION CHART OF THE ARIZONA STATE LEGISLATURE (*)

* Staff members are attached to most of the subdivisions of the Legislature, but are not shown here for the sake of simplicity.

12) Property Valuation and Taxation

What follows is a summary of rules for valuation of property for tax purposes and deductions offered by the State of Arizona for income tax purposes.

In essence, property is classified by 7 categories based upon who owns the property or what it is used for. In assessing property taxes, the class of property determines the rate at which taxes are assessed. Rather than defining all 7 classes of property, it is probably better to discuss the two major classes which will effect a geothermal developer. The first is Class 2 property, defined as property owned by a telephone or telegraph, gas, oil electric utility or pipeline company. If the geothermal developer is within this class, his tax assessment will be 50 percent of the fair market value of the property. The second relevant class is Class 3 property, defined as all real and personal property for commercial or industrial use. If the geothermal developer is within this category, his tax assessment will be 27 percent of the fair market value of the property. Finally, it should be noted that valuation of land and valuation of improvements on the land are dealt with separately. Also, if the geothermal resource is producing, valuation shall be placed at the amount of gross yield from the previous year.

In addition to property valuation, the Department of Revenue also requires geothermal producers to file an annual report. This report must contain the name of the county where the property is located and a description of this property.

Aside from property taxes which a geothermal producer must pay, the State Department of Revenue also grants deductions to geothermal resource users. There are two deductions which the State Department of Revenue recognizes, one for development expenses and a second for exploration expenses. Expenses paid or incurred for the development of a geothermal resource qualify for a deduction of the full amount from gross income or charge to a capital account. Expenses, incurred or paid for exploration shall qualify for a deduction not to exceed $75,000 in computing net income. Exploration refers to amounts of money paid for ascertaining the existence, location, extent or quality of any deposit. This does not apply to improvement of property.

The State Department of Revenue also offers a depletion allowance for geothermal resources. In computing net income, a geothermal resource qualifies for a reasonable allowance for depletion and depreciation of improvements. The Department has established rules and regulations for implementing the depletion allowance, the details of which are still under study. General rules are as follows: in cases of leases, deductions shall be equitably apportioned between lessor and lessee. In cases of geothermal resources, the depletion allowance shall be 27.5 percent of gross income less rents or royalties. The allowance shall not exceed 50 percent of net income computed before the depletion allowance.

REFERENCES FOR SECTION 3.

3-1 D.E. Byerly and R.H. Stott, An Attempt to Define the Curie Point Isotherm in Northern and Central Arizona (Geophysics 1977), Vol. 42, No. 7.

3-2 M. Reiter and C. Shearer, Terrestrial Heat Flow in Eastern Arizona, A First Report, (Geoph. Res. 1979, in press).

3-3 W.R. Hahman, Sr., C. Stone and J.C. Witcher, Preliminary Map, Geothermal Energy Resources of Arizona, Geothermal Map No. 1, (Arizona Bureau of Geology and Mineral Technology, Geological Survey Branch, 1978).

3-4 W.R. Hahman, Sr., Arizona Bureau of Geology, May 1979.

3-5 Geophysical, Geohydrological, and Geochemical Reconnaissance of the Luke Salt Body, Central Arizona, *U.S.G.S., 1972).

3-6 Arizona Oil and Gas Conservation Commission, Thermal Gradient Anomalies, Phoenix, Arizona, Feb. 1978.

3-7 Inside Phoenix, 1979, (Phoenix Newspapers, Inc., 1979) p. 5.

3-8 Arizona Statistical Review, (Valley National Bank of Arizona, Sept. 1978) p. 65.

3-9 Pop., Emp., & Income Projections for Arizona Counties 1977-2000, (Dept. of Economic Security, July 1978), p. 90.

3-10 Ibid. p. 90.

3-11 Inside Phoenix, 1979.

3-12 Pop., Emp. & Income Projections for Arizona Counties 1977-2000.

3-13 Inside Phoenix 1979.

3-14 Arizona Statistical Review, p. 30.

3-15 Arizona Agricultural Statistics, (Arizona Crop and Livestock Reporting Service, 1978).

3-16 Pop., Emp. and Income Projections for Arizona Counties 1977-2000, p. 103.

3-17 Pop., Emp. and Income Projections for Arizona Counties 1977-2000, p. 103.

3-18 Ibid. p. 102.

3-19 Arizona Statistical Review, p. 65.

3-20 Ibid. p. 65.

3-21 Arizona State Water Plan Alternative Futures, (Arizona Water Commission, Feb. 1977), p. 77.

3-22 Ibid., p. 77.

3-23 Ibid., p. 78.

3-24 Ibid., p. 78.

3-25 W.R. Hahman, Sr., et al., Preliminary Map. Geothermal Energy Resources of Arizona, Geothermal Map No. 1, Arizona Bureau of Geology, Geological Survey Branch, Tucson.

3-26 S. Gardinia and J.B. Conley, 1978, Thermal Gradient Anomalies. Arizona Oil and Gas Conservation Commission, Report of Investigation 6.

3-27 J.C. Witcher, A Preliminary Study of the Geothermal Potential of the Tucson Metropolitan Area. W.R. Hahman, Sr., ed., Geothermal Reservoir Site Evaluation in Arizona, Semiannual Report for the period 7/15/79 - 1/15/79: Arizona Bureau of Geology, Geological Survey Branch, Tucson, 1979, p. 73-90.

3-28 Ibid., p. 73-90.

3-29 Department of Planning, City of Tucson, 1979.

3-30 Ibid.

3-31 _Arizona Statistical Review_, p. 27.

3-32 Ibid., p. 34.

3-33 Ibid. p. 68.

4.0 SUMMARY OF MAJOR FINDINGS AND RECOMMENDATIONS

As a result of recent work, it is beginning to become accepted that the commercial development of geothermal energy is likely to have a significant and important impact on Arizona's economy and future. Progress toward the goal of commercialization is beginning to gain a foothold in Arizona and it is encouraging to know that the outlook into the future appears brighter than it did just a few months ago. This first half of 1979 has been filled with examples of growing interest in developing geothermal energy in Arizona.

Recent findings show that there is much more interest in discovering geothermal resources in Arizona. The United States Geological Survey has agreed to drill fifty heat flow holes in Arizona to gain further knowledge of geothermal reservoir temperatures. Further, they have entered into a joint agreement to convert uranium exploration holes into geothermal gradient holes. In addition, Richard Hahman, Sr., has interacted with numerous private individuals and businesses interested in drilling for geothermal resources in the State.

Leasing of state and federal land has also increased during the past eight months. Currently, over 40,000 acres of land have been leased or are pending final decision. All of this land is being leased for geothermal development and interested groups range from private individuals to large corporations. It is also believed that current interest is just a beginning of geothermal exploration on a large scale in Arizona.

Commercial interest is also developing in the state. Phillips Petroleum Corp, has leased KGRA's in the Clifton area of Arizona. Interest has also been shown in the Hyder area of Arizona. Atlantic Richfield has applied for leases in the Aquarius Mountains and Mobil Oil has leases pending south of Kingman. The Arizona Geothermal Team has also interacted with local industry, operators of Park Mall and the military in an attempt to develop interest in geothermal energy on a commercial scale.

Political entities in or connected with the state are also beginning to show interest in geothermal energy development. Recently, the Southwest Regional Border Commission, an organization of border counties concerned with economic development, recognized the importance of developing geothermal energy in border counties stretching from Texas to California. In Arizona, interest has developed towards the idea of a geothermal power plant in Clifton Arizona. Also, the numerous telephone calls and letters to State and local leaders can only serve to enhance the prospect of geothermal development, or at least further an awareness of this potential energy source in Arizona.

Finally and most important is the Outreach Program implemented by the Arizona Geothermal Team. The Outreach Program will take on numerous fronts through the use of various techniques. A public relations firm has been hired in order to educate the general public about the benefits and potential of geothermal energy development in Arizona. Such education will be accomplished through use of newspaper releases, billboards, brochures and bumper stickers. All of these techniques will attempt to make geothermal energy a common word in the State. Further, through the dedicated work of the Arizona Geothermal Team throughout the year, hundreds of persons in state agencies and private industries have been confronted with the concept of geothermal energy. This has proven to be one of the most effective methods of spreading the word on geothermal energy in Arizona. Also, a survey and information packet was distributed to over 400 state institutions and buildings in an attempt to develop interest in geothermal applications. Although the return rate of this survey has been small the information was passed on to persons in decision making positions.

Aside from all of these external occurrences, the Arizona Geothermal Team has also progressed considerably with respect to specific contract tasks. First, the fourteen counties of the State of Arizona were tentatively divided into seven regions for Area Development Plans. To date, a majority of work has been completed on the largest and most difficult of these areas, Maricopa County. Work has been started on Pima County and on the Graham/ Greenlee region. By year end, these three Area Development Plans will be complete. Second, the Institutional Handbook has been completed, except for minor editing. This task should be completed in its entirety by the end of August. Lastly, site-specific work has been done on various applications mentioned in the contract, but to date they are incomplete. In all, it appears that alot of the contract tasks have been completed or are well on their way to completion.

In all, the outlook for geothermal commercialization in Arizona looks promising. However, much work remains to be done, both in the planning phase of the project as well as in the actual development of geothermal energy on a commercial scale. Thus, the Arizona Geothermal Team wishes to present their recommendations to various persons and entities related to geothermal energy development.

1) Provide the State of Arizona with more federal funding for the specific purpose of drilling exploratory geothermal wells.
2) Structure and coordinate major energy related activities in the State through the establishment of an Arizona Energy Department, with the objective of formulating a comprehensive State energy policy.
3) Pass legislation to require the Arizona Corporation Commission to encourage the innovative development of new sources of energy.
4) Allow for the Arizona Corporation Commission to issue another Certificate of Convenience and Necessity for a power plant fueled by alternative energy sources, even though said area is being serviced by a conventional energy plant.
5) Provide for annual appropriations to a state agency such as the Arizona Bureau of Geology and Mineral Technology's Geothermal Group to drill exploratory geothermal wells.
6) Clarify the difference between geothermal water and groundwater as defined in statutes, specifically regarding temperature.
7) Provide for the Arizona Corporation Commission to encourage cogeneration - the use of geothermal resources or waste heat for a district heating system.
8) Encourage local government entities to expedite the issuance of utility franchises.

A P P E N D I C E S

APPENDIX A.

Unusually warm water wells, Maricopa and Pima Counties

The wells appearing in the table were selected on the basis of:

1) Very high thermal gradient (T.G. > $140^{o}C/km$) regardless of depth, or

2) High thermal gradients (T.G. > $45^{o}C/km$) when total depth $\geq$ 135 m

UNUSUALLY WARM WATER WELLS, MARICOPA AND PIMA COUNTIES

Maricopa Co

Tnship	Rge	Sec	MAT(°C)	B H T	Depth	T.G. (°C/km)
1N	6E	23 ad	20.6	42.2°C	92.4m	234
		cd	20.6	41.7°C	99.1m	213
		db	20.6	41.1°C	91.5m	224
1N	6E	24 ac	20.6	54.4°C	305 m	111
1N	6E	26 ac	20.6	37.0°C	107 m	153
1N	7E	36 da	21.1	47.4°C	397 m	66
2N	4E	25 bc	20.6	36.6°C	168 m	95
1N	1W	16 db	21.7	50.0°C	458 m	62
1N	2W	2 cc	21.7	48.5°C	549 m	49
1N	2W	3 db	21.7	43.3°C	348 m	62
1N	2W	8 ab	21.7	49.0°C	549 m	50
1N	2W	21 dc	21.7	36.1°C	277 m	54
1N	2W	26 db	21.7	33.3°C	153 m	76
1N	8W	7 cb	21.1	40.5°C	244 m	80
2N	1W	19 ba	21.1	53.9°C	707 m	46
2N	1W	21 ab	21.1	48.8°C	318 m	87
2N	2W	36 bc	21.7	48.0°C	534 m	49
2N	7W	26 aa	21.7	48.5°C	63.4m	422
3N	1W	15 cb	20.6	36.1°C	222 m	70
2S	1W	28 ca	21.1	37.0°C	246 m	65
2S	2W	27 cc	21.1	37.0°C	287 m	55
2S	4W	25 cc	21.1	36.0°C	261 m	57
2S	4W	32 ca	21.1	36.0°C	140 m	106
4S	10W	6 bb	22.2	35.0°C	139 m	92
5S	4W	31 cb	21.1	48.5°C	534 m	51
5S	10W	16 bb	22.2	45.6°C	387 m	60
6S	5W	2 bc	21.1	38.0°C	300 m	56
1S	7E	4 bc	21.1	40.6°C	336 m	58

MAT = mean annual air temperature
BHT = bottom-hole temperature

Cont.....

Pima Co

Tnshp	Rge	Sec	MAT(^{o}C)	B H T	Depth	T.G. (^{o}C/km)
14S	1W	27 bb	19.4	33.3^{o}C	143 m	97
12S	12E	19 cb	19.4	35.0^{o}C	110 m	142
13S	8E	11 bd	19.4	35.6^{o}C	30.5m	531
17S	4E	25 ad	18.3	41.7^{o}C	35.7 m	655
17S	4E	30 cb	18.3	35.6^{o}C	214 m	81
19S	1E	5 ca	19.4	46.7^{o}C	128 m	213
19S	1E	7 db	19.4	45.6^{o}C	218 m	120
20S	5E	15 cb	17.8	36.1^{o}C	223 m	82

Giardinia, Jr., S. and Conley, J.B., 1978, Thermal Gradient Anomalies: Az. Oil and Gas Conservation Commission, Phoenix.

APPENDIX B

ELECTRICAL ENERGY SUPPLY AND RESOURCES USED

In meeting our contractual obligations under the second year of study, it was necessary for us to assess the total electrical energy generation capacity for Arizona as a whole. This was done for the present year as well as to the year 2000. Thus, these data represent current plans of expansion by major Arizona utilities to 2000.

This step in our work is necessary in order to assess the possibility of integrating geothermal energy for electrical power generation into the existing power generation structure. Currently, excess capacity exists in the system but the future must also be considered. Thus, we present a future picture of Arizona electrical energy supply to the year 2000 for the state as a whole.

Tables B-1 and B-2 list the current and future sources of electricity production capacity in Arizona. Both of these tables deal in capacities, not in actual production. Since power plants normally operate at less-than-full capacity a calculation of megawatt-hours from megawatt capacity would be an overestimate of what is actually produced. In fact, some of the plants listed did not operate at all for certain periods during the year. The reason for concentrating on capacity rather than actual production is that we are interested in the amount of energy that could be produced rather than what is produced. An analysis of consumption amounts and patterns will enable us to ascertain the degree to which the plants provide for peak demands.

These tables indicate the amount of production capacity available to Arizona utilities and thus do not consider power sales to or from the utilities. Thus, sales of electricity to out-of-state utilities or to out-of-state consumers are not considered, nor are purchases of electricity from outside sources. These amounts are relatively small and fluctuate a great deal.

Table B-1 provides the following breakdown of fuel of the net megawatt production capacity available to Arizona utilities for 1978:

TABLE B-1 - CURRENT SOURCES OF ARIZONA ELECTRICITY CAPACITY

POWER PLANT	NO. OF UNITS	LOCATION	OWNERSHIP - BY PERCENTAGE	GENERATION TYPE AND FUEL USED	TOTAL NET CAPACITY (Mw)	NET CAPACITY AVAILABLE TO ARIZONA UTILITIES[1]
Hydroelectric Plants						
Hoover Dam	19	Colo. River	USBR 100% → APA 12% [2]	Conventional Hydroelectric	1344.8	165.0
Glen Canyon Dam	8	Lake Powell	USBR 100% → WAPA [3]	Conventional Hydroelectric	950.0	396.6[4]
Parker Dam	4	Colo. River	USBR 50% → WAPA, Other 50%[3]	Conventional Hydroelectric	120.0 }	145.3[4]
Davis Dam	5	Colo. River	USBR 100% → WAPA[3]	Conventional Hydroelectric	225.0 }	Combined
Roosevelt Dam	1	Salt River	SRP 100%	Conventional Hydroelectric	36.0	36.0
Mormon Flat	2	Salt River	SRP 100%	Conv. Hydro & Pumped Storage	54.0	54.0
Horse Mesa	4	Salt River	SRP 100%	Conv. Hydro & Pumped Storage	129.0	129.0
Stewart Mountain	1	Salt River	SRP 100%	Conventional Hydroelectric	13.0	13.0
Childs	3	Verde River	APS 100%	Conventional Hydroelectric	3.6	3.6
Irving	1	Verde River	APS 100%	Conventional Hydroelectric	1.3	1.3
Crosscut	1	Tempe, Arizona	SRP 100%	Conventional Hydroelectric	2.0	2.0
Coolidge	2	Gila River	BIA 100%[5]	Conventional Hydroelectric	10.0	10.0
Subtotal - Capacity from Hydroelectric Plants					2888.7	955.8
Coal Plants						
Navajo	3	Page, Ariz.	SRP 21.7%, APS 14%, TEPC 7.5%, WAPA 24.3%, other 33.5%	Steam Gen - Coal	2250.0	1518.8[6]
Cholla	2	Joseph City, Ariz.	APS 100%	Steam Gen - Coal	351.0	351.0
Four Corners	3	Shiprock, New Mexico	APS 100%	Steam Gen - Coal	572.0	572.0
	2	Shiprock, New Mexico	SRP 10%, APS 15%, TEPC 7%, other 68%	Steam Gen - Coal	1600.0	512.0
San Juan	2	San Juan, New Mexico	TEPC 50%, Other 50%	Steam Gen - Coal	620.0	310.0
Mohave	2	Clark County, Nevada	SRP 10%, other 90%	Steam Gen - Coal	1580.0	158.0
Hayden #2	1	Hayden, Colo.	SRP 80%, other 20%	Steam Gen - Coal	261.0	208.8
Apache	1	Willcox, Az	AEPC 100%	Steam Gen - Coal	175.0	175.0
Subtotal - Capacity from Coal Plants					7409.0	3805.6

TABLE B-1 Cont.

POWER PLANT	NO. OF UNITS	LOCATION	OWNERSHIP - BY PERCENTAGE	GENERATION TYPE AND FUEL USED	TOTAL NET CAPACITY (Mw)	NET CAPACITY AVAILABLE TO ARIZONA UTILITIES[1]
Oil/Gas Plants						
Yuma Axis	4	Yuma, Arizona	APS 100%	Combustion Turb. - Oil or Gas	157.2	157.2
Yucca	1	Yuma, Arizona	APS 33%, Other 67%	Steam Gen - Oil or Gas	75.0	25.0
Santan	4	Gilbert, Arizona	SRP 100%	Combined cycle - Oil or Gas	288.0	288.0
Irvington	1	Tucson, Arizona	TEPC 100%	Steam Gen - Oil or Gas	420.0	420.0
DeMoss - Petrie	1	Tucson, Arizona	TEPC 100%	Steam Gen - Oil or Gas	98.0	98.0
TEPC Peaking Turbines	1	Tucson, Arizona	TEPC 100%	Combustion Turb - Oil or Gas	220.0	220.0
Crosscut	4	Tempe, Arizona	SRP 100%	Steam Gen - Oil or Gas	32.0	32.0
Apache	2	Willcox, Arizona	AEPC 100%	Gas Turbine - Gas	90.0	90.0
	1	Willcox, Arizona	AEPC 100%	Combined Cycle - oil	75.0	75.0
	1	Willcox, Arizona	AEPC 100%	Combined Cycle - Gas	10.0	10.0
Douglas	1	Douglas, Arizona	APS 100%	Combustion, Turb - Oil	20.7	20.7
Agua Fria	3	Maricopa County, Az	SRP 100%	Steam Gen - Oil or Gas	398.0	398.0
	3	Maricopa County, Az	SRP 100%	Combustion Turb. - Oil or Gas	198.0	198.0
Ocotillo	2	Ocotillo, Arizona	APS 100%	Steam Gen - Oil or Gas	229.4	229.4
	2	Ocotillo, Arizona	APS 100%	Combustion Turb - Oil or Gas	111.8	111.8
West Phoenix	3	West Phoenix, Ariz.	APS 100%	Steam Gen - Oil or Gas	108.3	108.3
	2	West Phoenix, Ariz.	APS 100%	Combustion Turb - Oil or Gas	112.4	112.4
	3	West Phoenix, Ariz.	APS 100%	Combined Cycle - oil	225.0	225.0
Kyrene	2	Tempe, Arizona	SRP 100%	Steam Gen - Oil or Gas	104.0	104.0
	4	Tempe, Arizona	SRP 100%	Combustion Turb - Oil or Gas	180.0	180.0
Saguaro	2	Pinal County, Ariz.	APS 100%	Steam Gen - Oil or Gas	214.0	214.0
	2	Pinal County, Ariz	APS 100%	Combustion Turb - Oil or Gas	109.0	109.0
Subtotal - Capacity from oil/gas plants					3475.8	3425.8
TOTAL CAPACITY					13,773.5	8187.2

TABLE B-2 - FUTURE AVAILABILITY OF ELECTRICITY PRODUCTION

POWER PLANT	NO. OF UNITS	LOCATION (NEAREST TOWN)	DATE COMMERCIAL	OWNERSHIP - BY PERCENTAGE	TYPE OF GENERATION	TOTAL NET CAPACITY (Mw)	NET CAPACITY AVAILABLE TO AZ UTILITIES[1]
Additions							
Apache	1	Willcox, Arizona	Aug, 1979	AEPC 100%	Steam Gen - Coal	175	175
Coronado	1	St Johns, Arizona	Aug, 1979	SRP 70%, Other[7] 30%	Steam Gen - Coal	350	245
	1	St. Johns, Arizona	Late, 1980	SRP 70%, Other 30%	Steam Gen - Coal	350	245
	1	St. Johns, Arizona	Indefinite	SRP 70%, Other 30%	Steam Gen - Coal	350	245
Cholla	1	Joseph City, Arizona	1980	APS 100%	Steam Gen - Coal	250	250
	1	Joseph City, Arizona	1981	APS 100%	Steam Gen - Coal	350	350
	1	Joseph City, Arizona	Indefinite	APS 100%	Steam Gen - Coal	350	350
Springerville	1	Springerville, Arizona	June, 1985	TEPC 100%	Steam Gen - Coal	350	350
	1	Springerville, Arizona	June, 1987	TEPC 100%	Steam Gen - Coal	350	350
	1	Springerville, Arizona	About 1991	TEPC 100%	Steam Gen - Coal	350 flexible	350 flexible
Craig	1	Craig, Colo.	Sept. 1979	SRP 29%, Other 71%	Steam Gen - Coal	400	116
	1	Craig, Colo.	1980	SRP 29%, Other 71%	Steam Gen - Coal	400	116
San Juan	1	San Juan, N.M.	1980	TEPC 50%, Other 50%	Steam Gen - Coal	468	234
	1	San Juan, N.M.	1995	TEPC 60%, Other 40%	Steam Gen - Coal	468	281
Palo Verde	1	Buckeye, Arizona	1982	APS 29.1%, SRP 29.1%, Other 41.8%	Nuclear	1,270	739
	1	Buckeye, Arizona	1984	APS 29.1%, SRP 29.1% Other 41.8%	Nuclear	1,270	739
	1	Buckeye, Arizona	1986	APS 29.1%, SRP 29.1% Other 41.8%	Nuclear	1,270	739
	1	Buckeye, Arizona	1988	APS 39.1%, Other 60.9%	Nuclear	1,270	497
	1	Buckeye, Arizona	1990	APS 39.1%, Other 60.9%	Nuclear	1,270	497
TOTAL ADDITIONAL CAPACITY						11,311	6868

PLANNED DECREASES	BEGINNING DATE	ENDING DATE	EXPLANATION		NET CAP. INVOLVED (Mw)
To Colo - UTE Power Co from SRP	January, 1982	None	Recapture of 30% of Hayden #2		78.3
Total Decreases					78.3
OVERALL INCREASE				11,311	6789.7

TABLES B-1 and B-2 NOTES

1. This figure indicates the amount of net capacity which is owned by Arizona utilities or is sold to Arizona utilities under contractual obligation.

2. USBR is committed to sell 12% of the dam's capacity to APA each year.

3. While the USBR owns Glen Canyon Dam, 50% of Parker and all of Davis, WAPA is in charge of electricity distribution.

4. This is the amount of electricity generated and sold to Arizona utilities and users in 1978.

5. The BIA sells this electricity to utilities and consumers.

6. This figure includes the WAPA share, which is to be used by the USBR for the Central Arizona Project.

7. In this table "Other" indicates ownership by out-of-state utilities.

The information in these tables was gathered from publications of utilities and government agencies and conversations with their representatives. Those entities listed in the tables are current as of June 1, 1978. These tables do not include electric capacity available to private entities from private generation.

List of Abbreviations

APA - Arizona Power Authority

AEPC- Arizona Electric Power Cooperative

APS - Arizona Public Service

BIA - Bureau of Indian Affairs

SRP - Salt River Project

TEPC- Tucson Electric Power Company

WAPA- Western Area Power Administration

Megawatt capacity from hydroelectric plants:	955.8 (11.7%)
Megawatt capacity from coal plants:	3630.6 (44.3%)
Megawatt capacity from gas/oil plants:	3600.8 (44.0%)
Total megawatt capacity available:	8187.2(100.0%)

Table B-3 shows the annual resource use for Arizona's portion of this production capacity. It can be broken down as follows:

Coal:	1.0×10^7 tons
Oil:	9.5×10^6 bbls
Natural Gas:	50.3×10^6 MCF

The additional capacity listed in Table B-2 can be divided as follows:

Additional megawatt capacity from coal plants:	3657.0	(53.2%)
Additional megawatt capacity from nuclear	3211.0	(46.8%)
Total additional megawatt capacity available	6868.0	(100.0%)

The megawatt capacity to be available in the year 2000, as shown by the current sources plus the future additional production capacity available can be listed as follows:

Megawatt capacity from hydroelectric plants:	955.8	(6.3%)
Megawatt capacity from coal plants:	7287.6	(48.4%)
Megawatt capacity from gas/oil plants:	3600.8	(24.0%)
Megawatt capacity from nuclear plants:	3211.0	(21.3%)
Total megawatt capacity available in 2000:	15,005.2	(100.0%)

Table B-4 presents an estimate of the resource needs for the additional electric generation capacity in tons of coal.

As can be seen from this information the trend of electricity production is strongly in the direction of more generation from coal and nuclear plants. Again, this is only in terms of total capacity and does not consider the actual use of these plants. Because of this, the trend toward coal and nuclear generation shown in these figures is probably underestimated.

As was mentioned earlier much of the information in this area is dated or incomplete. In addition, some of the agencies and utilities contacted were unable or unwilling to provide certain information, especially in regards to resource use. A third problem which arose was the conflicting information on megawatt capacity and other issues which I often came across. When I did find an inconsistency I either resolved it or used the source

TABLE B-3: FOSSIL FUEL RESOURCES USED BY POWER PLANTS PROVIDING ELECTRICITY TO ARIZONA

Power Plant and Number of Units	Percent of Generation Available to Arizona	Quantities of Fuels Used for Generation of Electricity for Arizona in 1978		
		Coal (1000 tons)	Oil (1000 bbls)	Gas (1000 MCF)
Navajo - 3	43.2	2,591.1		
Cholla - 2	100.0	984.7	8.9	42.8
Agua Fria - 6	100.0		1,098.1	9,452.2
Ocotillo - 4	100.0		251.7	6,337.8
West Phoenix - 8	100.0		14.0	475.9
Four Corners - 3	100.0	2,361.1	251.7	639.5
Four Corners - 2	32.0	1,189.7	155.1	
Kyrene - 2	100.0		54.1	1,081.7
Saguaro - 4	100.0		402.0	5,315.5
Yuma Axis - 4	100.0		70.7	667.4
Yucca - 1	33.3		26.4	968.5
San Juan - 2	50.0	1,041.1	43.2	
Mohave - 2	10.0	268.4		
Hayden - 1	80.0	1,242.4		
Santan - 4	100.0		461.2	
Irvington - 1	100.0		1,135.3	13,675.0
Demoss-Petrie - 1	100.0		121.0	5,070.0
North Loop	100.0			1,836.3
Peaking Turbines				4,732.2
Apache	100.0	330.6[1]	4.4	
Douglas	100.0		5,429.0	
Total		10,009.1	9,526.8	50,294.8

(1) Apache's coal unit did not begin operation until August.

Sources: Utility reports and personal conversations; Energy Data Reports, Monthly Reports, Cost and Quality of Fuels for Electric Utility Plants, Department of Energy, Energy Information Administration, Office of Energy Data, DOE IEIA-0075/8(78), data for January - December 1978.

TABLE B-4: ESTIMATED ANNUAL COAL CONSUMPTION OF FUTURE POWER PLANTS

Power Plant	Percent of Generation Available to Arizona	Date Commercial	Annual Quantity of Coal to be Used for Generation of Electricity for Arizona (1000 tons)[1]
Apache #2	100.0	August, 1979	619.6
Coronado #1	70.0	August, 1979	673.9
Coronado #2	70.0	Late 1980	973.9
Coronado #3	70.0	Indefinite	973.9
Cholla #3	100.0	1980	879.1
Cholla #4	100.0	1981	1,231.3
Cholla #5	100.0	Indefinite	1,231.3
Springerville #1	100.0	June, 1985	1,209.8
Springerville #2	100.0	June, 1987	1,209.8
Springerville #3	100.0	About 1991	1,209.8
Craig #1	29.0	Sept. 1979	444.9
Craig #2	29.0	1980	444.9
San Juan #3	50.0	1980	943.7
San Juan #4	60.0	1995	1,133.2
Total			13,479.1

(1) Based on equation in Power Generation in Arizona and its Environmental Implications, Stephen Edgerly Smith, University of Arizona:

$$\text{Fuel Rate (tons/day)} = \frac{\text{MW(Th)} \times 3412 \frac{\text{BTU}}{\text{HR-KW}} \times 10^3 \frac{\text{KW}}{\text{MW}} \times 24 \frac{\text{HR}}{\text{DAY}}}{\text{Coal heat value} \frac{\text{BTU}}{\text{lb}} \times 2000 \frac{\text{lb}}{\text{ton}}} \times .85 \text{ plant factor}$$

Coal heat values not listed in this source were estimated to be 10,500 $\frac{\text{BTU}}{\text{LB}}$

which was closed to the actual electricity production (e.g. when a utility report differed from a document by an outside source about the utility I used the information in the utility report.

It is well known that power companies do look to the future in their planning efforts and this analysis has been an attempt to mirror their current planning efforts. However, the construction of a plant scheduled to come on line in 1990 would begin in 1986. Therefore, time is available to change these plans and possibly integrate a geothermal power plant into the plans of various Arizona utility companies.

APPENDIX C

COPPER DUMP LEACHING IN PIMA COUNTY

C.0 Introduction

Pima County is the largest copper producer in Arizona, it provides 40% of the copper produced in the state. There are about eight operating mining locations in the county. The amount of proven copper ores in the area is about 2,200 million tons and some form of leaching is practiced in all of these mines. Given the fact that the increase in the temperature of the leaching fluid enhances the rate of extraction of copper; geothermal energy could be used to heat the leaching fluid.

The heating of the leaching fluid to increase the extraction rate of copper is not a new idea, in fact during the first quarter of this century a mining company in Arizona used to heat their leaching fluid by means of fuel burners to enhance their copper recovery (C-1). This practice was stopped later due to the increase in the cost of fuels. Thus, since the mining industry in Pima County is still growing and is expected to grow due to the large ore reserves; this geothermal application of copper dump leaching may prove very promising when it is given the appropriate concern that it warrants.

C.1 Status of Copper Leaching in Pima County

Arizona is rich in copper reserves and Pima County is the major producer of copper in Arizona. The copper deposits in the state are shown in Fig. C-1. Some form of leaching is used in most of the copper mines in Pima. The amount of ore in the dumps in Pima County is quite large, it is about 2,200 million tons. A list of the major copper dumps in Pima County is given in Table C-1. Usually, copper dump leaching is used to extract copper from the lower grade ores, yet several mines do not actually classify their ores but rather dump varied types of lower and higher grade ores and leach the copper from these dumps. Thus, this leaching operation does not have to be for lower grade ores and may produce a good portion of the copper in the mine. Actually, the percent production of copper from the dumps may be as low as 15% to as high as 100% of the

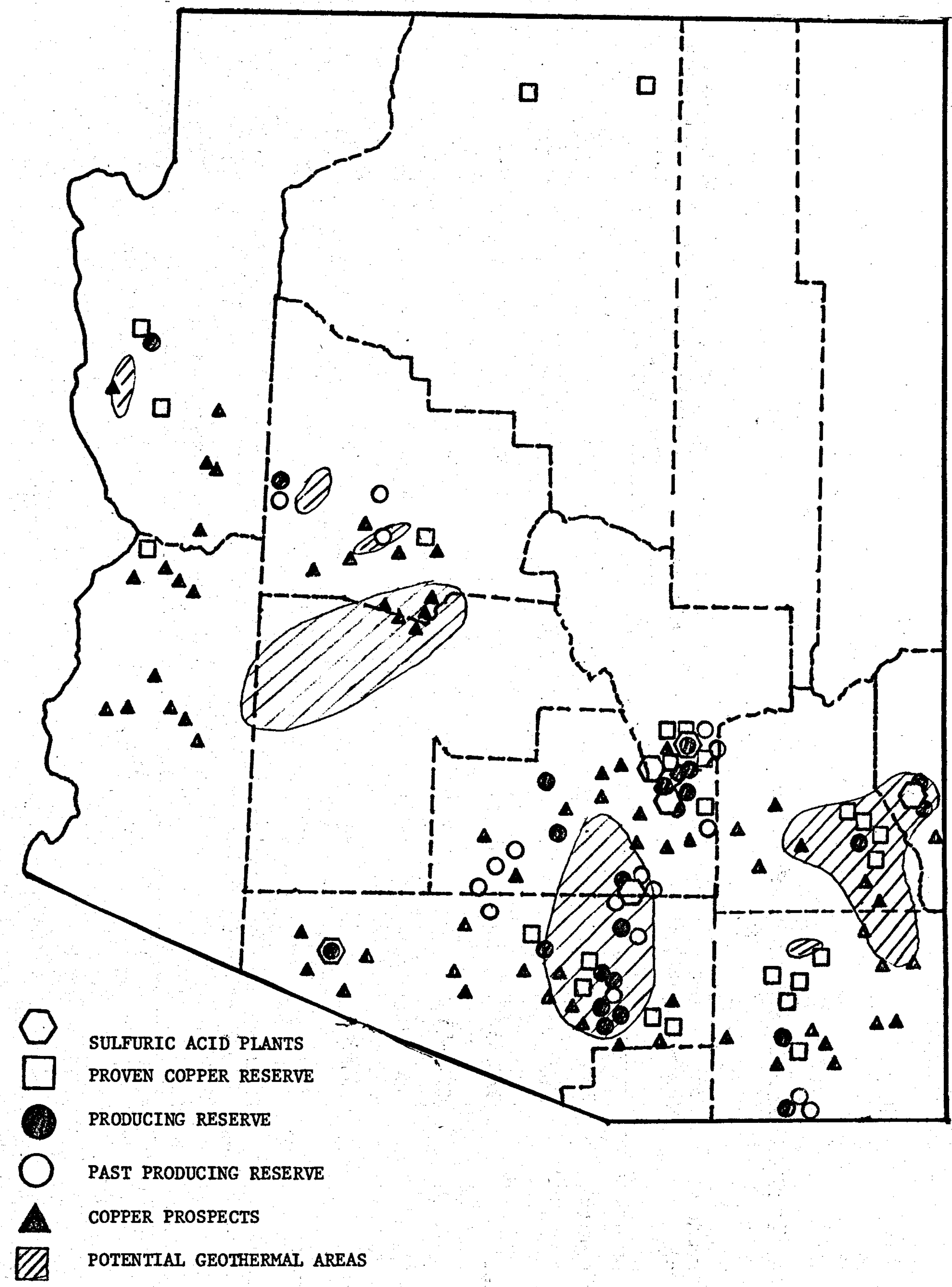


FIG. C-1. ARIZONA COPPER RESERVES, DEPOSITS AND OVERLAPPING GEOTHERMAL AREAS

Table C-1: Existing and Potential Dumps in Arizona

Name of Property or Location	Size of Ore Deposit 10^6 Tons	Avg. Annual Temp. in °C	Proposed Operating Temp. in °C	Energy Needed by Proposed System (BTU x 10^{12})/Yr	Equivalent Barrels of Oil Mbbl/Yr
Ajo (New Cornilia)	126	20	70	4.1	0.9
Sierrita	259	19	70	8.3	1.9
San Xavier	167.052	15	70	5.4	1.2
Mission	104.455	15	70	3.4	0.8
Pima	146	15	70	4.8	1.1
Esperanza	21.850	15	70	2.1	0.5
Twin Buttes	714	19	70	23.0	5.3
Silver Bell	26.059	23	70	1.8	0.4
Total				53.0	12.1

total production of copper in each mine depending on the individual operation. An illustration of a copper dump leaching operation is presented in Fig. C-2 (C-2). In conclusion, the copper dump leaching operation is an expanding industry that can be an important potential user of geothermal energy.

C.2 Geothermal Energy Potential

Solid evidence for the subsurface occurrence of economic geothermal deposits has been lacking in the less explored areas in Arizona. Escalating exploratory activity is manifested in both published reports and recent leasing activity. Whereas less than 23,400 acres of geothermal leases are now active on State and Federal lands, over 30,000 acres of land are presently under review by the Bureau of Land Management. The deepest geothermal test exhibited a high thermal gradient of about 50°C/km. When more drilling, specifically for geothermal deposits commence, the resource data base will expand, enabling more accurate geologic inferences to be made. It is now estimated that many structural basins (often coincident with valleys) having a depth greater than 500 meters store water warmer than 50°C in large volumes. Pima County lies within the Basin and Range province which is expected to have a high geothermal potential. Moreover, some geothermal reservoirs overlap the copper mining locations in the County. Fig. C-1 shows the coincidence of the copper deposits with the geothermal resources.

C.3 Proposed Geothermal Application

A combination of the copper dump leaching operations with the geothermal resources could have a considerable impact on the copper industry in Pima County and the imported fossil fuels in the state as a whole. This is due to the fact that the increased temperature of the leaching fluid will enhance the copper recovery per unit time and the use of geothermal energy to heat the leaching fluid will substitute the possible use of fossil fuels to achieve the higher temperatures. Ultimately this proposed application may lead to increased copper production and will aid in conserving part of the dwindling reserves of fossil fuels.

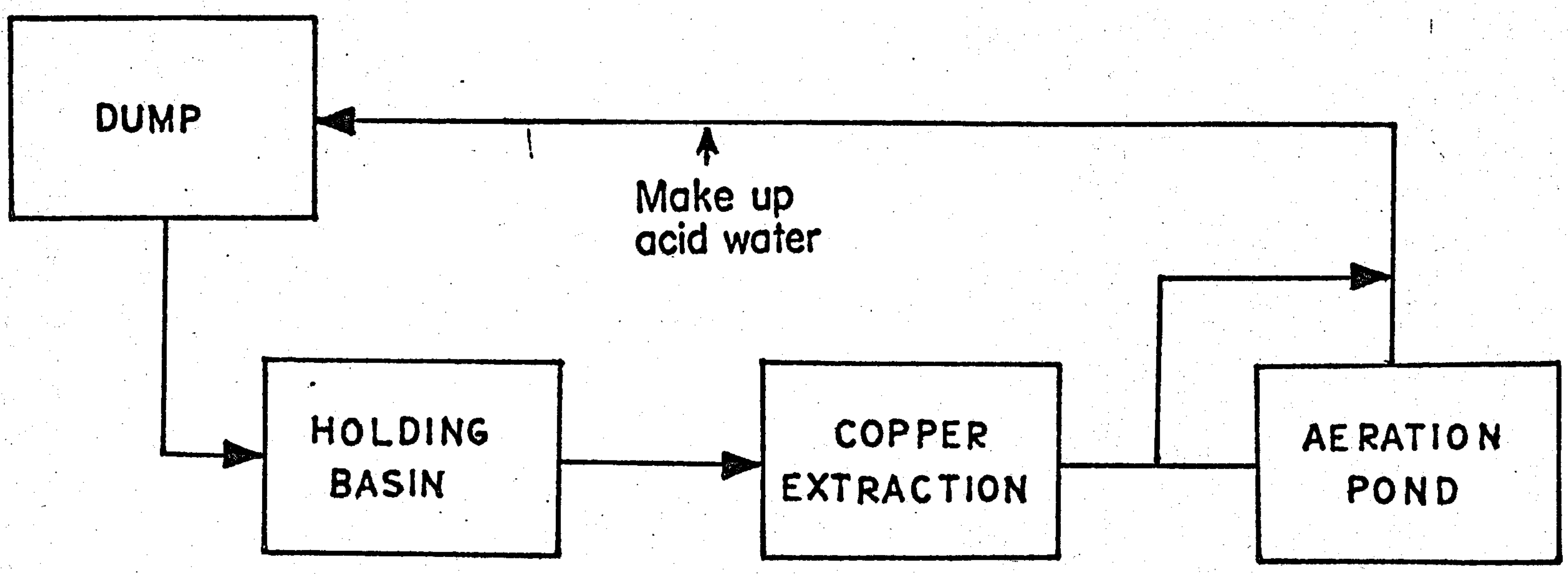


FIG. C-2: SCHEMATIC OF A DUMP LEACHING OPERATION

Several studies have shown that the rate of extraction of copper increases with the increase in temperature of the leaching fluid (C-3,C-4,C-5). Fig. C-3 presents some curves illustrating this relationship. As can be seen from Fig. C-3 this application does not require high geothermal temperature like those required by power generation. Consequently, this application could use the potentially abundant low-moderate geothermal resources in Pima county.

C.4 Analysis of this Proposed Geothermal Application

Some characteristics of a copper dump leaching operation are presented below together with a method of calculation of the amount of energy needed to heat the leaching fluid from the ambient temperature to 70°C.

- Amount of ore in dump: 259,000,000 tons
- Surface area of dump: 22,000,000 ft^2
- Average height of dump: 100 ft
- Leach material is hauled and dumped by trucks on existant topography which allows the pregnant liquor to flow by gravity into a holding pond.
- Flow rate of leaching fluid to dump: 10,445,000 lb/hr
- Ambient seasonal temperature of area: Winter - 5-10°C
  Summer - 27-32°C
- Leaching fluid and pond temperatures are very close to ambient temperatures.
- Geothermal brine will be used to heat the leaching fluid in a heat exchanger.
- Amount of energy needed to heat leaching fluid:
  Energy (Btu/day) = (flow rate) x (specific heat) x (ΔT) x (1.8) x (24)
  = (10,445,000) x (1.0) x (70-19) x (1.8) x (24)
  = 2.3×10^{10}
- Annual amount of energy needed to heat leaching fluid, (Btu/year): 8.4×10^{12}.

Thus, the amount of energy needed to heat the leaching fluid is 8.4×10^{12} Btu/year. If heating oil was to be used to accomplish this heating about 1,900,000 bbl will be needed annually. Table C-1 presents the amount of energy needed for each dump and the equivalent barrels of oil that could be saved if the idea of heating the leaching fluid was to be implemented. As shown in Table C-1 the total amount of heat energy needed

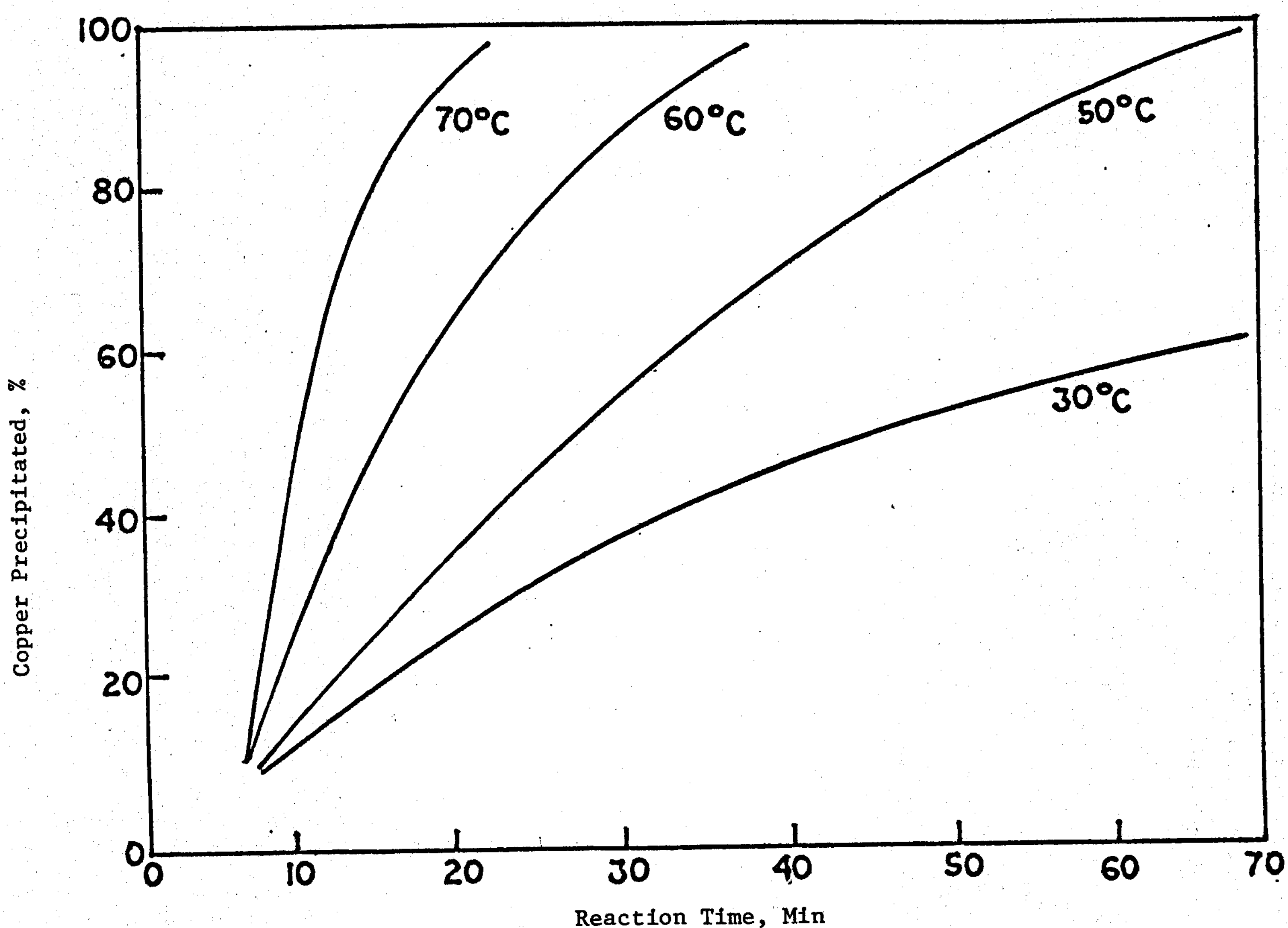


FIG. C-3: EFFECT OF TEMPERATURE ON COPPER PRECIPITATED AND REACTION TIME (C-3) annually is 53 trillion Btu or the equivalent of about 12.1 Mbbls. Geothermal energy could be used to achieve this heating and the results will be an increase in copper recovery and saving 12,100,000 bbls of the dwindling oil resources.

Despite the above savings and increase in copper recovery this proposed system has some disadvantages:

1) The cost of drilling wells and completion of the geothermal system might require a high capital investment. This assessment should be site-specific and must include many practical considerations.
2) Geothermal brine with a relatively high salinity may cause corrosion problems which would increase the operating cost of the project. However, this is not a major problem if the geothermal fluid were to be used indirectly as suggested in this system.
3) The waste geothermal brine must be carefully disposed to avoid contamination of nearby potable water reservoirs. Nevertheless, this factor is not a major problem if dealt with carefully.
4) Possible deleterious effects upon beneficial bacteria in copper leach dumps must be taken into consideration.

C.5 Alternative Routes for this Geothermal Application

The proposed system discussed above has some restrictions, mainly regarding the geothermal resource. Other resources in the state might be more advantageous and could lead to more substantial savings. Some of these alternative routes are listed as follows:

1) Geothermal brine with very low salinity. If a geothermal resource was very low in total number of dissolved solids then this brine could be used directly as the make-up water for the leaching fluid. The savings of this sytem would be: a) a heat exchanger will not be needed thus reducing the system's cost drastically; b) reinjection wells will not be needed since the geothermal water will go to the holding ponds and will be recycled consequently reducing the cost of the system; c) to replace the dwindling water table by geothermal water, thus making the diminishing water resources more available for other uses such as irrigation and domestic uses.
2) If hot springs exist near the copper dump leaching operation and if the flow rate of those springs meets the demand for water in the mine, then no production wells would be necessary and this diminishes the cost of the system.

3) If hot springs exist near the mining locations and if these springs had sufficient flow rate and the brine was low in dissolved solids then this geothermal water might be used directly to constitute the make-up water of the leaching fluid and the savings would be ideal due to the following facts: a) no production wells are needed, b) no heat exchangers are needed, c) no injection wells are needed, d) the regular water will be more available for other uses.

C.6 Conclusion

In general, the proposed use of geothermal energy in copper dump leaching appears to be attractive from the technological and the resource conservation viewpoints. A detailed and factual economic analysis is required to determine the economic feasibility of such application. Further the copper industry would have to be convinced of the advantage of this system since it will make their copper recovery more efficient.

REFERENCES FOR APPENDIX C

C-1 Aldrich, H.W. and W.G. Scott, "Leaching and Electrolytic Precipitation of Copper at Inspiration", Engineering and Mining Journal (Oct. 1929).

C-2 Wadsworth, M.E., "Physico-Chemical Aspects of Leaching", University of Utah, Salt Lake City, Utah (1976).

C-3 Bauer, D.J. and R.E. Lindstrom, "Use of Chelating Agents for Recovery of Copper from Carbonate and Silicate Ores", J. of Metals, 5, 31 (1971).

C-4 Sullivan, J.D. and A.J. Sweet, "Factors Governing Removal of Soluble Copper from Leached Ores", U.S. Bureau of Mines and the Department of Mining and Metallurgy of the University of Arizona (1929).

C-5 Hiskey, J.B. and M.E. Wadsworth, "Galvanic Conversion of Chalcopyrite", Proceedings of 103rd AIME Annual Meeting, Dallas, Texas, 422 (Feb, 1974).

DISTRIBUTION RECORD FOR DOE/ID/12015-1

Internal Distribution

1 - Chicago Patent Group - DOE
9800 South Cass
Argonne, IL 60439

1 - R. L. Blackledge
Idaho Operations Office - DOE
Idaho Falls, ID 83401

1 - H. P. Pearson
Information Processing - EG&G

6 - INEL Technical Library

100 - Special Internal

External Distribution

2 - Technical Information Center - DOE
Box 62
Oak Ridge, TN 37830

Total Copies Printed: 111