GEOTHERMAL DEVELOPMENT PLAN: NORTHERN ARIZONA

Prepared by

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INTRODUCTION

Alternative sources of energy will have to be developed as the availability of traditional energy resources continues to diminish. Arizona is supplied with geothermal reserves which could potentially supplement the existing energy supplies. Consequently, planning efforts have concentrated on estimating the potential of geothermal energy utilization in Arizona and in providing information necessary for its prospective commercialization.

Geothermal commercialization plans were prepared for seven distinct intrastate subdivisions. The geothermal resource prospect and the potential geothermal uses for each area are discussed in separate Area Development Plans (ADPs). The major objective of the ADP is to provide information for the prospective development and commercialization of geothermal energy in the specified area. Attempts are made to match the available geothermal resources to potential residential, commercial, industrial and agricultural users.

Much of the northern counties (Apache, Coconino, Gila, Mohave, Navajo and Yavapai) is located in the Colorado Plateau province, a region of low geothermal potential. Two areas that do show some potential are the Flagstaff - San Francisco Peaks area and the Springerville area. Flagstaff is rapidly becoming the manufacturing center of Arizona and will have many opportunities to use geothermal energy to satisfy part of its increasing need for energy. Using a computer simulation model, projections of geothermal energy on line as a function of time are made for both private and city-owned utility development of a resource.

AREA DEVELOPMENT PLANS

Arizona has been divided into seven distinct single or multicounty subdivisions for which Area Development Plans (ADPs) for geothermal commercialization have been developed. A map of Arizona presented in Figure 1 shows these areas which are numbered in order of planning priority.

This ADP is concerned with the northern counties. Both metric and English units are provided in the text. However, only metric units appear in the tables and figures. For convenience, some common conversion factors are listed in Table 1. In this report, one million Btu = MBtu.

TABLE 1: SOME COMMON CONVERSION FACTORS

Length and Volume Conversions:

To Convert:	Multiply By:	To Obtain:
meters	3.281	feet
kilometers	0.6214	miles
cubic kilometers	0.2399	cubic miles
liters	0.2642	gallons

Temperature Conversions: $^oF = (1.8 \times {}^oC) + 32$

GEOTHERMAL RESOURCES

Much of the northern counties is located in the Colorado Plateau province, a region characterized by low heat flow and little geothermal potential. The Flagstaff - San Francisco Peaks and the Springerville areas, however, do exhibit some geothermal potential. Geologically young volcanism has occurred in the San Francisco Peaks area, and U.S. Geological Survey studies in the San Francisco Peaks volcanic field suggest that there may be significant residual volcanic heat at depth.

Priorities

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

County Names

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

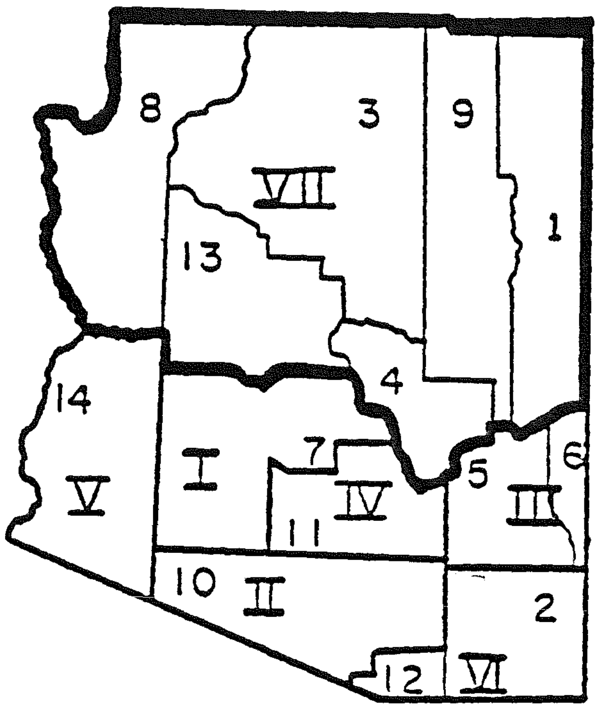


Figure 1: Area Development Plans for Arizona.

Abnormally high heat flow occurs in the Springerville area, an area located in northeastern Arizona (Apache County) where both geologically young and extinct volcanoes are observed. There is one hot spring in Apache County that discharges water having a temperature of 21.7°C (71.1°F). Sixty wells located in the county ranging from 200 m (660 ft) to 400 m (1310 ft) in depth produce water ranging in temperature from 20°C (68°F) to 27°C (81°F).

Further studies are being conducted by the Arizona Bureau of Geology and Mineral Technology to identify additional geothermal resources. Results of these studies will be available next year.

ECONOMY

Population

The 1980 population of the northern Arizona counties was 355,657 people. The combined land area of the counties is 65,709 square miles which results in a population density of 5.4 persons per square mile. The ethnic breakdown of the population is 55 percent white, 28 percent Indian, 11 percent Hispanic and 1 percent black.

Growth

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

Population projections for the combined counties indicated in Figure 2 show steady growth for the next forty years.

The largest city in northern Arizona is Flagstaff. This city is rapidly becoming the manufacturing center of northern Arizona due to its access to two main interstates.

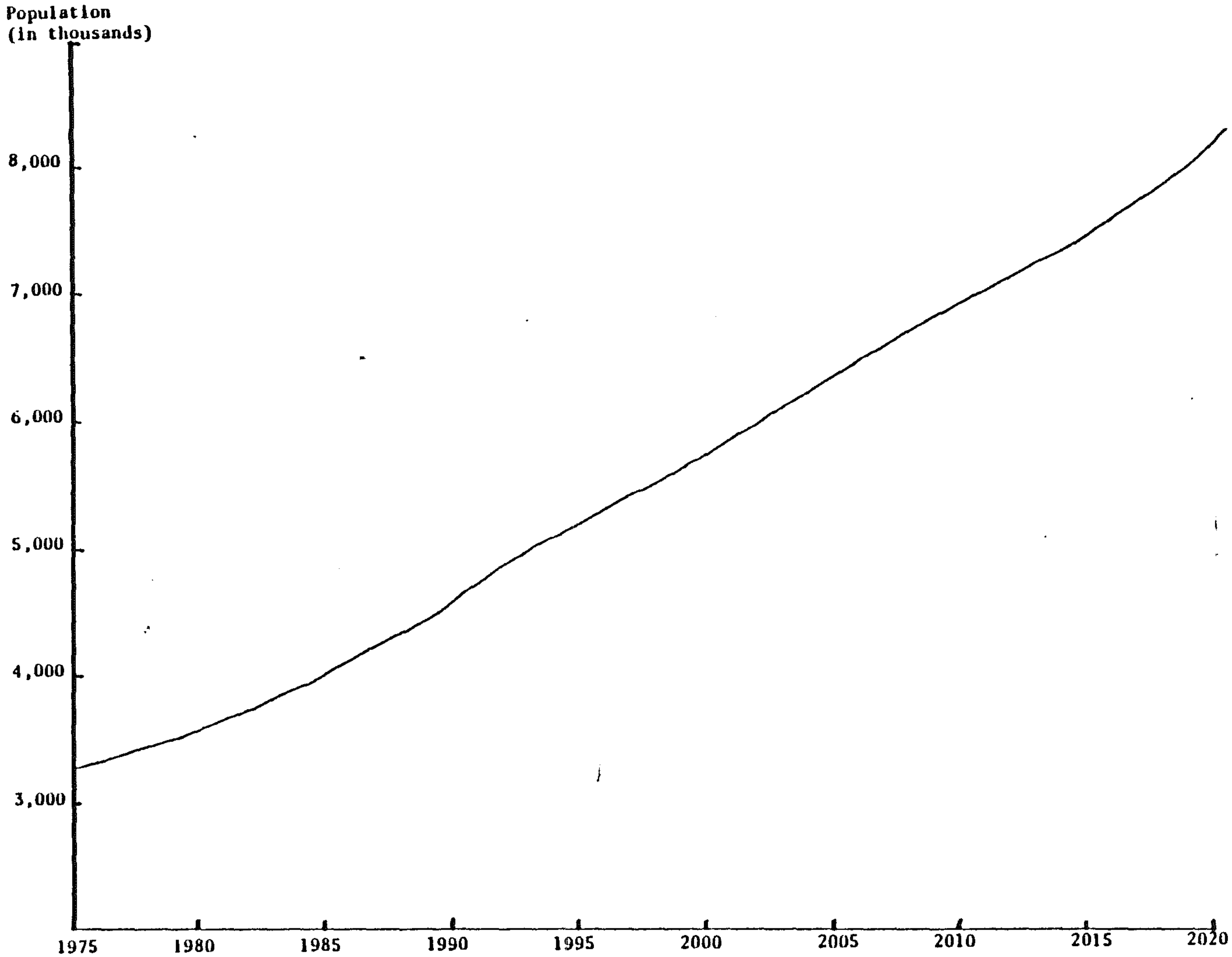


Figure 2: Population Projections for the Northern Arizona Counties to 2020.
Source: Technical Advisory Committee (DES)

TABLE 2: ANNUAL POPULATION GROWTH RATES FOR THE NORTHERN COUNTIES, 1970 - 1978

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

Industry and Employment

Figures 3 and 4 show current and projected employment levels for the various sectors in the northern counties. Presently, the largest employment sectors are the trade and service sectors. By the year 2000, the trade and service sectors are projected to increase 77 percent and 79 percent, respectively; manufacturing is projected to increase 67 percent and the mining and utility sectors are both expected to grow 71 percent. Employment in agriculture is expected to decrease 17 percent.

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

Income

In addition, several other economic indicators show positive growth in northern Arizona. Figure 5 presents projections of personal per capita income for the northern counties to 2000. Annual growth rates are shown in Table 3.

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

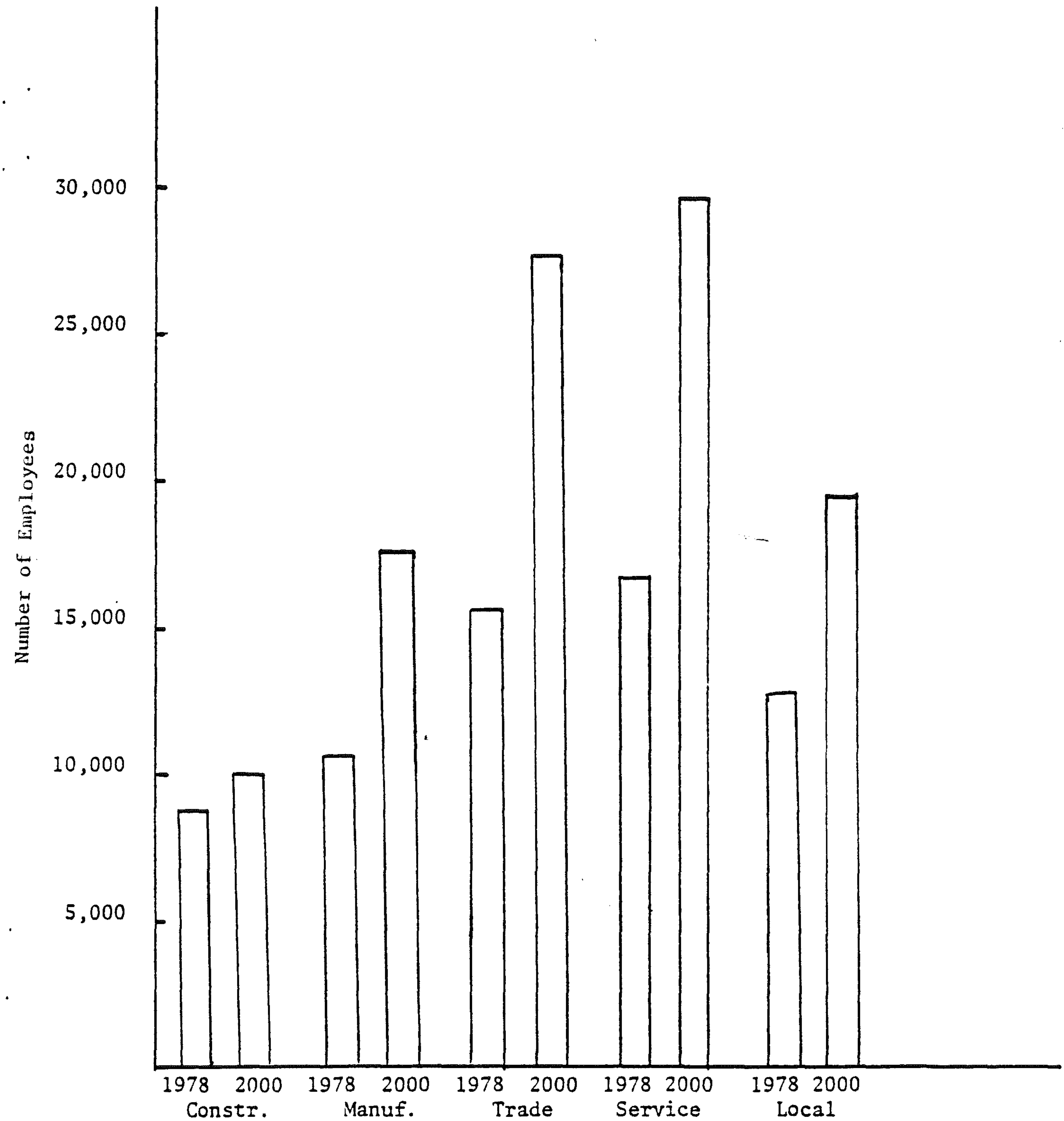


Figure 3: Major Employment Sector Projections for the Northern Counties.
Source: Department of Economic Security

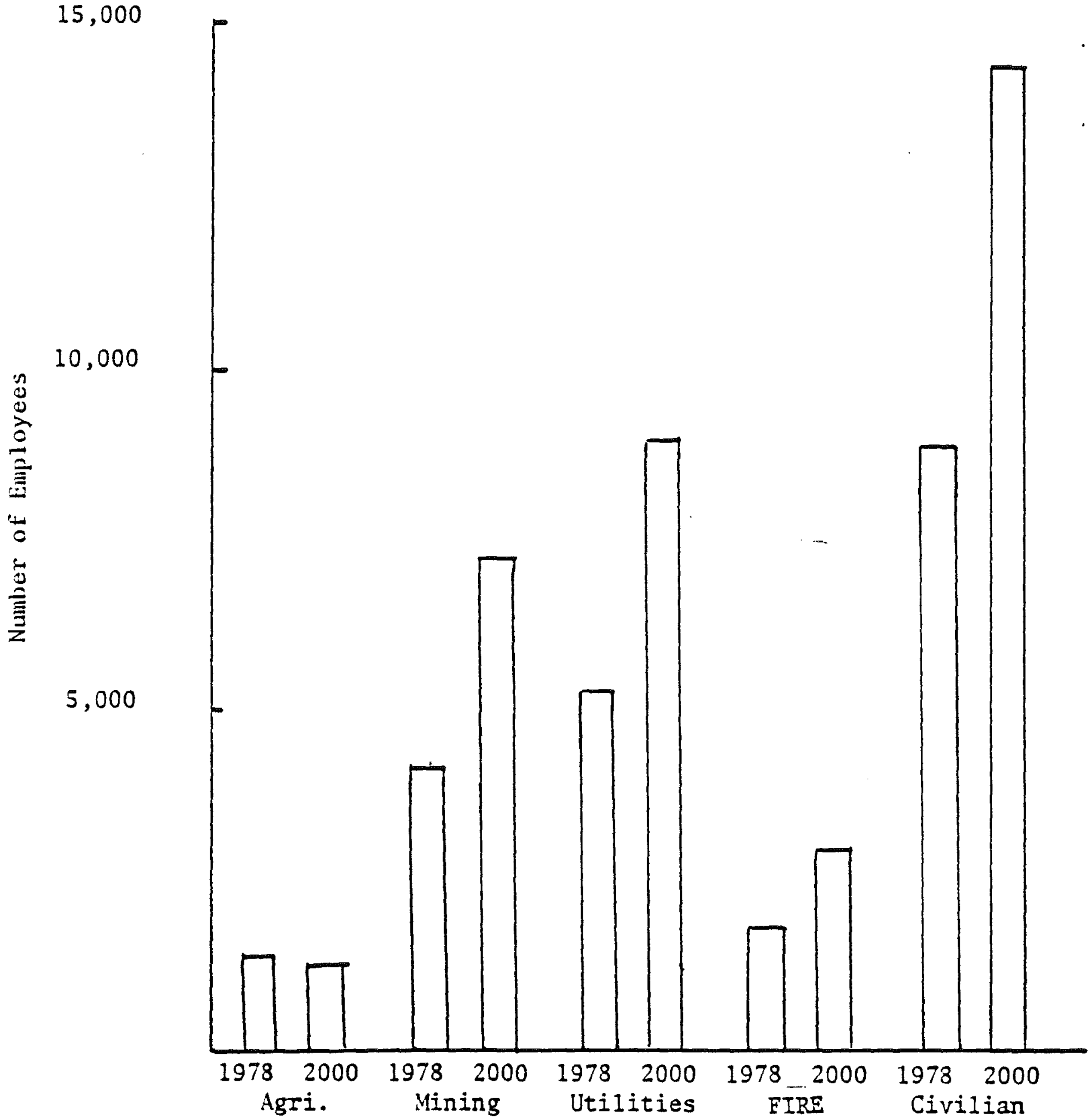


Figure 4: Other Employment Sector Projections for the Northern Counties.
Source: Department of Economic Security

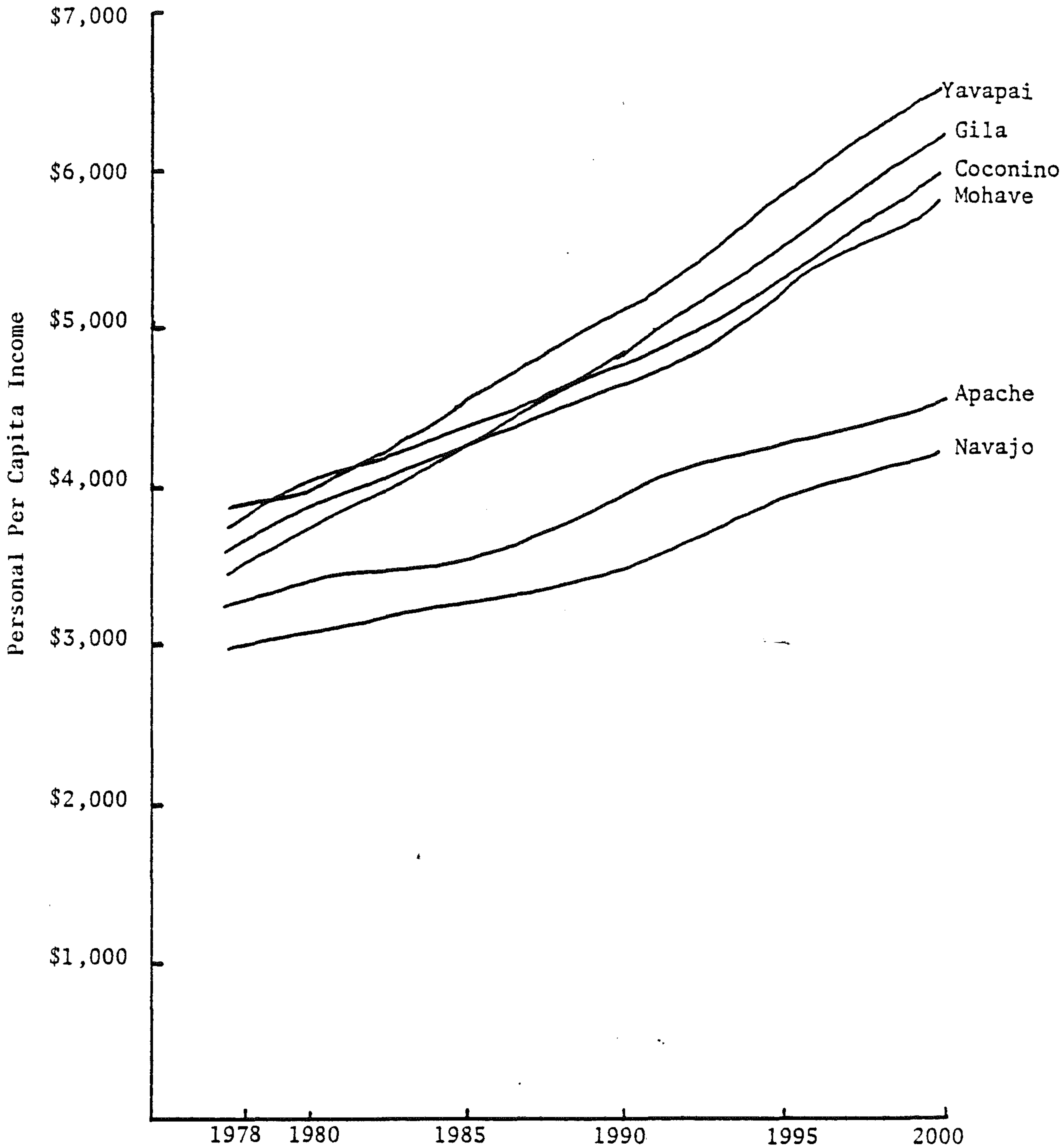


Figure 5: Projections of Personal Per Capita Income for the Northern Counties (1972 Dollars)
Source: Department of Economic Security

TABLE 3: PROJECTIONS OF PERSONAL PER CAPITA INCOME GROWTH TO 2000

County	% Annual Personal Income Growth	% Annual Per Capita Income Growth
Apache	3.6	1.6
Coconino	5.5	2.1
Gila	4.4	2.7
Mohave	4.6	2.2
Navajo	4.2	1.6
Yavapai	4.5	2.4

Other Economic Indicators

Between 1968 and 1978 the value of retail sales steadily increased in both counties. Table 4 indicates the percentage increase in retail sales and bank deposits over the ten-year period.

TABLE 4: RETAIL SALES IN THE NORTHERN COUNTIES

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

The sparse population of the northern counties and the lack of an industrial base have resulted in few potential developers of geothermal energy. However, increases in the major economic indicators suggest that the historically slow growth of the northern counties is changing. With population growth and the encouragement of light industry, the opportunities to use geothermal energy will also increase.

LAND OWNERSHIP

Figures 6, 7, 8, 9, 10 and 11 show general land ownerships maps for Apache, Coconino, Gila, Mohave, Navajo and Yavapai counties. Table 5 gives acreage breakdowns for each ownership class.

TABLE 5: BREAKDOWN OF LAND OWNERSHIP

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

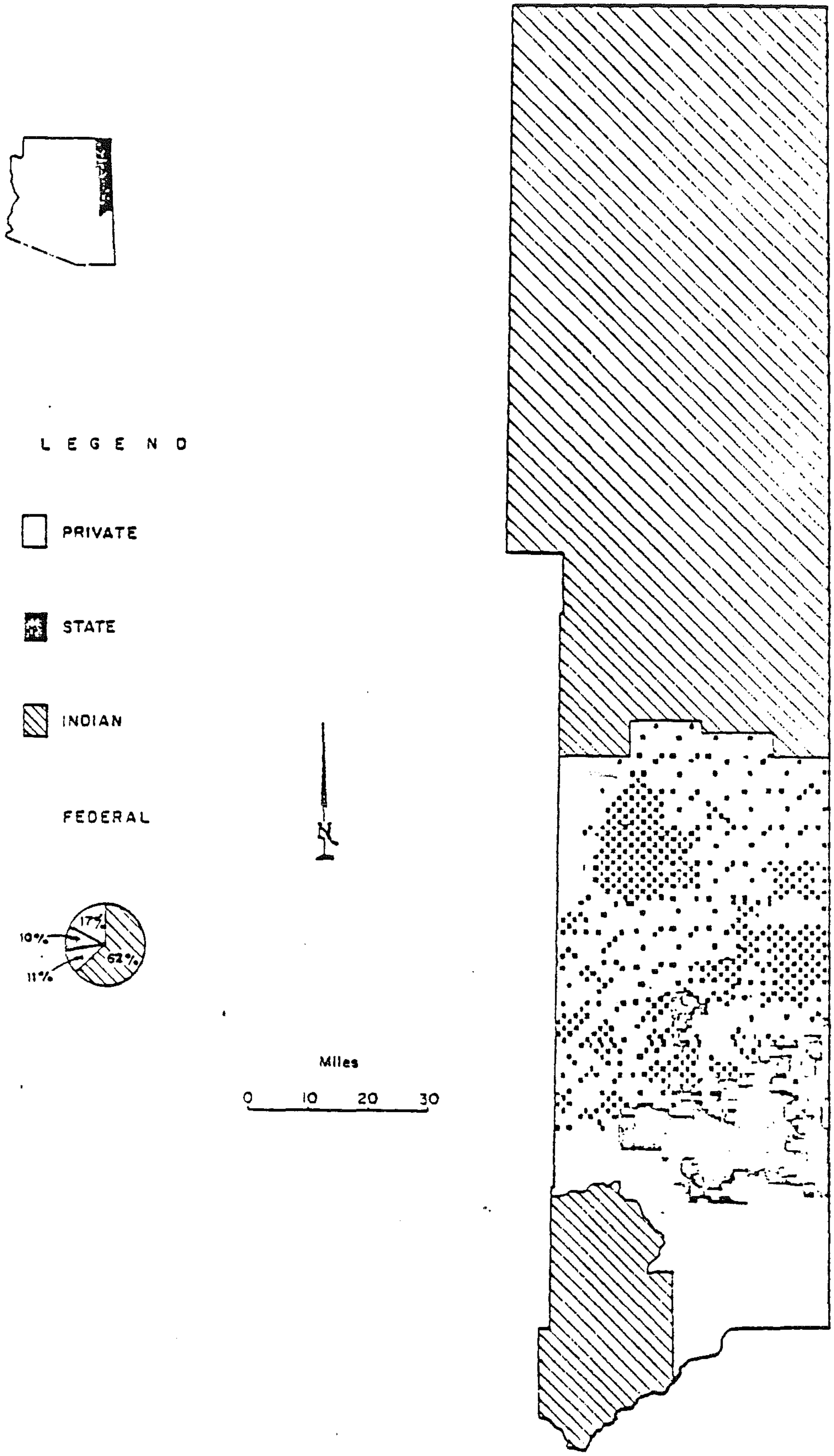


Figure 6: General Land Ownership Map for Apache County.
Source: Arizona Water Commission (1977)

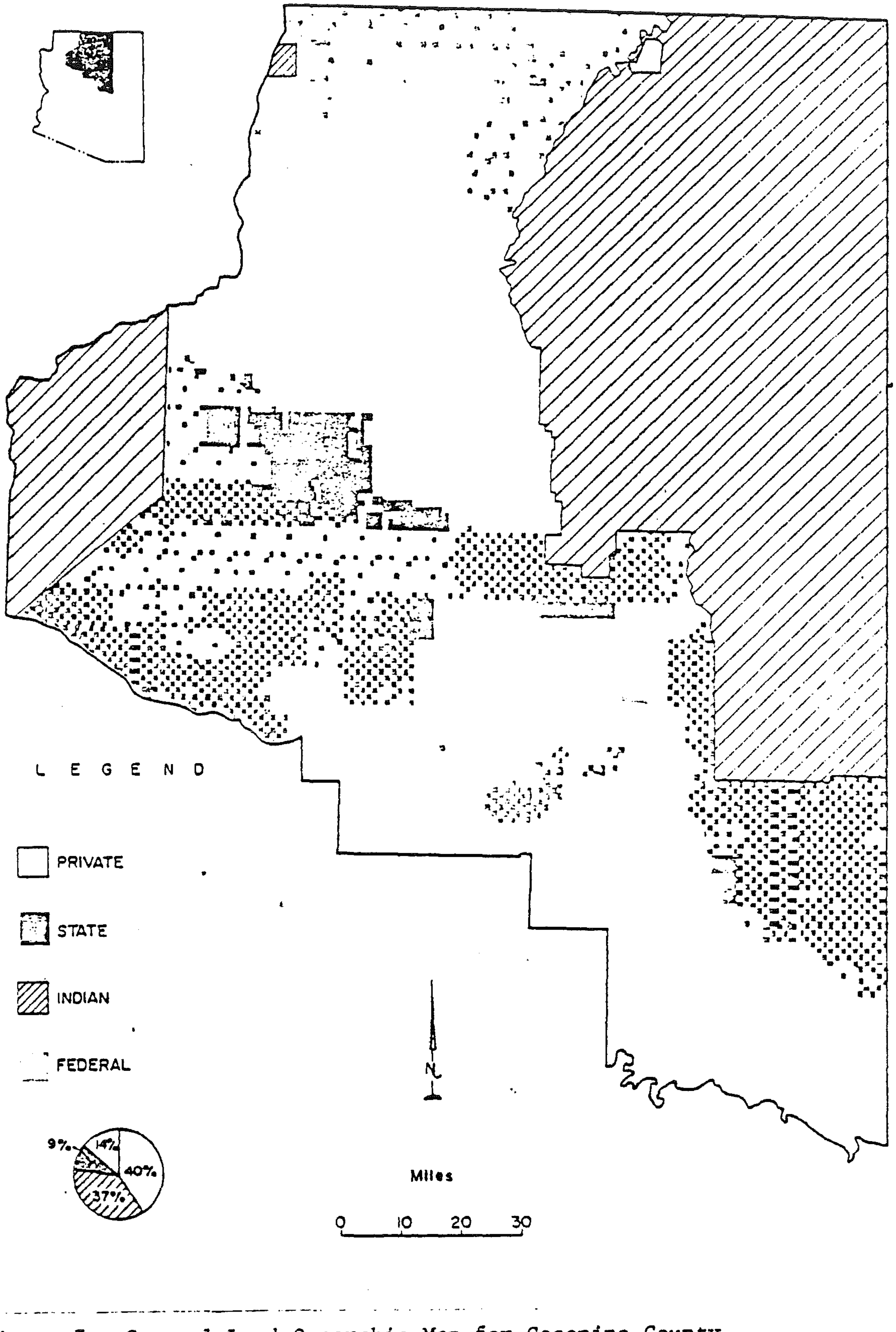


Figure 7: General Land Ownership Map for Coconino County.
Source: Arizona Water Commission (1977)

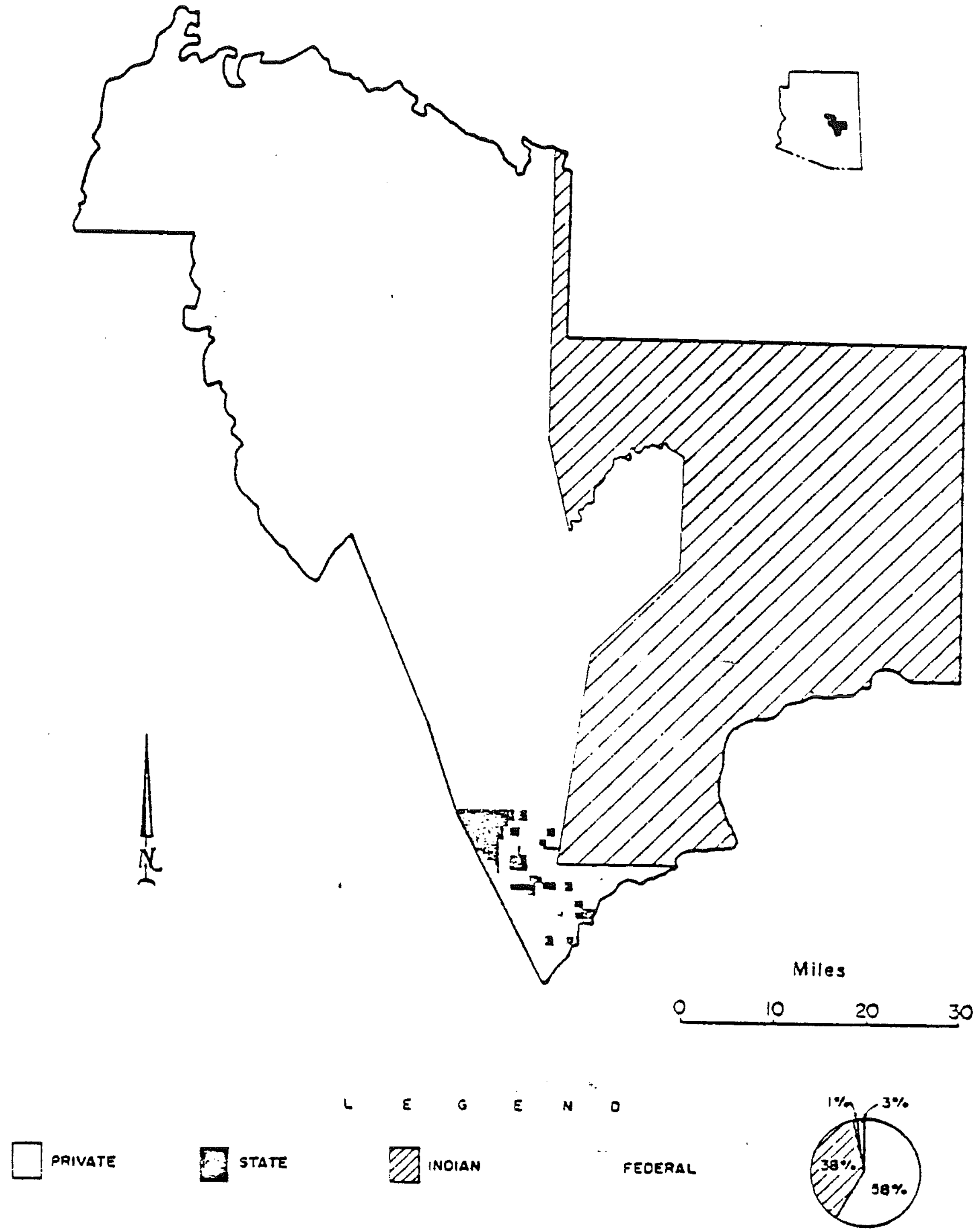


Figure 8: General Land Ownership Map for Gila County.
Source: Arizona Water Commission (1977)

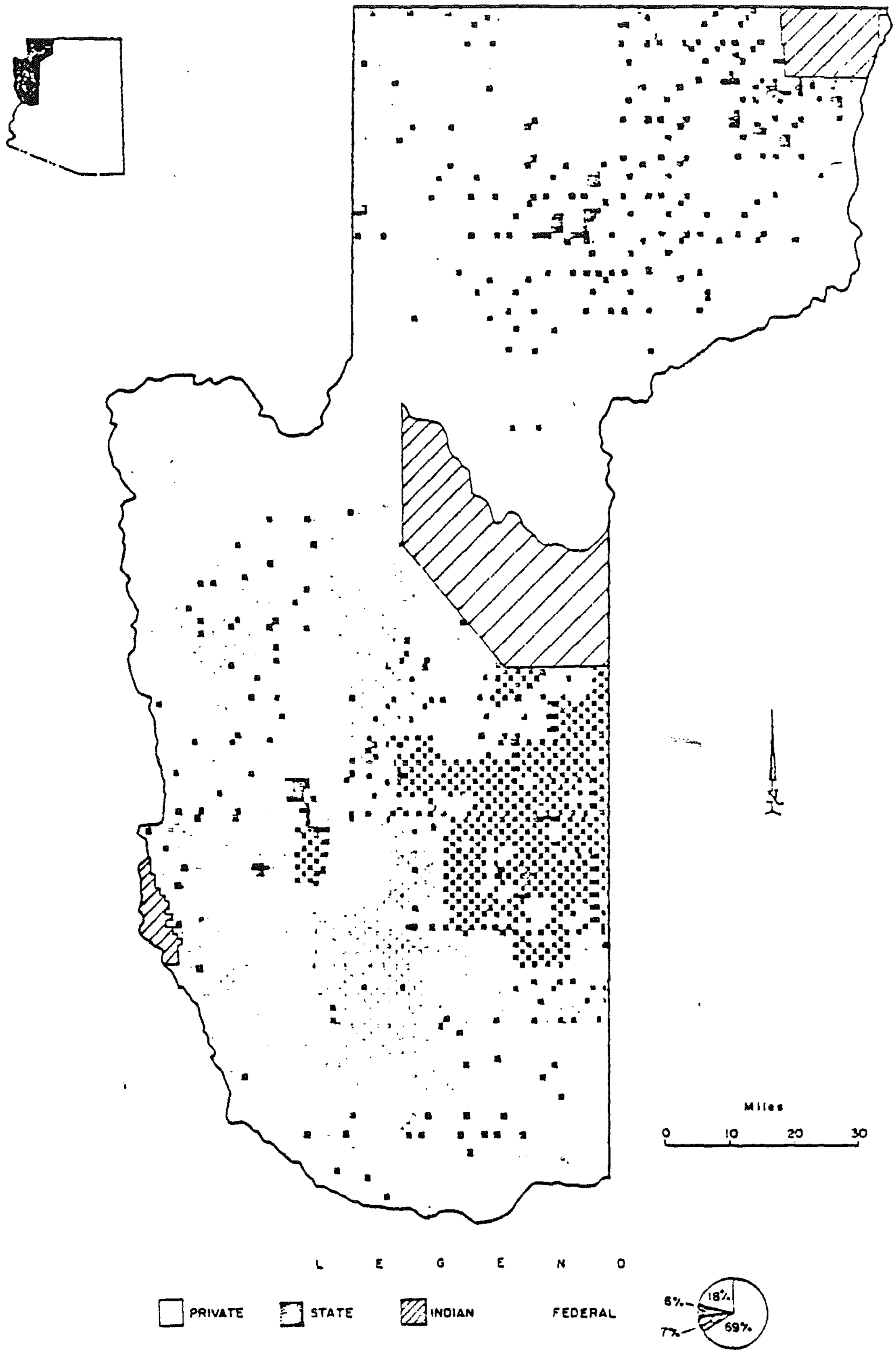


Figure 9: General Land Ownership Map for Mohave County.
Source: Arizona Water Commission (1977)

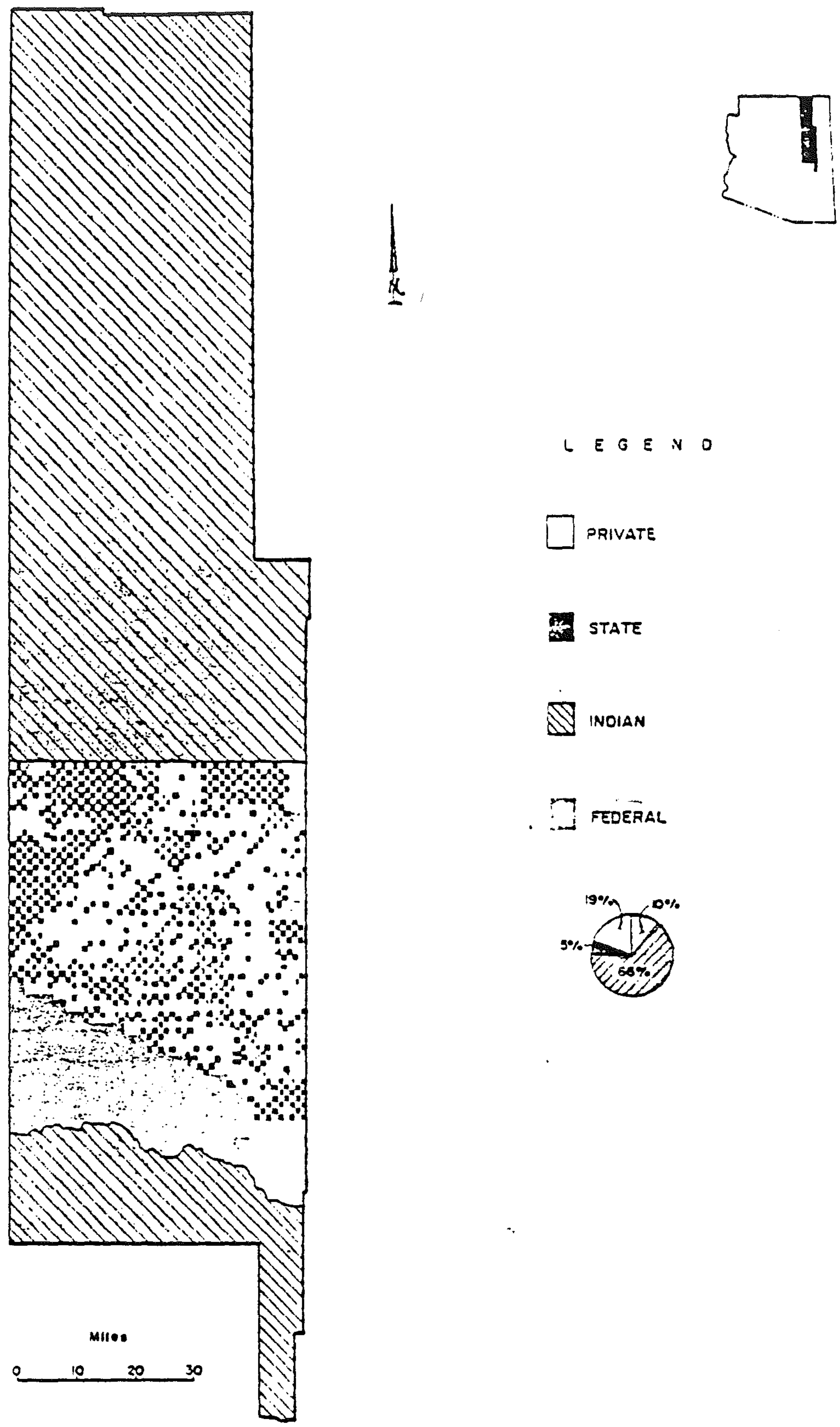


Figure 10: General Land Ownership Map for Navajo County.
Source: Arizona Water Commission (1977)

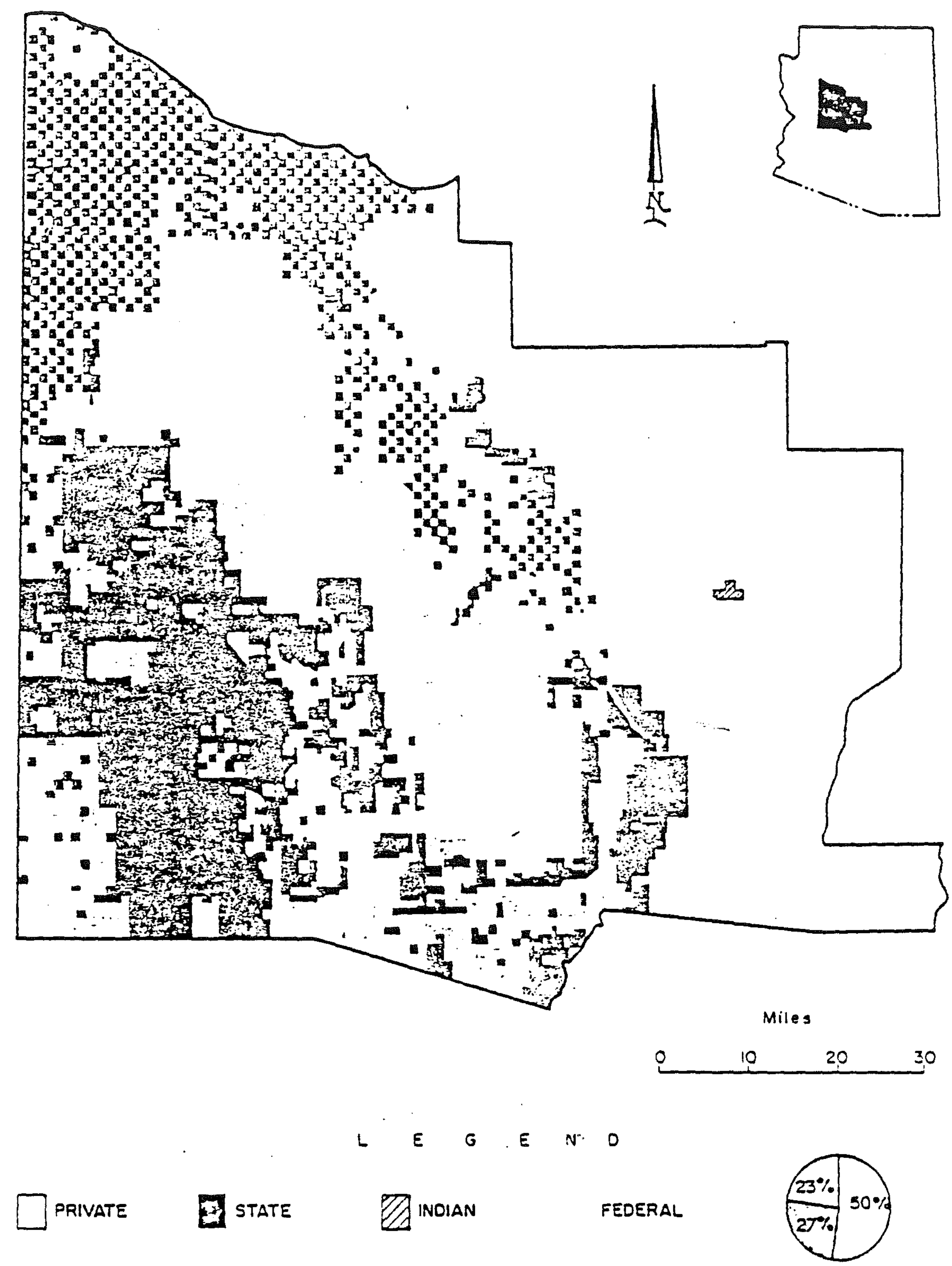


Figure 11: General Land Ownership Map for Yavapai County.
Source: Arizona Water Commission (1977)

ENERGY USE

The largest electric utility company serving northern Arizona is Arizona Public Service Company. Other electric utility companies include Navopache Electric Cooperative which serves both Navajo and Apache counties and Mohave Electric Cooperative, Inc., which serves Mohave County.

Southern Union Gas provides natural gas to Prescott, Kingman and Flagstaff. Natural gas sales for the residential, commercial, public authority and industrial user classes are presented in Figures 12, 13 and 14 for Prescott, Kingman and Flagstaff, respectively. Residential users are clearly the largest consumers of natural gas in the winter months due to the use of natural gas for heating. Demand for natural gas drops off rapidly in the summer months and is at its lowest in August. With one exception, this general pattern of high demand for natural gas in the winter months and decreasing demand in the summer months is consistent for the other user classes as well. Unlike the other user classes, the industrial class of Kingman, consisting primarily of the copper mine northwest of the town, uses more natural gas during the summer in generating electricity.

For comparative purposes, Table 6 shows the average natural gas consumption per facility for the residential, commercial and industrial user classes of three towns in the northern counties and of the southern counties as a whole. The figures show that the northern counties consume significantly more natural gas than do the southern counties. The disparity can be attributed to the severity of the winters in the northern counties, causing more natural gas to be consumed by the northern counties for heating purposes.

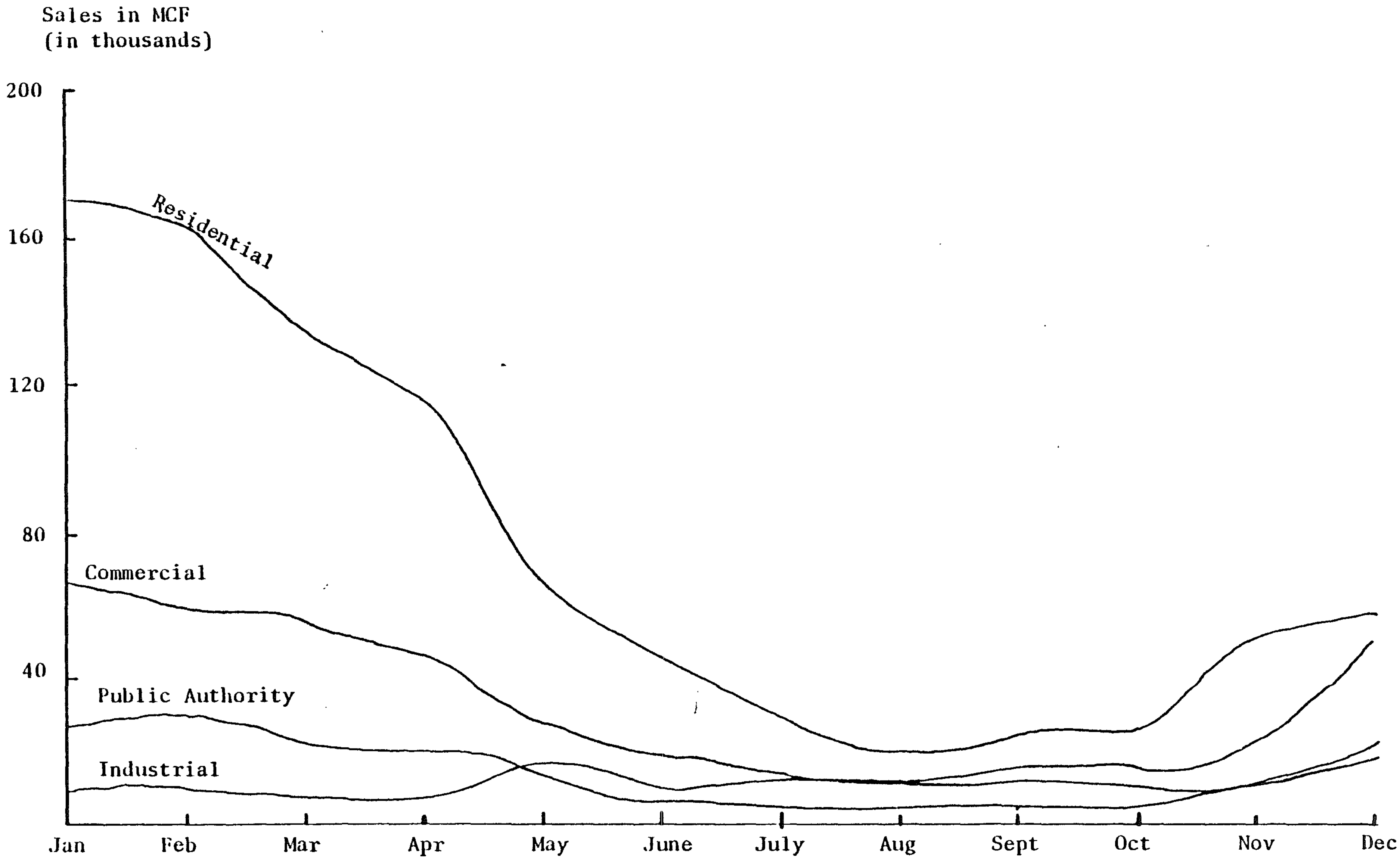


Figure 12: Estimated Natural Gas Sales by Month in 1979
for Prescott (Yavapai County).
Source: Southern Union Gas Company

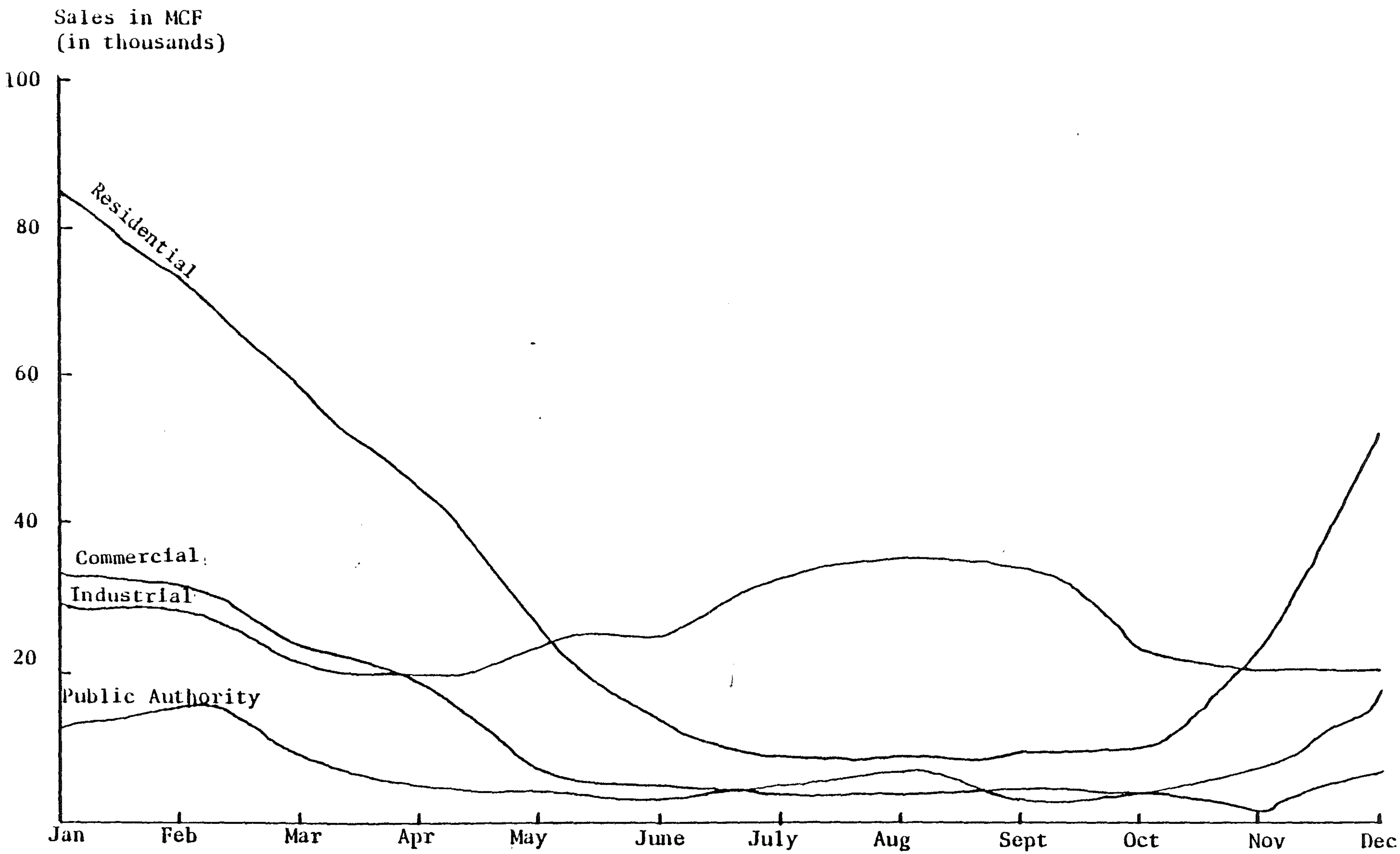


Figure 13: Estimated Natural Gas Sales by Month in 1979 for Kingman (Mohave County).
Source: Southern Union Gas Company

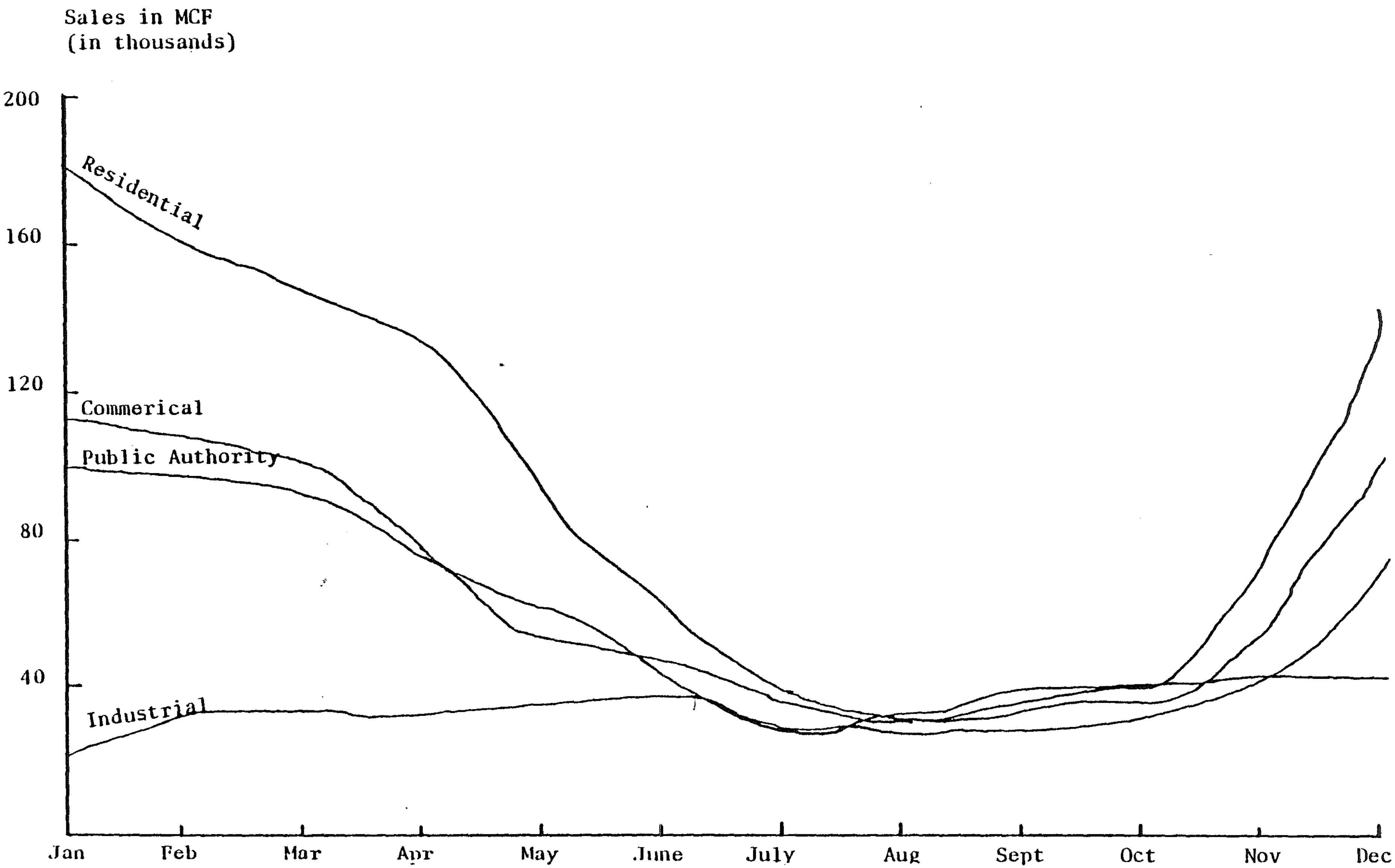


Figure 14: Estimated Natural Gas Sales by Month in 1979 for Flagstaff (Coconino County).
Source: Southern Union Gas Company

TABLE 6: COMPARISON OF AVERAGE CONSUMPTION OF NATURAL GAS PER FACILITY BY USER CLASS, 1979

Northern Counties

	Residential	Commercial	Industrial
Flagstaff	134.0 MCF	758.26	42416.7
Kingman	89.0 MCF	407.45	87557.25
Prescott	106.34 MCF	442.25	17555.0

Southern Counties

	Residential	Commercial	Industrial
Southern Counties	62.9 MCF	467.7	13786.8

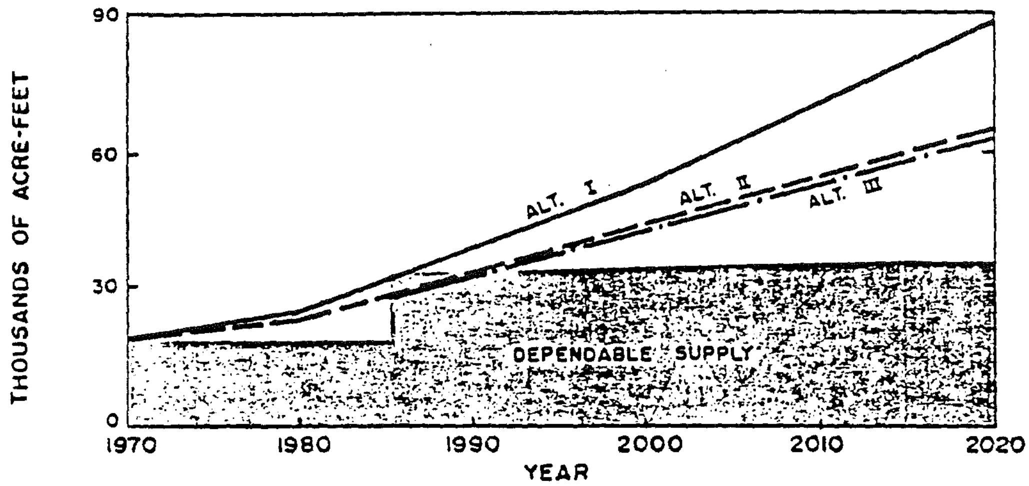
Source: Southern Union Gas Corporation
Southwest Gas Corporation

WATER

Figures 15 through 20 present alternative futures for water use for the northern counties. The three alternatives take into account a variety of factors such as population growth, industrial development and consumer lifestyles that will have an effect on the future level of water use. In general, urban water depletions are expected to be even greater than what would be expected due to the projected population increases alone. In Apache, Coconino and Navajo counties, the current per capita rate of use is much lower than the remainder of the state. These rates are expected to show small increases.

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

PROJECTED ALTERNATIVE WATER DEPLETIONS AND DEPENDABLE SUPPLY

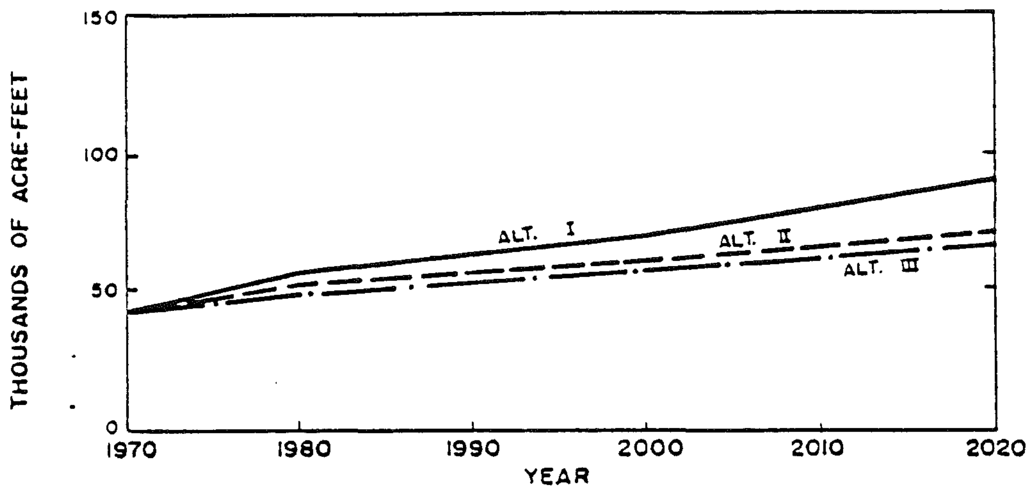


ALTERNATIVE FUTURES SUMMARY

ITEM (Quantities in Thousands)	1970	ALTERNATIVE I 1990	I 2020	II 1990	II 2020	FUTURES III 1990	III 2020
POPULATION	29.3	53.9	65.2	40.5	56.4	40.5	56.4
HARVESTED ACRES	1.0	1.2	1.3	1.0	1.0	0.8	0
URBAN DEPLETIONS AF/YR	2.9	3.8	4.9	2.9	4.2	2.9	4 2
STEAM ELECTRIC DEPLETIONS AF/YR	0	0	0	0	0	0	0
MINERAL DEPLETIONS AF/YR	14.0	33.0	82.0	29.0	60.0	29.0	60.0
AGRICULTURAL DEPL. AF/YR	2.0	2.3	2.6	2.0	2.0	1.6	0
TOTAL WATER DEPL. AF/YR	19	39	89	34	66	33	64
DEPENDABLE WATER AF/YR	19	34	37	34	37	34	37
SURPLUS SUPPLY (Def.)	0	(5)	(52)	0	(29)	1	(27)

Figure 15: Projected Alternatives for Water Use in Gila County.
Source: Arizona Water Commission (1977)

PROJECTED ALTERNATIVE WATER DEPLETIONS



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

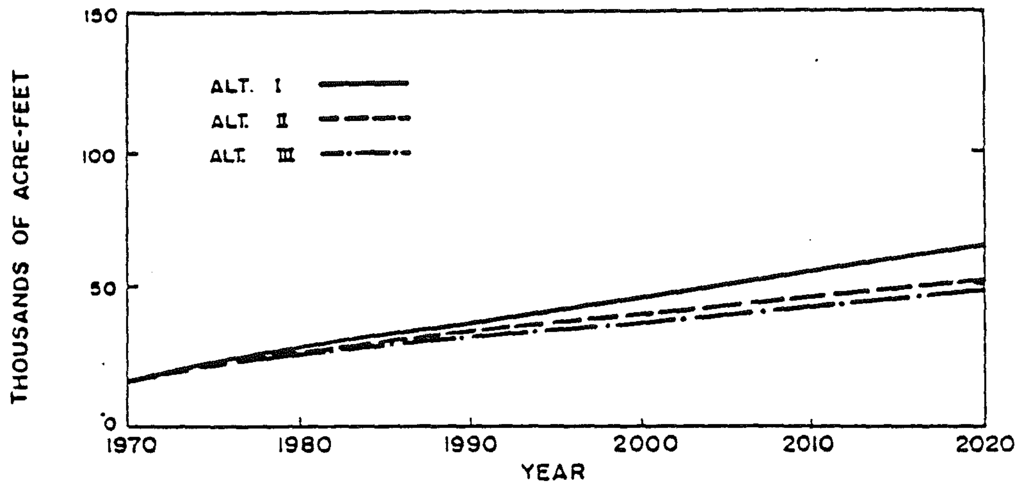
ALTERNATIVE FUTURES SUMMARY

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

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

Figure 16: Projected Alternatives for Water Use in Navajo County.
Source: Arizona Water Commission (1977)

PROJECTED ALTERNATIVE WATER DEPLETIONS



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

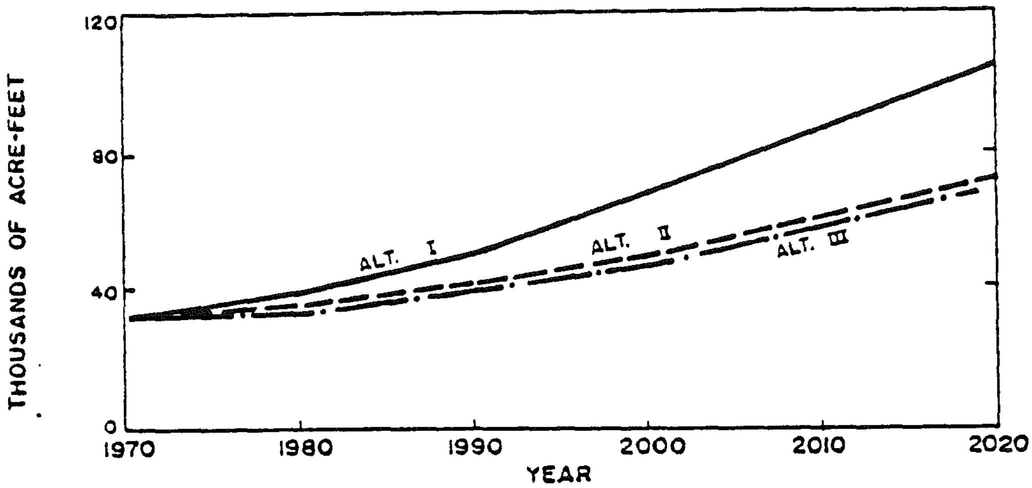
ALTERNATIVE FUTURES SUMMARY

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

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

Figure 17: Projected Alternatives for Water Use in Apache County.
Source: Arizona Water Commission (1977)

PROJECTED ALTERNATIVE WATER DEPLETIONS AND DEPENDABLE SUPPLY



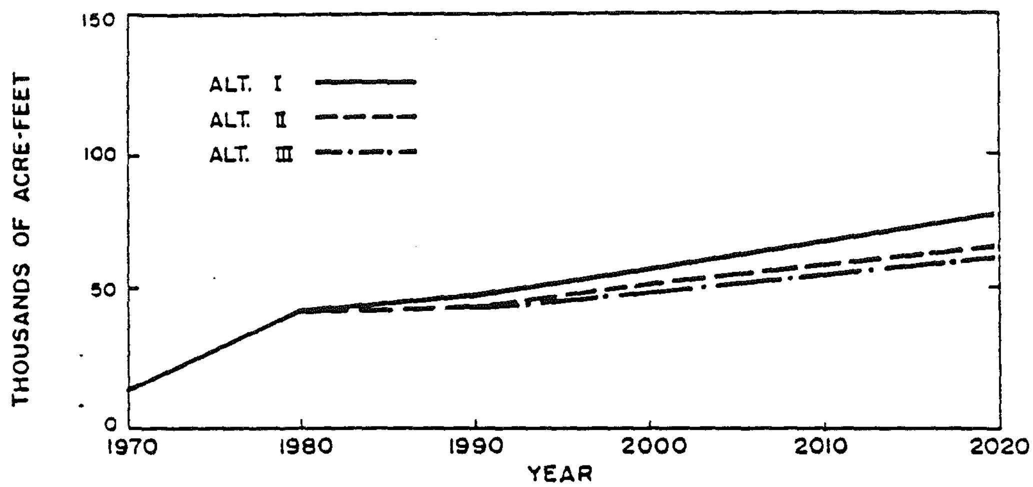
ALTERNATIVE FUTURES SUMMARY

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

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

Figure 18: Projected Alternatives for Water Use in Yavapai County.
Source: Arizona Water Commission (1977)

PROJECTED ALTERNATIVE WATER DEPLETIONS



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

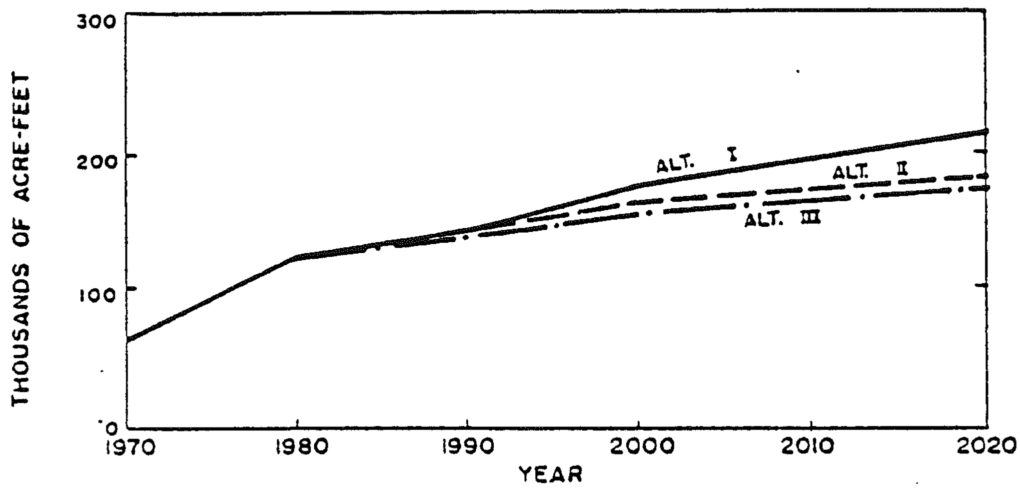
ALTERNATIVE FUTURES SUMMARY

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

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

Figure 19: Projected Alternatives for Water Use in Coconino County.
Source: Arizona Water Commission (1977)

PROJECTED ALTERNATIVE WATER DEPLETIONS



ALTERNATIVE FUTURES SUMMARY

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

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

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

Figure 20: Projected Alternatives for Water Use in Mohave County.
Source: Arizona Water Commission (1977)

For Gila, Navajo, Apache and Yavapai counties, little change is expected in water use for irrigated agricultural production. Under Alternatives II and III, water use in Coconino County in the year 2020 is projected to be over double the current levels. In Mohave County, all three alternatives show water use for irrigated agricultural production at least tripling by 1990 and continuing to increase to the year 2020.

Large increases are forecast in the amount of water used to cool steam electric power plants. Water use has increased significantly due to the construction of new and the expansion of existing power plants. Additional coal-fired plants and plant expansion are anticipated so that by 2020, water use will range from 68,000 to 154,000 acre-feet per year. As much as 23,000 acre-feet of this may occur in Yavapai County if the high projection of electrical power generation in Arizona is realized.

Both Yavapai and Mohave counties anticipate major expansions of the existing copper mines. Although water used for this purpose will increase with the projected increase in mineral production, it will continue to be less than 10 percent of the statewide levels.

Several surface water hydrologic areas supply water to northern Arizona. The Colorado River Drainage Basin supplies water to most of the developed areas in Apache, Coconino and Navajo counties. The Verde River Basin supplies water to urban development in Yavapai County. The Colorado River supplies Mohave County with water. Future dependable supplies along the Colorado River are projected to equal depletions. However, off-river uses of water will result in deficiencies for Mohave County under all three alternatives.

DISTRICT HEATING

Both Springerville and Alpine, located in the White Mountains of east-central Arizona, experience severe winters. Evidence for geothermal potential in the area suggests that geothermal district heating systems for the two towns may be feasible.

Alpine

The community of Alpine is a small town located in the White Mountains of east-central Arizona approximately 25 miles south of Springerville, Arizona. The community has a population of 500 people and has historically experienced very slow growth. Future growth is expected to be only one percent per year during the next 20 years. Because the community is isolated, utility services are not available. Most people heat their homes with purchased diesel oil or propane. In addition, the mountain location results in severe winters of much longer duration than is the case in southern Arizona. For comparison, heating degree days for Alpine are 7500 versus 1500 in Phoenix. These circumstances make Alpine a possible candidate for a geothermal heating system.

Preliminary studies on the potential existence of geothermal energy resources in the Alpine and Springerville area have been completed by the Arizona Bureau of Geology and Mineral Technology, Geothermal Group. Although the conclusions of the study are far from definitive, several comments are worth noting. First, the study concludes that "a relatively shallow heat source of unknown character and dimension exists, probably beneath the area between Springerville and Alpine. Second, groundwater supplying the eastern half of the area is positively affected by this heat source." In addition to these conclusions, a shallow bore hole has been drilled just north of Alpine. The hole had a temperature of 33°C (91°F) at a depth of 357 m (1170 ft). The estimated temperature gradient was 75°C/km (5°F/100 ft). The economic analysis which follows assumes the existence of a geothermal resource with the above characteristics.

The following analysis concerns the economic factors necessary to develop a geothermal heating district in Alpine. Two cases are considered. The first case assumes that the City of Alpine establishes a local public service company responsible for the development, distribution and management of the heating district. The intent of the utility would be to provide hot water for domestic and commercial space heating and hot water needs while earning a modest profit. The second case assumes that a private (investor-owned) utility would be responsible for development, distribution and management of the district heating system. The intent of the utility would be to earn a profit on its operations. Both options are considered feasible methods for geothermal development.

The geothermal heating district for Alpine would consist of 167 residential houses as well as commercial buildings. It is assumed that commercial heat demand is equal to residential heat demand. Estimated residential peak demand for the community is 7,516,000 Btu/hr. The developer would be required to drill wells necessary for the system. It is assumed that 60°C (140°F) geothermal water could be discovered at 914 m (3000 ft) at a distance of one mile from Alpine. It is further assumed that the flow rate would be 1890 l/min (500 gpm). Lastly, people living in Alpine must purchase fuel oil or propane for use in heating houses and businesses. It is assumed that the price of purchased energy is $7.00/MBtu. Table 7 presents a summary of assumptions for the two cases considered.

TABLE 7: ASSUMPTIONS FOR ALPINE DISTRICT HEATING SYSTEM

Variable	City Development	Private Development
Resource Temperature	$60^{o}C$ ($140^{o}F$)	$60^{o}C$ ($140^{o}F$)
Depth	914 m (3000 ft)	914 m (3000 ft)
Flow Rate	1890 l/min (500 gpm)	1890 l/min (500 gpm)
Distance	1609 m (1 mile)	1609 m (1 mile)
Bond rate (above inflation)	1%	2%
Equity Capital	10%	10%
Sales Tax Rate	0%	5%
State Tax Rate	0%	15%
Federal Tax Rate	0%	46%
Geothermal Tax Credit	0%	15%
Minimum Tax Rate	0%	15%
Property Tax Rate	0%	1%
Regular Investment Tax Credit	0%	10%
Required Rate of Return (above inflation)	1%	20%
Conventional Fuel Price (MBtu)	\$7.00	\$7.00
Real Fuel Price Growth (per year)	2%	2%
Project Life (years)	20	20

Using the above-outlined assumptions, a life-cycle cost for geothermal energy was calculated and compared to the price of propane. The price of geothermal energy was found to be \$4.55 under private development and \$4.33 under city development. In both cases, geothermal energy can be supplied at a price less than the price of currently available fuel. Net fuel cost savings over the life of the project total \$3,693,000 under city development and \$2,795,000 under private development. Table 8 presents an itemized cost summary for the two cases considered.

TABLE 8: COST SUMMARY FOR ALPINE DISTRICT HEATING SYSTEM

Category	Present Value of Capital Costs City Development	Private Development
Research Investment[1]	$ 461,291	$ 453,062
Design	179,684	159,915
Wells[2]	325,269	271,468
Transmission	195,967	178,770
Distribution Costs:		
Residential Retrofit	362,570	330,753
Residential Hookup	125,892	114,845
Commercial Conversion	255,309	232,905
Heat Exchangers	75,963	69,297
Central System	925,280	844,084
Totals	$2,907,225	$2,655,099

(1) Research Investment includes the cost of the first well, leases and pumps.

(2) Well cost is the present value of a well drilled 10 years later to provide for system expansion and necessary leases, pumps and injection wells.

In addition to capital costs there are also operating costs which include maintenance and electricity costs to run the pumps and fans for the system. These costs are assumed to be 2.5 percent of the cumulative investment per year. Operating costs are not a separate line item. Rather they are reflected in the final price per million Btu.

Of most interest in the above analysis is the difference in the price of geothermal energy depending on the type of developer. The advantages of city development include a lower cost of capital, a lower required rate of return and exemption from state and federal taxes. However, because a private developer can take advantage of geothermal tax credits and regular investment tax credits, the private developer is able to offset some of the advantages of a city developer.

Springerville

Springerville, Arizona, along with the adjacent community of Eagar, is located about 220 miles northeast of Phoenix in the White Mountains of Apache County. Historically, Springerville has been an agricultural community relying heavily on cattle and sheep grazing. Today, the largest employment sector is the lumber industry followed by the construction industry. Currently, two large coal-fired power plants are under construction in the area. The population of the Springerville area is estimated to be 5,600 people and the annual compound growth rate during the past 10 years was 5.8 percent. Future population projections suggest a growth rate of 4.2 percent per year over the next 20 years. As was the case with Alpine, Springerville experiences long winters and very mild summers. Heating degree days exceed 6000 for the Springerville area, making it a good candidate for district heating using geothermal energy.

The economic analysis which follows assumes the existence of a geothermal resource. As was the case with the Alpine analysis, only preliminary studies on the local geothermal resource potential have been performed. The reader should refer back to the Alpine section for resource information.

In this analysis, the economics of a geothermal district heating system are compared for two cases. The first case assumes that the district heating system is established for existing residential and commercial buildings. The second case assumes that a new subdevelopment would be constructed with the intention of using geothermal energy to provide space heating and hot water. In both cases it is assumed that a city utility develops the district heating system. It is also assumed that current energy users consume electricity for their space heat and hot water needs.

For both cases, the geothermal district heating system would consist of 250 residential houses as well as commercial buildings. It is assumed that total commercial demand is equal to 10 percent of residential demand. Estimated total peak demand for the system is calculated to be 10,518,750 Btu/hr. It is assumed that 60°C (140°F) geothermal water could be discovered at 914 m (3000 ft) at a distance of one mile from the site. It is further assumed that the flow rate would be 3780 l/min (1000 gpm). Table 9 presents a summary of assumptions for the analysis.

TABLE 9: ASSUMPTIONS FOR SPRINGERVILLE DISTRICT HEATING SYSTEM

Variable	Assumed Value
Resource Temperature	60°C (140°F)
Depth	914 m (3000 ft)
Flow Rate	3780 l/min (1000 gpm)
Distance	1690 m (1 mile)
Bond Rate (above inflation)	1%
Equity Capital	10%
Taxes (Federal and State)	0
Tax Credits	0
Population	750
Rate of Return (above inflation)	1%
Price of Conventional Fuel (per MBtu)	$10
Project Life (years)	20

Under the above assumptions, two life-cycle costs for geothermal energy were calculated. If the development of a geothermal district heating system involved retrofitting existing homes and commercial buildings, the life-cycle price of geothermal energy was calculated to be $5.53 per million Btu. This price includes the costs for hookup and conversion of each structure to be heated. If a new development were built and designed to use geothermal heat, the price of geothermal energy would be $3.96 per million Btu. In addition, each home would require $1,250 worth of hookup and heating equipment. In both cases, the geothermal price compares quite favorably with local costs for both electricity and propane. In the retrofit case, total fuel cost savings over 20 years would equal $2,618,000; in the new growth case, total fuel cost savings would equal $3,538,000. Table 10 presents an itemized cost summary for the two cases considered.

TABLE 10: COST SUMMARY FOR SPRINGERVILLE DISTRICT HEATING SYSTEM

	Present Value of Capital Costs	
Category	Retrofit Case	New Growth Case
Design	$ 238,011	$ 168,810
Wells*	515,983	515,983
Transmission	146,707	146,707
Distribution:		
Residential Retrofit	466,917	0
Residential Hookup	162,124	0
Commercial Conversion	32,879	0
Heat Exchangers	47,158	47,158
Central System	935,924	935,924
Totals	$2,545,701	$1,814,582

*Well cost includes production wells, injection wells, pumps and lease costs.

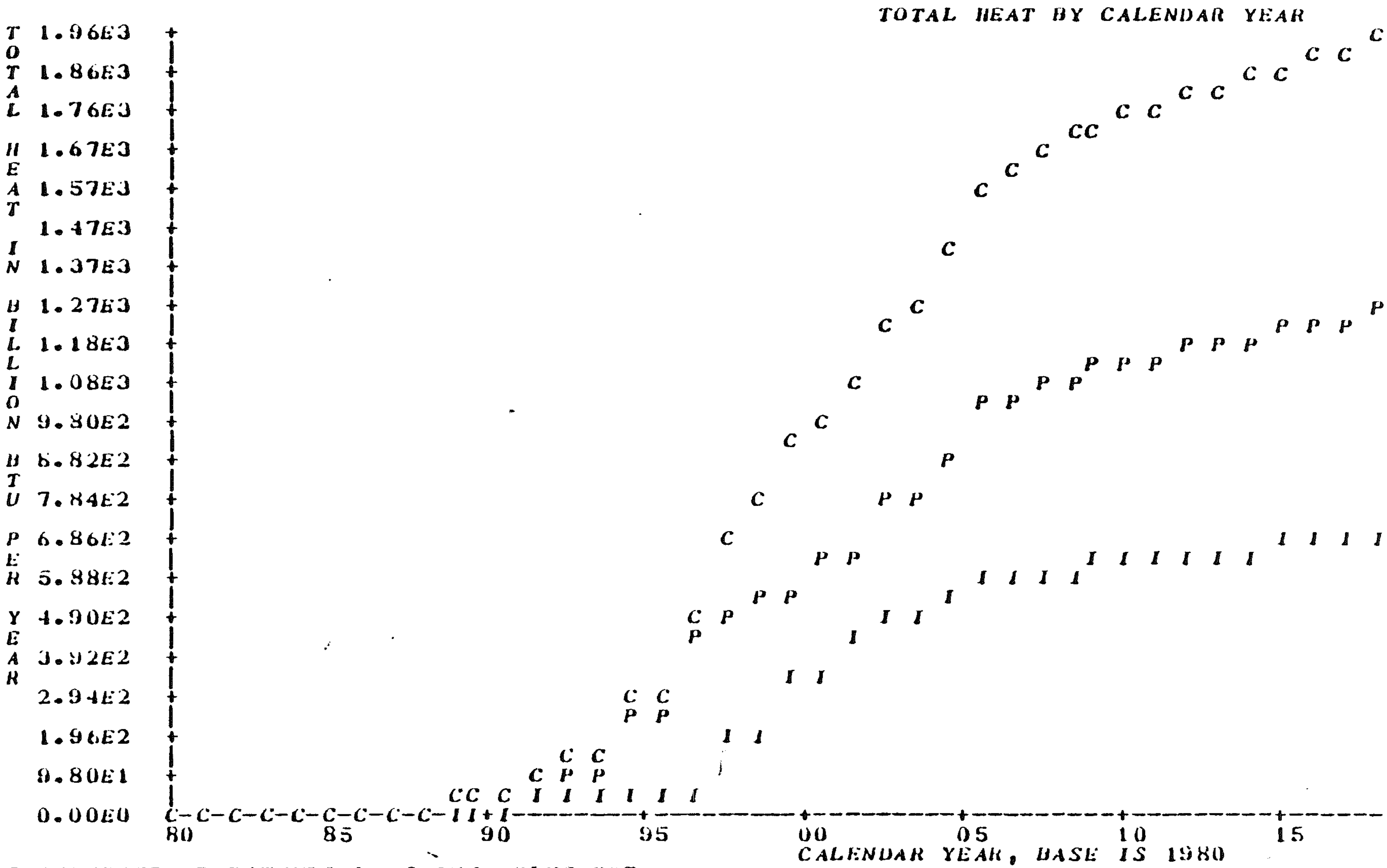
In addition to the capital costs are operating costs which are estimated to be 2.5 percent of the total cumulative investment in each year. These costs are reflected in the total price of the energy.

It is obvious from the above analysis that new growth situations are preferable to retrofit situations for establishing geothermal district heating systems. However, in the new growth situation, energy users must pay for the equipment installed in each home. The effect would be to increase the price of each home or commercial building although the price of the heating equipment is comparable to prices for current furnace units. A second point worth noting is that the system analyzed contains significant excess capacity. Expansion of the heating district to 750 homes would be possible without incurring additional drilling costs.

MATCHING GEOTHERMAL RESOURCES TO POTENTIAL USERS

In order to define a time frame in which geothermal energy will realize commercial use, projections were made of the amount of geothermal energy on line as a function of time. It was with the assistance of the New Mexico Energy Institute (NMEI) that this time line was produced. For modeling purposes, it was assumed that geothermal energy comes on line when its price becomes lower than that of energy alternatives. Projections of geothermal energy on line for industrial process heat under private development and city-owned utility development are presented in Figure 21 and Figure 22, respectively. Projections of geothermal energy on line for the residential, commercial and industrial sectors under private development and city-owned utility development are presented in Figure 23 and Figure 24, respectively.

The figures show that city-owned utility development of a resource occurs sooner than does private development. For example, Figure 21 indicates that under private development geothermal energy for industrial process heat would come on line by 1989 and would rise rapidly to 2020 as prices of other forms of energy increase. Figure 22 shows that geothermal energy for industrial process heat would come on line even sooner (1983) under city-owned utility development with the amount on line rising rapidly to 2005. The major reasons for a resource being



I=INFERRED P=POTENTIAL C=INF. PLUS POT.

STATE: ARIZONA APPLICATION: INDUSTRIAL
PRIVATE DEVELOPER

Figure 21: Projected Geothermal Heat On Line Under Private Development.
Source: New Mexico Energy Institute

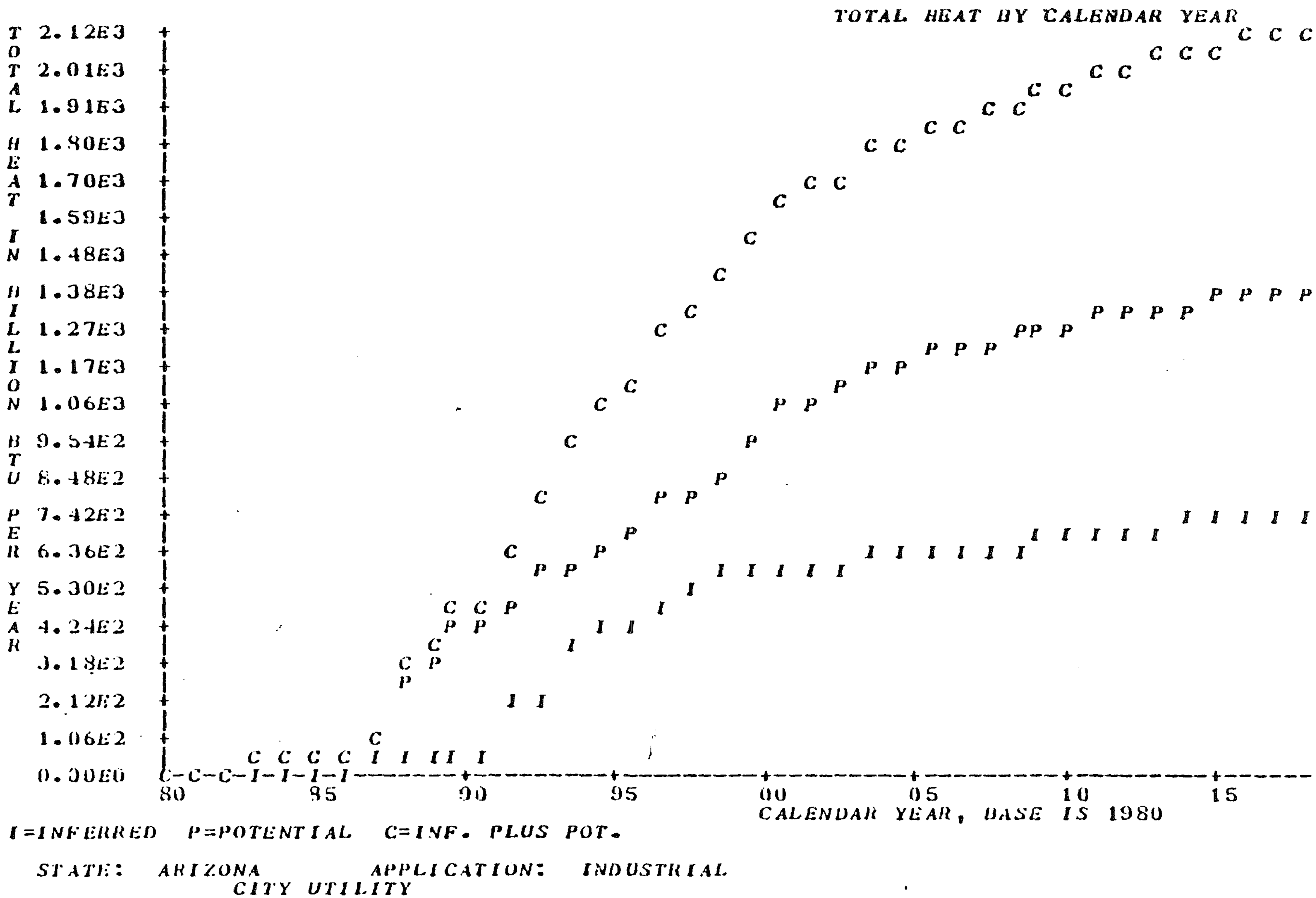


Figure 22: Projected Geothermal Heat On Line Under City Development.
Source: New Mexico Energy Institute

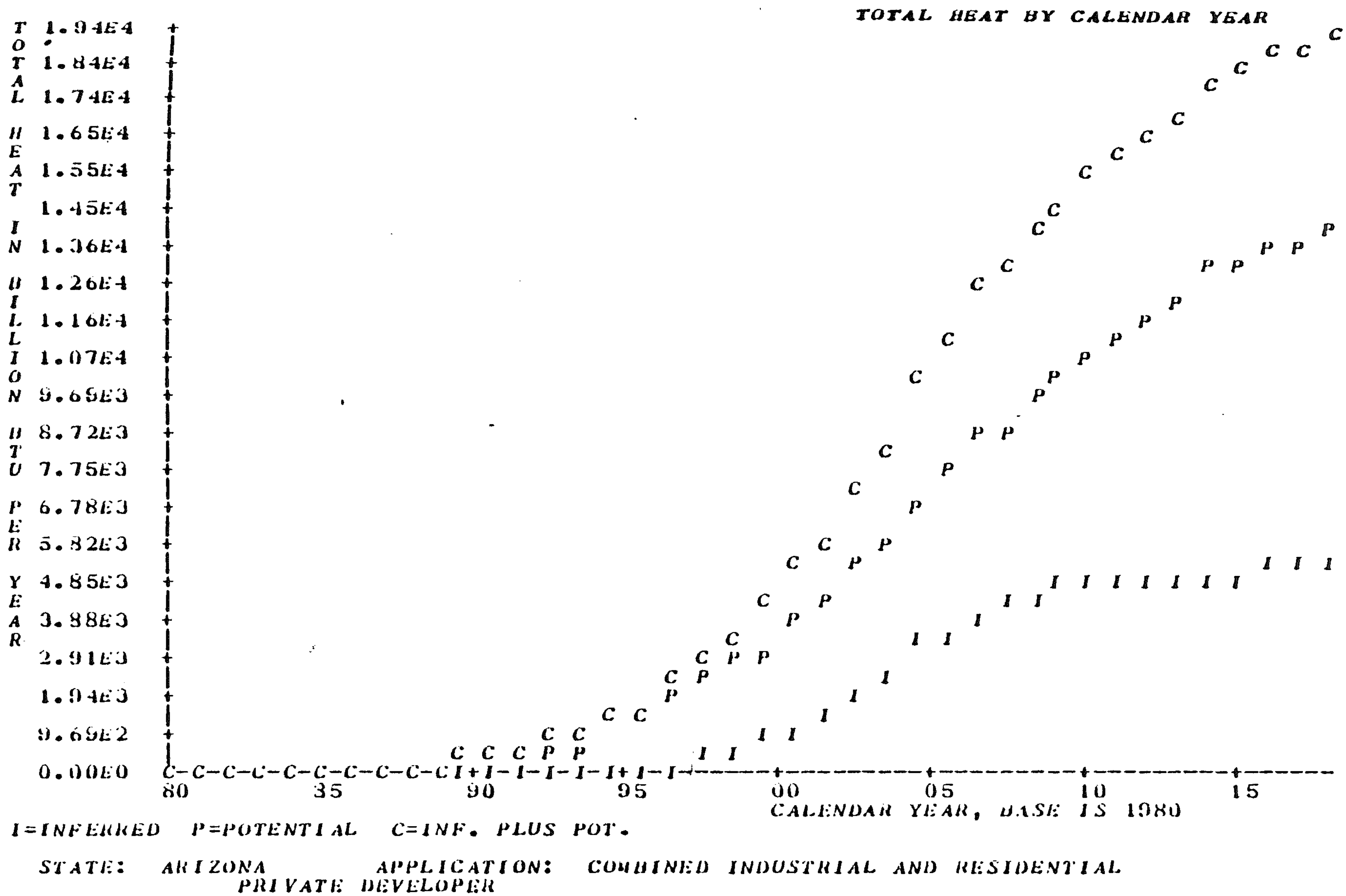


Figure 23: Projected Geothermal Heat on Line Under Private Development for the Residential, Commercial and Industrial Sectors.
Source: New Mexico Energy Institute

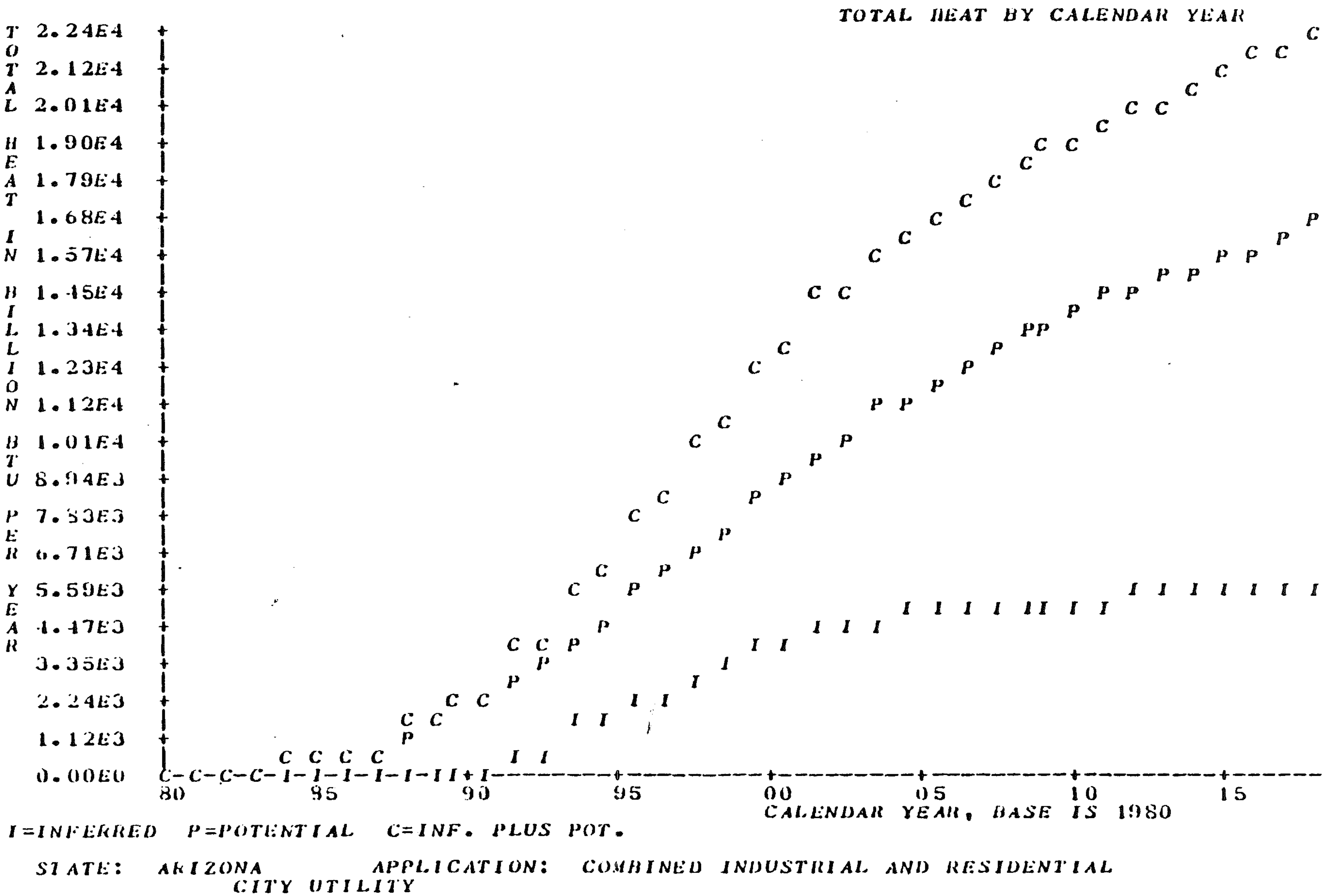


Figure 24: Projected Geothermal Heat On Line Under City Development for the Residential, Commercial and Industrial Sectors. Source: New Mexico Energy Institute

developed more quickly by a city-owned utility than by a private investor are that a city typically has lower capital costs than private industry and a city utility requires a lower rate of return on invested capital. For comparative purposes, Table 11 reports energy on line in terms of barrels of oil replaced annually by geothermal energy.

TABLE 11: BARRELS OF OIL REPLACED BY GEOTHERMAL ENERGY
Industrial Process Heat Market

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

Similarly, Figures 23 and 24 show that geothermal energy for the residential, commercial and industrial sectors (the residential and commercial sectors are combined) comes on line more quickly under city-owned utility development than under private development. Under city development, geothermal energy would come on line in 1983 while under private development, geothermal energy would not come on line until 1989. Table 12 reports energy on line in terms of barrels of oil replaced annually by geothermal energy.

TABLE 12: BARRELS OF OIL REPLACED BY GEOTHERMAL ENERGY
Residential, Commercial and Industrial Markets

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

Further details of the NMEI model for projecting geothermal energy on line are given in Appendix A.

Facilities serving a large number of people are potential users of geothermal energy. In northern Arizona these facilities include high schools, community colleges or universities and airports located in Holbrook, Winslow, Prescott and Flagstaff. Also, several industries located in or near the major cities of the northern counties may be able to use geothermal energy for both their space heating and process heat needs. In Winslow, the Wometco Coca-Cola Bottling Co. of Northern Arizona is a potential user of geothermal energy; Ramsey Logging and Timber Co., located 40 miles south of Winslow, is another potential user. Potential users in Prescott include Aquarium Pump Supply, Quality Plastics of Prescott, U.S. Electrical Motors and Morris Maler Shirt Manufacturing Co. In Kingman, industries which might benefit from the use of geothermal energy include General Cable Co. and Tucker Housewares.

Potential users in Flagstaff include E-Z Mills, Jeld-Wen, Incorporated of Arizona, Ponderosa Paper Products, Ralston Purina Company, Southwest Forest Industries and Spring City Knitting Co. Geothermal applications may also exist for the Snowflake Division of Southwest Forest Industries.

The ready-mix concrete and the sawmill industries of northern Arizona may be able to use geothermal energy for their process heat needs. Potential geothermal applications to processess within these industries, identified by a four-digit Standard Industrial Classification (SIC) code, are discussed below. Estimates of annual energy consumption as well as the process temperatures required by these industries were provided by the Solar Energy Research Institute. Information on the specific heat temperatures needed in each of the operations within these industries was gathered from three principal sources: the Noyes Data Corporation publication entitled "Energy-Saving Techniques for the Food Industry;" Drexel University's Energy Analysis of 108 Industrial Processes, Phase I of an Industrial Applications Study, 1979; and a Survey and Analysis of Solar Energy Process Heating Opportunities in Arizona prepared by the University of Arizona.

Ready-Mix Concrete Industry (SIC 3273)

There are seven large firms within this industry, most of which are located in Mohave County. The principal characteristic of the ready-mix concrete industry is that the concrete is poured wet and is allowed to set at ambient temperature. Therefore, little of the energy consumed by this industry is for process heat. Electricity is used in the crushing and mixing processes while fuel is used for transportation and mixing in transit. However, the industry does require large amounts of hot water for cleaning, mixing and storing. Geothermal energy possibly could be used to heat the water.

Sawmills Industry (SIC 2421)

There are four large mills within this industry located in northern Arizona, principally in Apache and Coconino counties. The process heat temperatures required by this industry never exceed 82°C (180°F) with most of the processes requiring a temperature of 25°C (77°F). Therefore, the assessed geothermal reservoir temperatures of 50°C (122°F) for Coconino County and 95°C (203°F) for Apache County are sufficient for most of the processes within the industry.

Electricity, the dominant energy source in the industry, is used in almost all of the processes. Some of this electricity could be displaced if geothermal energy were used in the washing of logs, bolts and carts (25°C temperature requirement), in operating the drying kiln (25°C temperature requirement) and for space heating.

The results presented in this section suggest that northern Arizona could experience significant geothermal development; however, additional factors may play a significant role to improve the potential for geothermal development. Northern Arizona has good potential for a substantial increase in residential and industrial development and is seeking to diversify its economy away from its traditional rural base. As additional industries and people are attracted to northern Arizona, greater development of its geothermal resource potential will become possible. Also, as additional resource assessment work is performed, greater resource potential may be discovered. Finally, northern Arizona could also benefit from geothermal space cooling as well as space heating, further adding to the use of geothermal energy resources.

Appendix A

The New Mexico Energy Institute at New Mexico State University has developed a computer simulation model, BTHERM, to assess the economic feasibility of residential and commercial district space heating, hot water heating and industrial process heating using low temperature geothermal energy. Another model, CASH, was developed to depict the growth of geothermal energy on line over the next 40 years as a function of price of competing energy sources. A major assumption of these models is that geothermal energy must be price-competitive with the lowest-cost conventional energy source in order to assure market capture.

Development of a geothermal resource is characterized by large capital outlays, but a long-term geothermal investment has the potential to provide relatively inexpensive energy at a stable price. Unlike natural gas and electricity, however, geothermal energy is an unknown energy involving certain risks such as price and reservoir life and the need for back-up systems. An analysis of the costs and economic competitiveness of geothermal energy must take these uncertainties into account. Thus, costs may be overestimated so that the benefits will not be overstated.

BTHERM models the residential, commercial and industrial sectors of a typical city, each sector having unique energy costs and energy system physical parameters as well as different growth rates. The model possesses the ability to model each sector individually and can analyze the application of geothermal energy to new growth only, to conversion of existing structures or to a combination of both. The model also has the capability to model both private and city-owned utility development of the geothermal resource.

Output of the model includes the levelized price per million Btu of delivered energy, the discounted present value of investment necessary and the undiscounted values of investments for policy studies. Also, from input of the price and price growth rate of conventional energy, the model determines the discounted or undiscounted values for federal and state taxes, tax credits, royalty rates, property taxes and consumer savings due to conversion from conventional energy to geothermal.

Certain limitations of the model have already been suggested. Costs, for example, may be overestimated due to safeguards built into the model to take into account the risks associated with geothermal energy. This overestimation of costs might result in the exclusion of a potential use of geothermal energy. Another limitation is that the price of natural gas is taken as the price of competitive (conventional) energy, but not all users have access to natural gas.

The output of the model is not a substitute for detailed engineering design studies but it is useful for determining order-of-magnitude costs and potential benefits of geothermal energy development.

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