OPEN FILE 80-11

COMMUNITY DEVELOPMENT OF GEOTHERMAL ENERGY IN PAGOSA SPRINGS COLORADO

by

Barbara A. Coe

Prepared for the
U.S. Department of Energy
Division of Geothermal Energy
Contract No. DE-79ID-12018

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
STATE OF COLORADO
DENVER, COLORADO

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This report of the Colorado Team for the Southwest Regional Geothermal Development Commercialization Project was funded by the U.S. Department of Energy and the Four Corners Regional Commission. Mr. Richard H. Pearl, Chief, Groundwater Investigation Section, is the Team Leader for the project.

ABSTRACT

The town of Pagosa Springs, Colorado occupies a site around the mineral hot springs that Indian people drawn to the area called "Pagosa," meaning healing waters. Since the early 1900's, geothermal energy has been used to heat buildings in Pagosa Springs, Colorado. With U.S. Department of Energy funding assistance, the town is now planning a district heating system for its central business district.

Historically and currently, unemployment in Archuleta County has been higher than that of the State, incomes are lower than the statewide average, and the County's assessed valuation differs from the statewide average.

Discussions with planners, local officials, and citizens of the Pagosa Springs area indicate that while they would not like to see extreme growth in the area, they would welcome increased economic vitality. They believe that the availability of geothermal energy can provide a helpful incentive to new industrial energy users.

Note: The data in this report were compiled during the first part of 1979.

ACKNOWLEDGEMENTS

A special thanks goes to Fred Ebeling and Vicki Hayes, staff of the Upper San Juan Regional Planning Commission, for the information and help they provided for this report.

The assistance of all those residents and officials of Pagosa Springs and Archuleta County who contributed to the report is also greatly appreciated. And last, but by no means least, thanks to Dr. William Bennett, consultant, for his technical assistance, and to Dr. Richard T. Meyer of Western Energy Planners, Ltd. for his technical review.

The persons who provided information and assistance leading to this compilation are numerous. Sincere appreciation is extended to all those who participated. A special thanks to Richard H. Pearl, for his freely contributing from his store of knowledge of geothermal resources in Colorado; to Shirley Denzler and Becky Andrews for their untiring manuscript typing and to Cornelia Sherry for her help in drafting the illustrations.

INTRODUCTION

The U.S. Department of Energy (DOE) requested as part of the Geothermal Commercialization Project study a detailed analysis of one direct-use geothermal project actually under way. It was believed that such an analysis of the development would help to amplify the required activities, their interrelationships and their time requirements. Further, it was thought that the results, especially a time-phased critical path flow chart, would help identify constraints to geothermal development. Finally, the analysis could serve as a model from which to postulate future development.

Since the early 1900's, geothermal energy has heated buildings in Pagosa Springs, Colorado. With DOE funding assistance, the city is now planning a district heating system for its central business district. Pagosa Springs was, therefore, the logical candidate in Colorado for this detailed analysis. The analysis follows the format of area and site specific studies, but describes in detail the recent, current, anticipated, and postulated geothermal development activities.

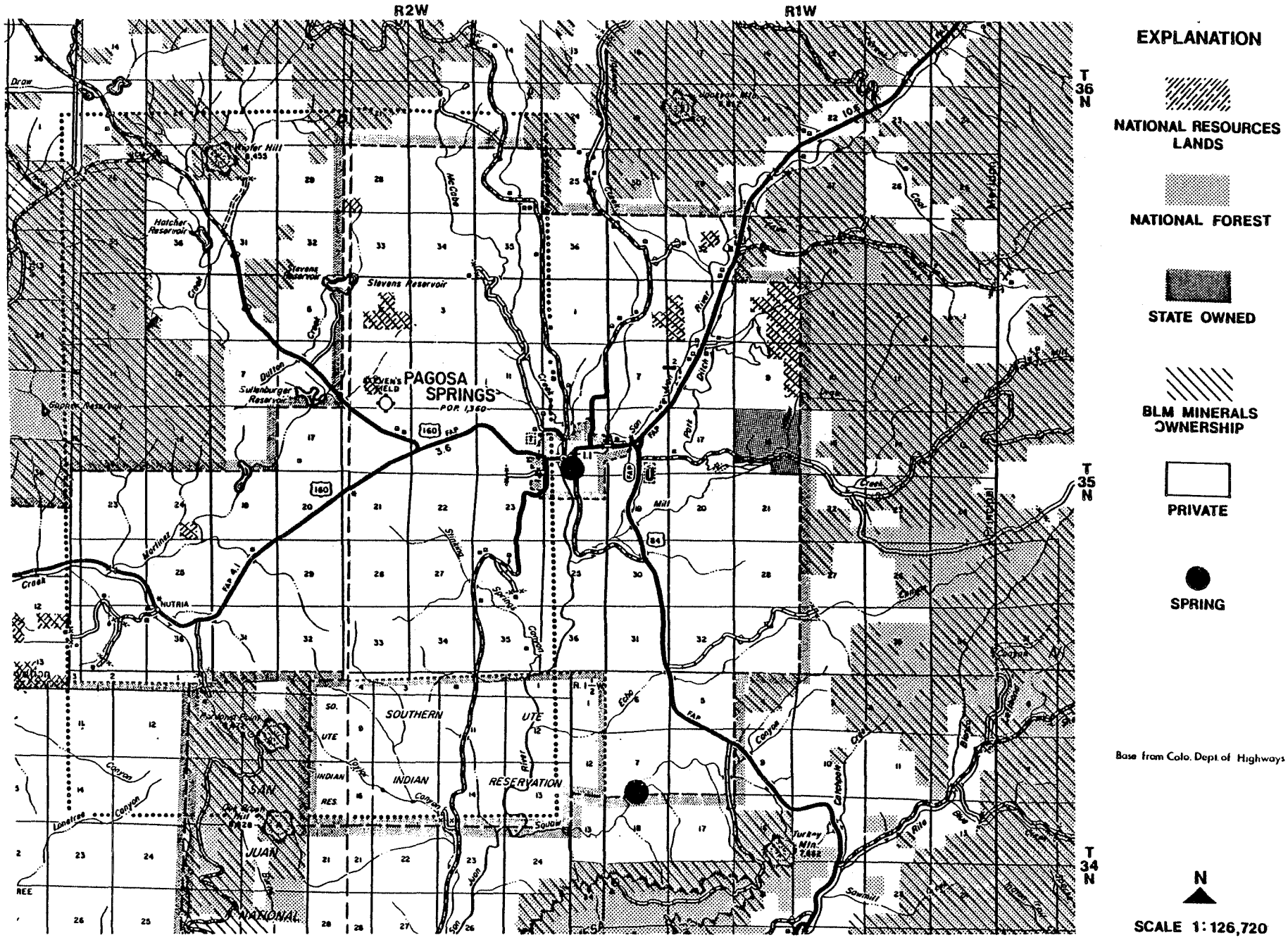
DESCRIPTION OF SITE

The town of Pagosa Springs, Colorado, occupies a site around the mineral hot springs that Indian people drawn to the area called "Pagosa," meaning healing water. The town covers an area of about 887 acres of rolling and valley land in southwest Colorado along the San Juan River as shown in Figure 1. The elevation is over 7,000 feet (Denver Research Institute, 1978). A gateway to the precious mineral areas of southwestern Colorado, it was originally the site of Ft. Lewis, established to protect white settlers from Indians.

National Forest lands cover a large part of Archuleta County, in which Pagosa Springs is located and have historically supplied timber for the industry that is the economic base of the county and town. Along the eastern and northern parts of the county are the San Juan Mountains, with some peaks in this area over 13,000 feet. Exit to the east is through the rugged Wolf Creek Pass. On the south is the Southern Ute Indian Reservation, bordered by the New Mexico line. On the west is La Plata County, with the City of Durango, a regional shopping hub, located about 60 miles to the west.

Land Use and Ownership

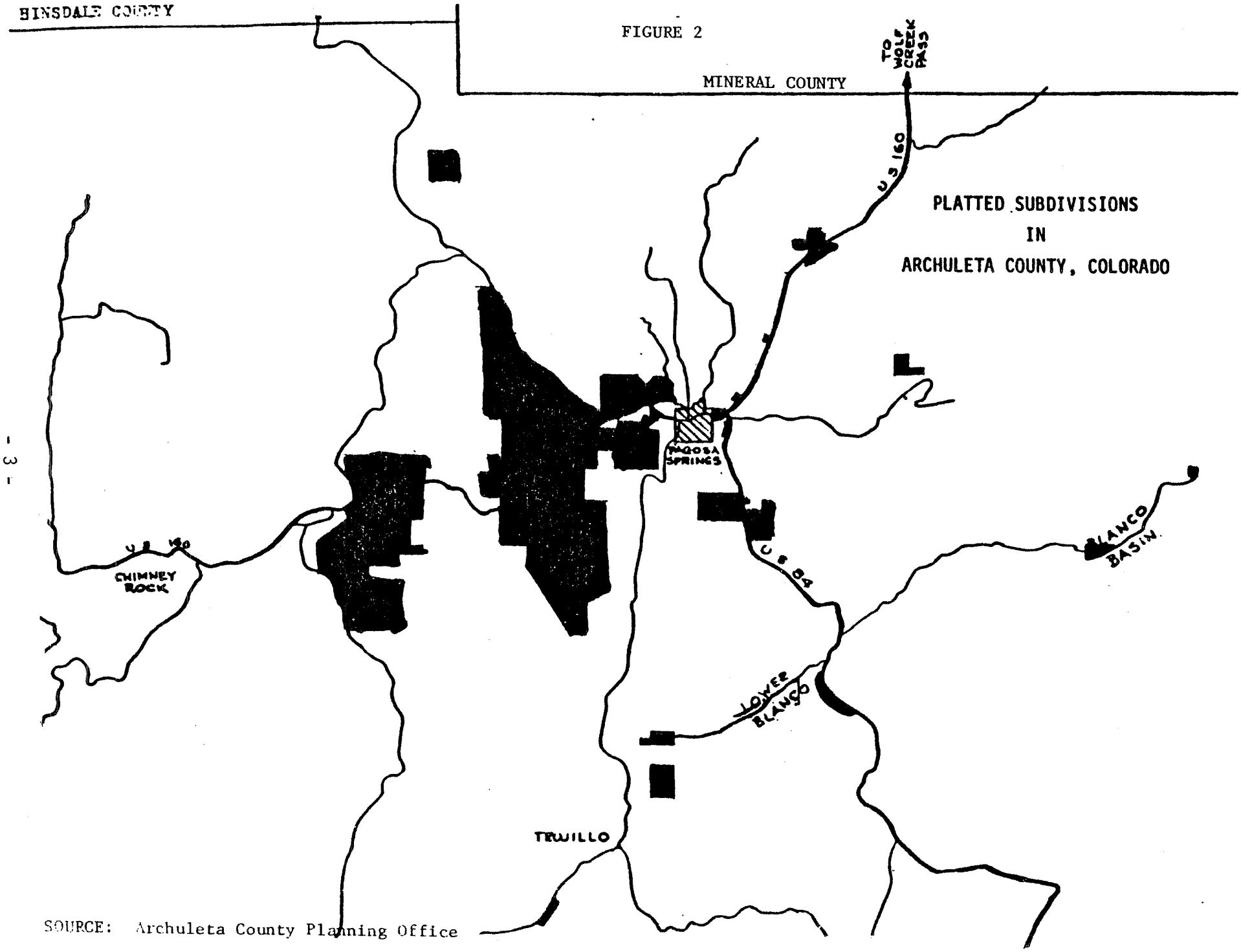
In the entire Archuleta County, 45.8 percent of the land is National Forest, 14.7 percent is Southern Ute Tribal land, and small proportions are Bureau of Land Management and State-operated, leaving only 37.8 percent that is privately-owned. As shown on the map, Figure 2, however, the Town of Pagosa Springs is surrounded by large areas of private land, most of which has been subdivided. The majority of the building is occurring in these subdivisions (Hays, pers. comm.).



LAND AND MINERAL OWNERSHIP OF PAGOSA SPRINGS AREA

FIGURE 1

FIGURE 2



SOURCE: Archuleta County Planning Office

In Pagosa Springs, as shown on Figure 3, the largest percentage of land, 40 percent, is devoted to public and quasi-public use. The next highest is residential use, a total of 25 percent. Business occupies another 9 percent of the land; industrial uses occupy less than 1 percent. The remainder is occupied by the river, and streets and alleys. The majority of the land, 50 percent, is, however, undeveloped. About half of this is privately owned and all but about 11 percent buildable land (BMML, 1978). As the zoning map, Figure 4 shows, large areas of vacant land are zoned commercial, indicating that no rezoning should be necessary to accommodate new commercial growth.

Population

A special census conducted in 1977 showed there were 3,594 residents in Archuleta County, with 1,382 of those residents in Pagosa Springs. An estimated 83 percent, or 2,983 residents, reside in an area within about ten miles of Pagosa Springs, an area referred to in this report as the Pagosa Springs Area. In 1970, a larger percentage of the Pagosa Springs residents than state residents were of school age, with a smaller percentage than statewide in the 20-24 year middle and older age brackets (Archuleta County Planning Office, 1979).

More than half the residents were Spanish-speaking. Since most of the new residents are Anglo-American, this percentage is changing (BMML, 1979).

The 1977 Pagosa Springs residents occupied 511 living units, with an average year-round occupancy of 2.7 persons per dwelling unit. Seventy-five percent of the units are single-family, 18 percent are multi-family, and eight percent are mobile homes. Nearly all residential development in the past 3 1/2 years has been outside the town (BMML, 1979).

The county population was forecast to be 9,000 by the year 2000, with the population of Pagosa Springs forecast to be 2,050 and the Pagosa Springs area forecast to be 8,200, or 91 percent of the county population (County Planning Office, 1978). Extrapolating to the year 2020 indicates over 20,000 residents in the County, 2,900 in the town, and 17,000 in the Pagosa Springs Area.

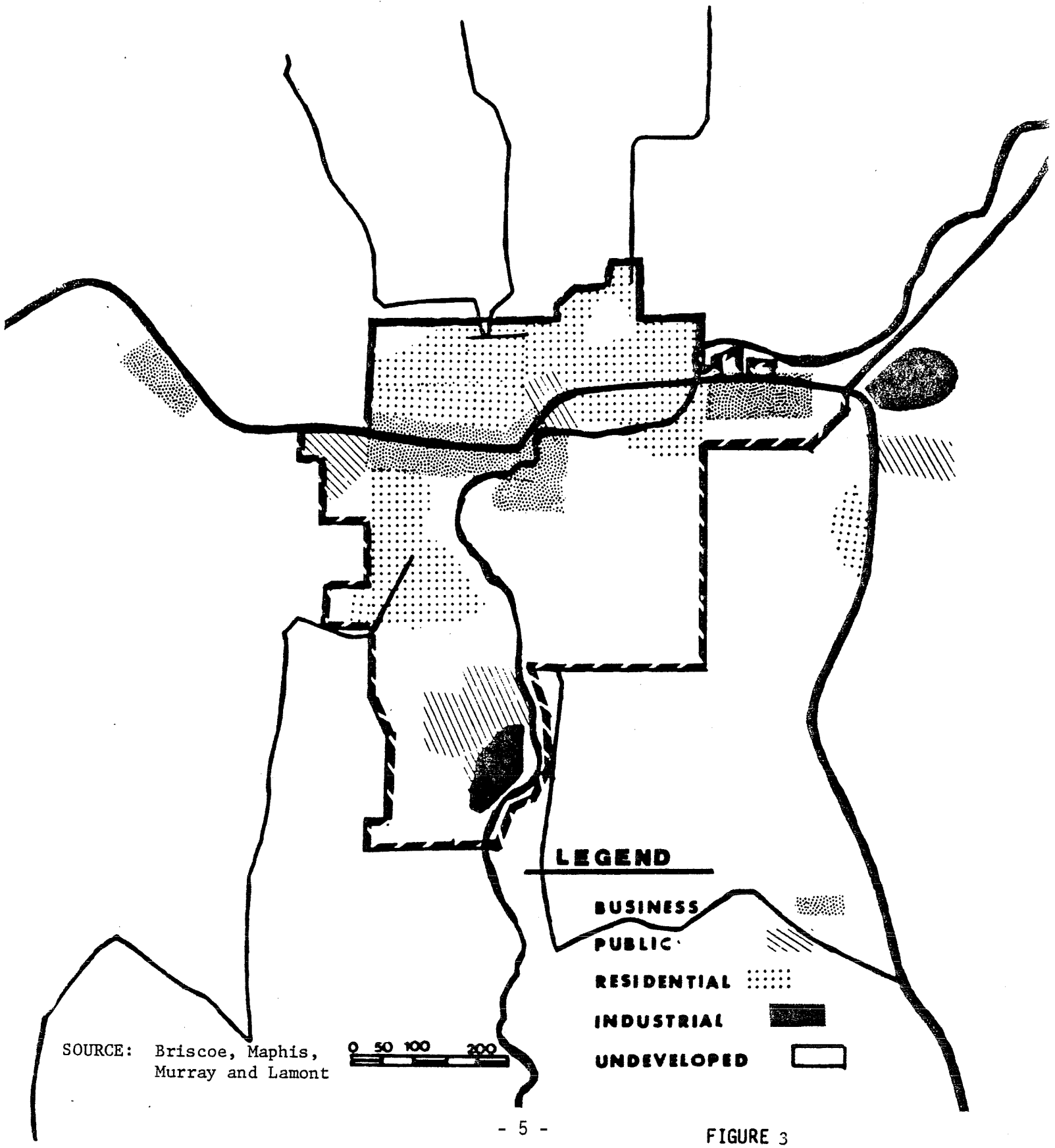
Economic Activity

The timber industry has traditionally been the mainstay of Archuleta County, with 20 percent of the labor force in Archuleta County, and 24 percent of the Pagosa Springs labor force in 1970 employed in the manufacture of furniture, lumber, and wood products (BMML, 1979). The major mill, San Juan Lumber Co., is now closed, however, and may not reopen. Following the mill closing, about 25 percent of the County labor force was unemployed (Fred Ebeling, pers. comm., 1978).

The equipment at San Juan Lumber Co. requires large diameter logs that were obtained primarily from the National Forest. Recently, nearby forest areas have been under review for possible designation as wilderness. During the review period, new roads were prohibited, precluding the opening of new harvest areas (Short, pers. comm.). About 63 percent of the timber has come from U.S. National Forest lands, with only 11 percent of the timber land privately owned (Div. Bus. Res., 1975).

Existing Land Use 1978

PAGOSA SPRINGS, COLO.

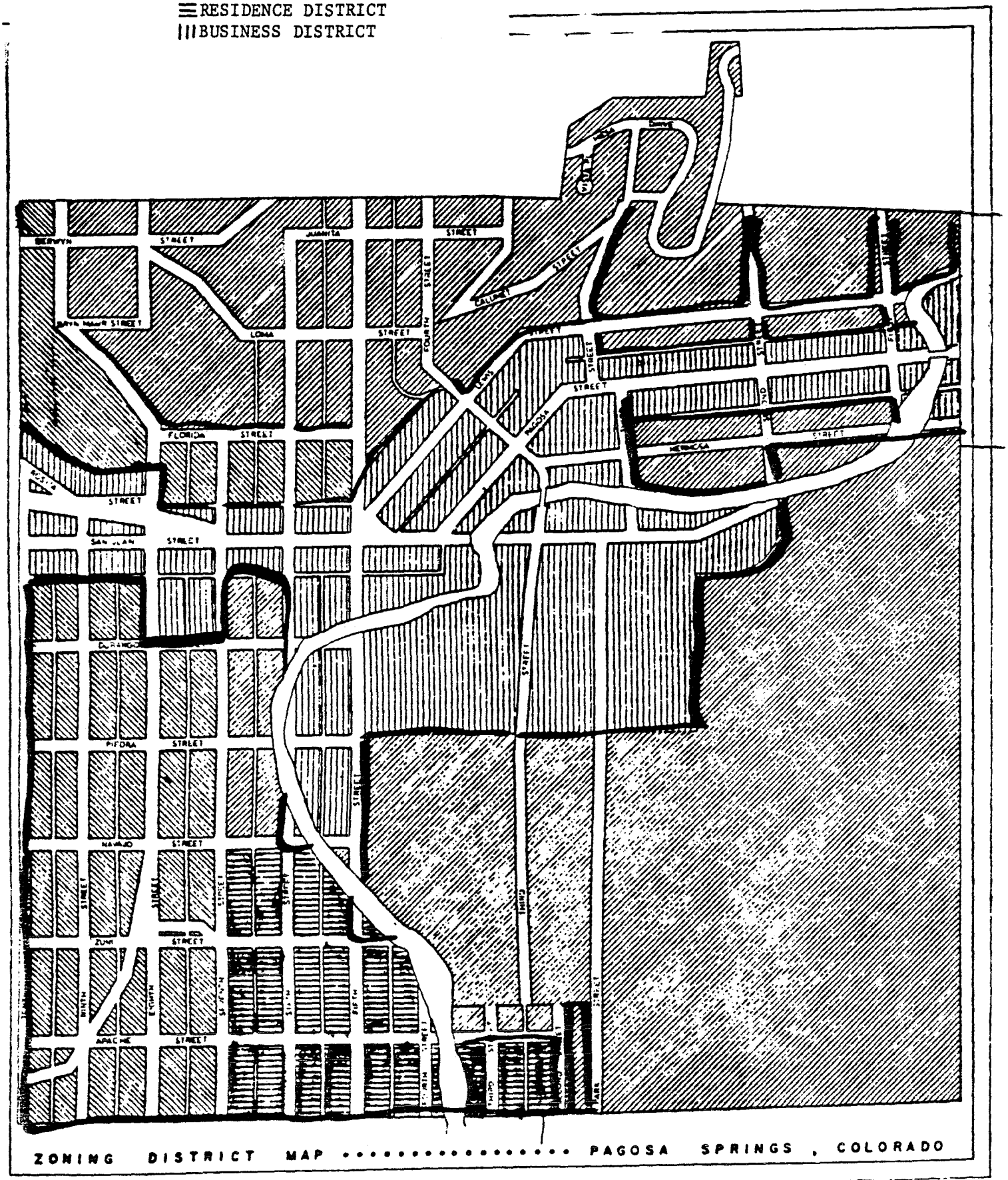


SOURCE: Briscoe, Maphis, Murray and Lamont

FIGURE 3

FIGURE 4

LEGEND:
/// RESIDENCE DISTRICT
\\\ RESIDENCE DISTRICT
≡ RESIDENCE DISTRICT
||| BUSINESS DISTRICT



SOURCE: ARCHULETA COUNTY PLANNING

Following review of the National Forest Roadless Areas, the Forest Service has recommended that a sufficient amount of land be designated non-wilderness to accommodate a proposed ski area northeast of Pagosa Springs. However, since the future of the area has been a controversial issue, the Governor of Colorado has recommended that the area be designated for further study (CGS, correspondence, 1979).

Although field crop production in Archuleta County is minimal because of the short growing season, hay and livestock production are significant contributors to the economy. Livestock raised includes cattle, swine, and sheep (Div. of Bus. Res., CU, 1975).

Mining employed only 2.3 percent of the Archuleta County labor force in 1970 (Div. of Bus. Res., 1975). Historically, the mining activity has consisted of a water diversion tunnel and sand and gravel operations. Although currently some coal is being strip-mined, the lack of a rail system will slow coal production in the area (Div. of Mines).

As shown on Figure 5, other manufacturing in 1970 accounted for only 3.5 percent of the labor force in Archuleta County. Those manufacturers in the Archuleta County area in 1976 are listed on Table 1. As shown, of the 1976 activities, only the manufacture of wood products uses process temperatures within the range found in the geothermal energy in Pagosa Springs.

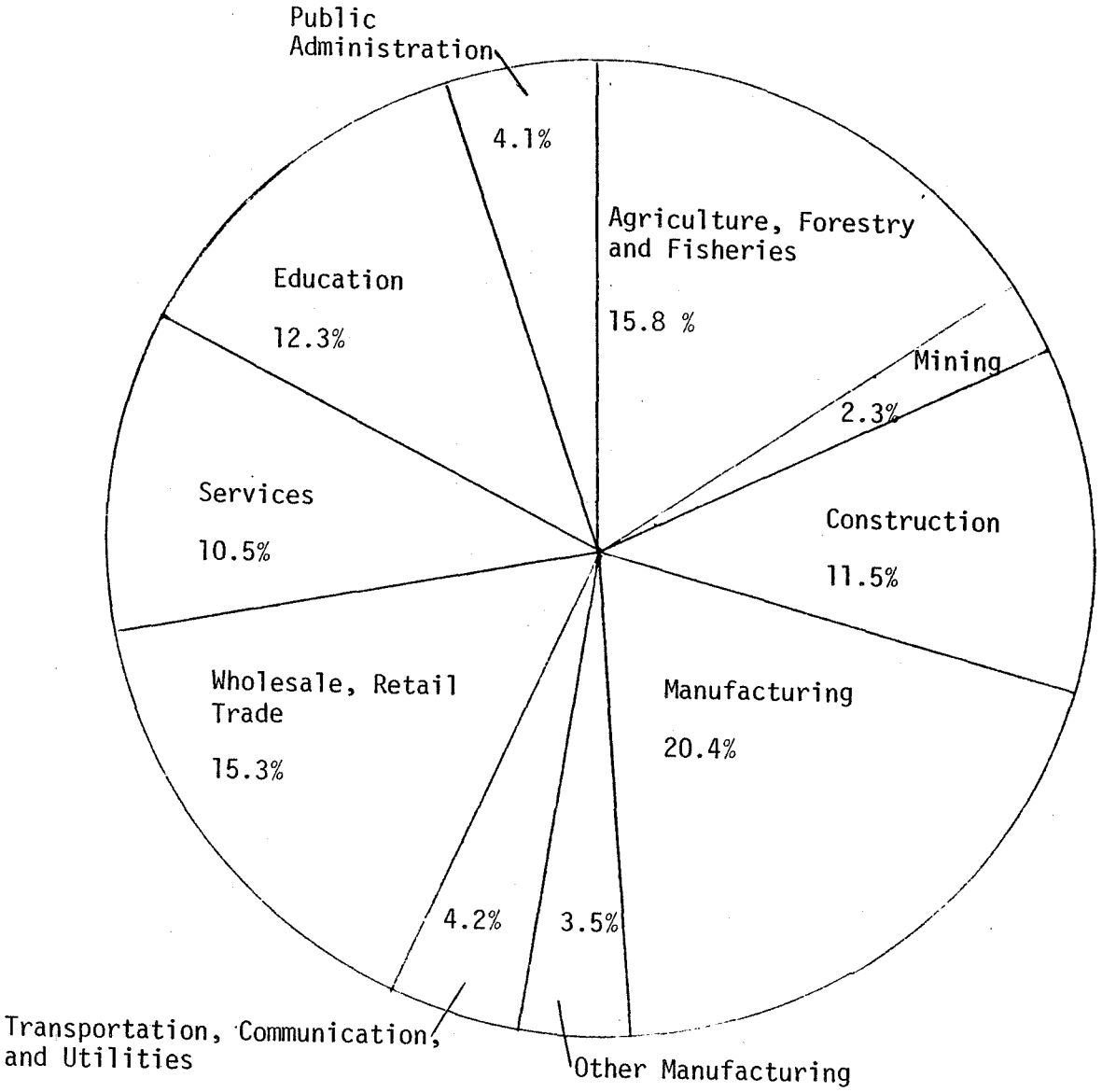
One of the stronger economic sectors in the Pagosa Springs area is wholesale and retail trade, which employed 17.6 percent of the labor force in 1970. Some 160 businesses have been tabulated for the Pagosa Springs area as shown on Table 2. This is about one for every 18 residents.

Associated with the growth of the tourism and recreation industry is the currently active construction industry that is attempting to satisfy the high demand for new homes and commercial structures (Short, pers. comm., 1979).

Shopping facilities will be constructed in the near future at the Pagosa development west of Pagosa Springs. Land there has also been donated for an athletic training camp, to be complete with clinics conducted by well-known trainers (Short, pers. comm., 1979).

Historically and currently, unemployment in Archuleta County has been higher than that of the State, as shown on Table 3. Incomes, too, are lower than the statewide average, 69 percent of the State average in 1974, as shown on Table 4 and Figure 6. As indicated in Table 5, income after taxes per household was less than $8,000 for 42.1 percent of the households in Archuleta County, while in the State, only 25.2 percent earned less than $8,000 (BMML, 1979).

FIGURE 5



PERCENT EMPLOYED BY INDUSTRY GROUP - 1970

ARCHULETA COUNTY

SOURCE: Briscoe, Maphis, Murray and Lamont, 1979

TABLE 1
MANUFACTURERS IN
PAGOSA SPRINGS, COLORADO
1976

Type	SIC Code	Number of Facilities[1]	Estimated Energy Need Per Facility[2]	Primary Process Temperature Required (°C)
Sawmills, Planing mills	2421	3 1/2	0.96	93
Nailed wood boxes & shook	2436	1/2	0.32	93
Newspapers	2711	1/2	0.216	149
Comm. printing, litho	2752	1/2	0.22	149
Special industry machinery	3559	1/2	0.60	1371
Electrical equipment & supplies	3699	1/2	NA	NA

[1] If less than 1, means facility has split functions.

[2] Solar Energy Research Institute, TR-34-091 draft.

TABLE 2
ARCHULETA COUNTY BUSINESS
1979

ATTORNEYS
Hamilton, Hamilton & Shand
Larsen, James C.
Candelaria, Roger

AUTOMOTIVE DEALERS, SERVICE STATIONS, ETC.
Buehler's Garage
Circle K Store #88
Johnson Chevrolet
Pagosa Conoco
Pagosa Ford Sales
Pagosa Texaco
Plateau Service
Poma Distributing
San Juan Chevron
Snow's Wrecker & Repair Service
D-J's Automotive
Superior Automotive
Tom's 66 Service
Turkey Springs Trading Post
Wayside Texaco
Walter's Body Shop
Jim's Glass & Body Shop

BUILDING CONTRACTORS, BUILDING SUPPLIES, BUILDING SERVICES
Backus Electric
Action Electric
Bleeker Blackhoe
Boyne Falls homes
Boise Cascade Homes
Brack Plumbing & Solar (wholesale)
Beeman Drilling
Caldera Construction
Cummings Construction
Earthworks West
Hatfield Construction
J Bar J Model Homes
J.R. Wilson Backhoe & Construction
Justice Log Homes
Ken Hamblin Construction
Lucky A. Construction
Ludwig Construction
Martin Construction
Mings Construction
Ram Electric
Ramrod Construction
Santana Luhan Construction
San Juan Electric
San Juan River Resort (modulars)
Sanders Drilling
Shaw Construction
Shawnee Construction
Tabor Construction
Tully Hill Construction
Tuttle Backhoe
W.C. Construction
Western Dan Construction
Wall Backhoe
Randy's Rock Work
Burnett Construction
Fitzhugh Backhoe
Highland Plumbing
Montano Cement Contractors
Pagosa Electric
Rocky Mtn. Trenching

BUILDING MATERIALS, SUPPLIES, HARDWARE
Crawford Overhead Door Co.
Day Lumber Co.
Hawking Trucking
Pagosa Glass
Pagosa Hardware
Ray Lumber Co.
Burnett Ready Mix
San Juan Supply
Snow Lumber
Pagosa Floors & Lights
Fryer Calmets
Tardiff Cabinets
Moore Cabinets
Martinez Carpets

Table 2 continued

CAMPGROUNDS
Blanco River Trailer Park
Chinde's Campgrounds
Elk Meadows Campgrounds
J Bar J Holiday Park
KOA Campgrounds
Sportsman Mobile Camping

CHURCHES
Assembly of God
Catholic Immaculate Heart of Mary
Church of Christ
Church of Jesus Christ of Latter Day Saints
Community Methodist Church
First Baptist Church
Jehovah's Witnesses
Mountain View Baptist Mission
Our Savior Lutheran
Pentacostal Mission
Pagosa Community Church
Seventh Day Adventist

CLEANERS, LAUNDRIES
KOA Campgrounds
Pagosa Laundromat & Cleaners
Solar Mall Wash & Dry
Town & Country Cleaners

COMMUNICATIONS
Backdoor Print Shop
Cowart & Co.
Pagosa Springs Sun
REACT (volunteer CB emergency)
Universal Telephone
UNICOM (airport)
Western Union Telegraph

EATING AND/OR DRINKING ESTABLISHMENTS
Adobe Tavern
Al's Cafe
Chimney Rock Rest. & Pint Jar Bar
Elkhorn Cafe
Hitching Post
Hole in the Wall
Hub Dairy Creme
Gallery Lounge
Inn at the Pass & Wild Wolf Tavern
Jan's Cafe & Pizza Cellar
Jerry's Chicken
La Cantana
Middle Earth Deli
Navajo Sportsman
Pagosa Bar
Pagosa Lodge
Poor Irishman
Relay Station
Rocky Mt. Mining Co.
Spring Inn
Super Scoop Ice Cream
Thunderbird Lodge

FINANCES
Cress Insurance
Citizens Bank of Pagosa Springs
Engles Accounting
Farmers Insurance
High Country Title Insurance
Louis Wright (income tax)
McClendon, Phillip, C.P.A.
Mesa Verde Saving & Loan
Pagosa Insurance Co.
Ted Lattin (income tax)
Turner Industrial Bank
Wolf Creek Insurance

Table 2 continued

FOOD, GROCERIES

Circle K Store #888
Chromo Mercantile
Hersche's Supermarket
J's Market
KOA Campground Store
La Tienda del Campo
Morningside Bakery
Marquez Grocery (Arboles)
Nature's Own
Piedra Store
Sportsman Supply
Walker Store (Arboles)
Wayside Market
Turkey Springs Trading Post

FURNITURE, APPLIANCES, REPAIRS

Biggens Barn (antiques)
Clark Radio & TV
Frank's TV Repair
Gambles
George's CB Shop
Lister's Furniture
Pagosa Floors & Lights
Pagosa Furniture Unlimited
Pagosa Glass
Furniture House
Thunderbird Electronics

GENERAL MERCHANDISE, DEPARTMENT STORES

Alley's Mercantile
Boot Hill
Chromo Mercantile
Goodman's Store
The Fabric Store
Montoya's Store
Petit Pincushion
Montgomery Ward's Catalog
Pioneer West
The Smart Shop

GIFT SHOPS

Crafts for Christ
Feed Store
Gallery of Art
Heritage House
Kurio Korral
Little Indian Shop
Lazy G Enterprises
Pagosa Taxidermy & Gifts
High Country Creation
Rocky Mtn. Aspen Gifts
Rocky Mtn. Taxidermy
Jan's Gift Shop
The Attic
The Studio
Thompson's Stained Glass

HAIR CARE

Ray's Barber Shop
Mullins Barber Shop
Phoebe's Beauty Shop
Tina's Beauty Shop
Your Beauty Shop

LIQUOR

Jackish Drug
Silver Solar Liquors
West Side Liquors
Wil's House of Bottles

LODGING, GUEST RANCHES, GUIDE SERVICES

Adobe Inn
Bruce Spruce Ranch
Cheeri Chateau
Chromo Mercantile
Chimney Rk Game Processing
Harvey's Motel
Inn at the Pass
Indian Head Lodge
Notch Ranch
Packsaddle Ranch

Table 2 continued

Lodging, Guest Ranches, Guide Services, continued

Ft. Williams Motel
Park Lane Motel
Piedra River Resort
Pinon Hills Lodge (Arboles)
Regester Cattle Co.
Cats Paw
Rock Ridge Motel
Pagosa Hotel
Pagosa Lodge
San Juan Motel
Sky View Motel
Spring Inn & Restaurant
Thunderbird Lodge

MARINA

Navajo Lake Marina
Seibel's Boat Storage

MEDICAL

Ambulance Service
Davis Randall, D.D.S.
Dr. Mary Fisher Medical Clinic
CO. Mounted Rangers (Vol. emergency)
Janssen, Gary, M.D.
Johnson, Ray, Med Tech
Marquez, Leonard, D.D.S.
Pagosa Veterinary Clinic

MISCELLANEOUS

Abel Martinez Carpet Cleaning
Adam's Apple Tole Shop
Avon Products (Mae Boughan)
Bob's LP Gas
Citizens Utility
Crouse Welding
Blue Sky Photo
Photography Shop
Pagosa Sun Office Supply
Secretarial Services by Lynda
Shakley Products (Linda Rose)
San Juan Native Nursery

Miscellaneous continued

Great American Music Co.
Fullerbrush (Dorothy Masco)
Jackish Drug
La Plata Electric
Mesa Theater
Minor's Storage
J.H.J. Disposal
Pagosa Answering Service
Pagosa Drafting Service
Pagosa Jeweler's
Pagosa Lodge Health Spa
Bill's Welding & Repair
Bob's Casing Crews, Inc.
Shrives Trout Ranch
Snow's Pagosa Hide & Fur
Snow's Welding & Repair
Southwest Disposal
Southwest Surveyors
Spa Hot Baths
U-Haul Rentals
Swap & Shop
Warr's Lapidary
Wayne's Service
Wolf Creek Trees & Traders
Wilsey's Professional Building
Lynch Mortuary

REAL ESTATE

Aspen Springs Associates
Eaton International Corp.
Chinde's Realty
Century 21
Colorado Properties
Holiday Acres
Pagosa Realty
Rawhide Realty
March Realty
San Juan River Resort
Southwest Co. Realty
United Realty

Table 2 continued

SPORTING GOODS

Colorado Canyon Sports
PaGo Shop
Pagosa Golf Shop
Pagosa Tennis Shop
Pagosa Springs Trading Co.
Pagosa Springs Trading Post
Ski Cellar
Sportsman Supply
Total Sports
Gunn Runners
House of Muskets
Pagosa Hardware

TRANSPORTATION

Continental Trailways
Air Charter Service
Pagosa Springs Aviation
Pagosa Rental Cars
Rio Grande Motorways
George's Trucking

WHOLESALERS, LIGHT, INDUSTRIAL

Boot Hill
Brack's Plumbing and Solar
Furniture House
House of Muskets
Four Corners Sheltered Workshop
Chimney Rock Coal Co.
Morningside Bakery
Miniature Automation
Pagosa Water Conditioning Service
Pagosa Sun Printing
Wolf Creek Industries

MUNICIPAL SERVICES

Daily Bus Service (Continental Trailways)
United Parcel Service
Ambulance Service
Charter Air Service
1 airport (5860 paved runway x 60')
1 jet airport (La Plata County)
2 swimming pools
1 radio station
1 weekly newspaper
3 major TV stations, 1 area station
13 Churches
County Sheriff Dept.
Local Police Dept.
2 volunteer fire departments
3 banks (1 full service bank)
Headquarters for 2 Ranger Districts (Natl. Forest)
Colorado State Patrol Officers
3 Wildlife Conservation Officers
1 library
3 schools
24 hour emergency phone for fire, police, medical
1 golfcourse
1 medical clinic
1 car rental service
Universal Telephone Company
La Plata Electric Company

SOURCE: Upper San Juan Regional Planning Commission

TABLE 3
LABOR FORCE AND UNEMPLOYMENT BY YEAR

YEAR	ARCHULETA COUNTY Total Labor Force	ARCHULETA COUNTY Percent Unemployed	STATE OF COLORADO Total Labor Force (000s)	STATE OF COLORADO Percent Unemployed
1970(a)	910	9.0	862	4.2
1974(b)	1095	9.8	1131	4.1
1975(b)	1093	12.2	1151	7.0
1976(b)	1180	8.6	1213	5.9
1977(b)	1252	13.9	1250	6.2
April 1978(b)*	1500	25.3	1256	5.7
July 1978 (b)*	1480	17.9	1319	5.5
November 1978(b)*	1195	12.5	1324	4.9

(a) Source: Bureau of the Census, 1970 Census of Population, Colorado, Civilian labor force 16 years old or over.

(b) Source: Colorado Division of Employment and Training, Research and Analysis Section, official labor force estimates for federal programs, based on U.S. Bureau of Labor Statistics household survey.

*1978 labor force and employment data is projected, not actual data.

Source: Briscoe, Maphis, Murray and Lamont, 1979.

Table 4

MEDIAN FAMILY INCOME

	1970	1975
Archuleta County	$7407	$9851
% of State	77.5	75.8
San Juan Basin	N.A.	10,072
% of State	N.A.	77.5
State of Colorado	$9552	$12,990

Source: Southwest Colorado Economic Development District, Durango, Colorado, Southwest Colorado Regional Overall Economic Development Program, April, 1978.

TABLE 5

EFFECTIVE BUYING INCOME (EBI)[a] - 1977

	ARCHULETA COUNTY	STATE OF COLORADO
Median Household EBI	$9300	$14,440
% of State Median	64.4	
Percent of Households by EBI Group:		
Less than $8,000	42.1	25.2
$8,000 - 9,999	13.8	7.1
$10,000 - 14,999	24.3	19.9
$15,000 - 24,999	15.0	31.3
$25,000 plus	4.8	16.5
	100.0	100.0

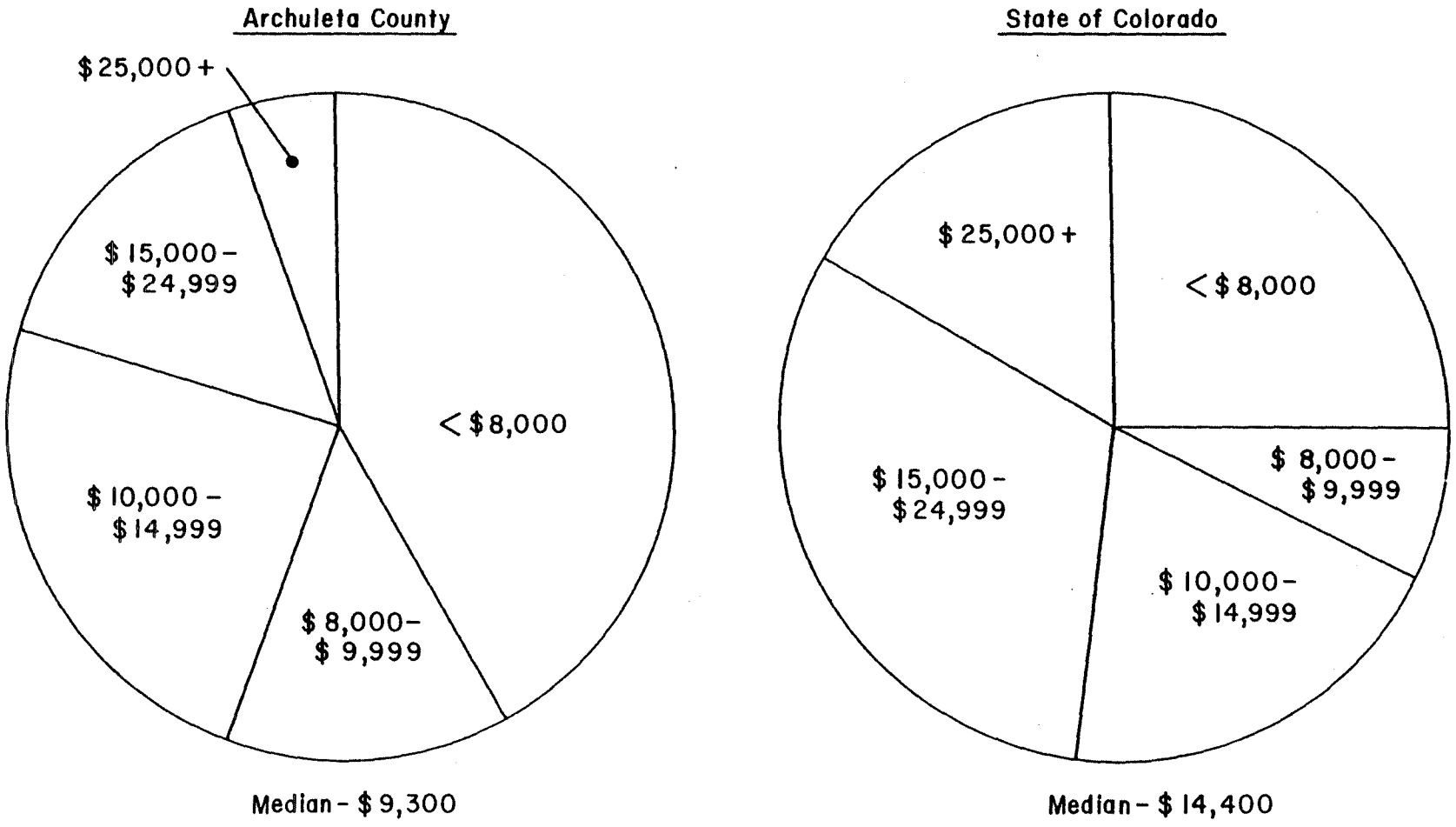
(a) Income after taxes.

Source: Sales and Marketing Management, July 24, 1978.

SOURCE: Briscoe, Maphis, Murray and Lamont, 1979.

FIGURE 6

EFFECTIVE BUYING INCOME* PER HOUSEHOLD - 1977



* Income after taxes

Source: Briscoe, Maphis, Murray & Lamont

TABLE 6

NATURAL GAS CONSUMPTION

PAGOSA SPRINGS, PAGOSA AND BAYFIELD

COLORADO

1977

RESIDENTIAL		COMMERCIAL		TOTAL	
MCF	NUMBER OF CUSTOMERS	MCF	NUMBER OF CUSTOMERS	MCF	NUMBER OF CUSTOMERS
30,941	296	52,050	102	82,991	398

SOURCE: PUBLIC UTILITIES COMMISSION, 1979

The County's assessed valuation differs from the statewide average, as well. Sixty-six percent of the valuation is from residential properties as contrasted with 45 percent statewide. Although the town's residential tax base is similar to the statewide average, the per capita assessed valuation is $2265 compared with $4023 for the state. The town has no general obligation debt, except for water utility improvements, which are exempt from the debt limit. This leaves their bonding capacity at $364,000. However, the Sanitation District, which is separate from the town, has an outstanding debt of $135,000 (BMML, 1979).

The sales tax is contributing less than it might, since the amount levied is 1 percent, while that allowed is 4 percent. Some seventy percent of the sales tax collected by the county and then split equally with the town is collected in Pagosa Springs (BMML, 1979).

Attitudes

Discussions with planners, local officials, and citizens of the Pagosa Springs area indicate that while they would not like to see extreme growth in the area, they would welcome increased economic vitality. They believe that the availability of geothermal energy can provide a helpful incentive to new industrial energy users.

Energy Demand

In order to estimate the energy demand for Pagosa Springs, the natural gas consumption in 1977 was investigated. As shown on Table 6, of the total natural gas consumed of 82,991 Mcf, residential users consumed 30,941 MCF and commercial users consumed 52,050 MCF. This is approximately 55 million Btu per residential customer and 300 million Btu's per commercial customer (Public Utilities Commission, 1979). The residential consumption is low relative to

the statewide average of 89 million Btu, probably because of the widespread use of wood to supplement other fuels. The commercial consumption relative to the residential consumption may be exaggerated because the commercial facilities at the Eaton development use natural gas while the residences do not.

Because of these disparities it was necessary to calculate rather than use than natural gas consumption to estimate the requirement for thermal energy in the Pagosa Springs area. The calculated average thermal demand was 135 billion Btu's, a figure that seems more reasonable given the 8400 degree days recorded in Pagosa Springs. Because the ratio of commercial to residential natural gas consumption in West Slope communities is about 1:1. The 1:1 ratio was used to estimate commercial demand in the Pagosa Springs area. Using these estimates, thermal energy demand was estimated for Pagosa Springs, the Pagosa Springs area and Archuleta County for 1977. Forecasts for the year 2020 assumed steady energy demand per customer and a steady commercial/residential consumption ratio (Table 7).

No natural gas customers were classified by the supplier as industrial. As was shown in the list of manufacturers, manufacturing activity in the area is scant. Attempts are being made to stimulate light manufacturing in the area to enhance the economic conditions.

A moratorium on natural gas taps has been in effect in the Pagosa Springs area, resulting in the installation of electric and propane heating systems in new buildings. Recently, the distributor indicated that moratorium had been lifted, with about 70 more gas customers being served as of April, 1979. However, residents of the area understand that new taps are still limited. And, regardless of the availability of natural gas, the current and projected price enhances the development of alternative systems. Beginning April 1, 1979, the average cost for natural gas per residence in the service area including Pagosa Springs was $2.90 per million Btu (Citizen's Utilities, oral comm., 1979). If an efficiency of 70 percent is assumed for that natural gas, the cost per million Btu is $4.07.

REQUIREMENTS FOR GEOTHERMAL ENERGY DEVELOPMENT

Institutional Considerations

Geothermal leases are often required prior to exploration for or of geothermal energy development. As shown on Table 8, geothermal leases are held by General Geothermal, Inc. on slightly less than two sections of State land near Pagosa Springs (State Land Board, 1979). Since most of the land in the area is privately-owned, were leases necessary, they would have to be obtained from private owners. The time and effort required to obtain leases can, therefore, vary enormously.

Distribution lines for geothermal development in the City can be located on existing City property. Were a system to be extended beyond the City boundaries, rights-of-way might be necessary. Most of this property would also be private, except where existing State or County road rights-of-way could be used. Again, the ease of obtaining right-of-way on private property is somewhat unpredictable. It is not expected that obtaining rights-of-way from the State or County would present any special problems.

In Pagosa Springs and outside the city in Archuleta County, State permits will be required for development of a geothermal system. Those permits include a

TABLE 7
RESIDENTIAL AND COMMERCIAL
ESTIMATED THERMAL ENERGY DEMAND
PAGOSA SPRINGS AREA AND ARCHULETA COUNTY, COLORADO

LOCATION	POPULATION 1977	DWELLING UNITS 1976	THERMAL ENERGY DEMAND 10^{10} BTU'S	FORECAST POPULATION 2020	FORECAST DWELLING UNITS 2020	FORECAST THERMAL ENERGY DEMAND 10^{10} BTU'S
PAGOSA SPRINGS	1,382	511	13.8	2,904	1,075	29.0
PAGOSA SPRINGS AREA[1]	2,983	1,105	29.8	17,796	6,591	178.0
ARCHULETA COUNTY	3,594	1,331	35.9	20,700	7,667	207.0

SOURCES: U.S. BUREAU OF THE CENSUS AND ARCHULETA COUNTY PLANNING OFFICE.

[1]APPROXIMATELY 10-MILE RADIUS

waste water disposal permit for the disposal of new pollutants into municipal waste treatment facilities or for disposal into streams or rivers. Since the spring and several wells are presently discharging to the river, an initial heating district would probably substitute its geothermal waste discharge for the existing discharge. Subsequent development could require reinjection into subsurface aquifers. The fluid may be reinjected into the formation from which it came after obtaining a permit from the staff. If reinjecting into a different formation is contemplated, the Commission itself must approve the application (Water Quality Control Commission, oral comm.).

No permit should be required for the City of Pagosa Springs to construct and operate a geothermal heating district, since municipalities are legally permitted to "operate water works, power plants, heating plants" within and outside their boundaries as long as they are local in the area (C.R.S. 40-1-101). However, since the legislation does not refer specifically to geothermal energy, the authority of towns to operate geothermal systems may at some point be questioned. (Archibald, oral comm.).

TABLE 8
ACTIVE GEOTHERMAL LEASES ON PUBLIC LANDS
PAGOSA SPRINGS AREA, COLORADO

JUNE, 1979

Lessee	Lessor	Acres Leased	Description	County
General Geothermal	State	560	35N; 1W, Sec. 16: E/2; NW/4; N/2 SW/4	Archuleta
General Geothermal	State	640	35N, 2W, Sec. 36	Archuleta

To drill additional wells in the Pagosa Springs area, permits will be required from the Oil and Gas Conservation Commission (Piro, pers. comm.). Applications are reviewed by the State Engineer to determine whether any detrimental effect upon prior water rights would be experienced. If the geothermal system is considered to be a non-tributary system, that is, not tributary to a river, only 1/100th of that water considered to be obtainable from under the land surface can be removed per year. In that event, a developer would be required to obtain the water rights from large tracts in order to develop the energy.

If the geothermal water is related to surface water, a plan of augmentation is necessary in order to replace that surface water. The water of the San Juan River waters have not been completely allocated, so water would probably be available. Since the Town of Pagosa Springs owns surplus water, their water supply should be sufficient for an initial heating district at least, and perhaps for more widespread use (Hays, pers. comm.). If the geothermal system should be determined to be non-tributary, the town could be delayed in obtaining sufficient water for their system.

Some institutional considerations are indirectly related but significant to geothermal development. The financing of facilities using geothermal energy can be difficult where lenders are unfamiliar with the dependability of the

energy resource. In the Pagosa Springs area, both the commercial bank and the savings and loan are convinced of the resource practicability and indicate they will not hesitate to finance buildings with geothermal heating. However, the banks' funds have been insufficient for the demand in recent months. (Winter, oral comm.).

Zoning restrictions can sometimes preclude or delay proposed geothermal development where the proposed facility does not conform to the existing zoning or zone requirements. However, in Pagosa Springs, ample land seems to be zoned "commercial" and "industrial" to accommodate any potential development. The County outside the incorporated municipality is thus far unzoned.

Additional sources of potential institutional barriers or delays are constractual requirements, obligations and delays. Pagosa Springs learned in October, 1978, that they would receive a grant from the Department of Energy to help fund their geothermal development. A contract was, however, not in place until July of 1979, because of the time required for contract negotiations. Also, additional reporting requirements may add about $20,000 to the cost of the project (Garing, oral comm.).

Environmental Considerations

Prior to drilling the exploratory well in Pagosa Springs, the Colorado Geological Survey commissioned the Denver Research Institute to prepare an environmental report. Although their findings refer specifically to the drilling of one well, some generalizations may be made to the effects of more widespread geothermal development.

Air

According to the report, some non-condensable gases could be released during the flow-testing of the well, but all efforts to control them were expected (DRI, 1978). The delivery system design and construction must preclude emissions that exceed air quality standards. Exhaust emissions during the drilling phases would be short-lived (DRI, 1978).

Land

Existing well sites can be used initially, thus precluding any new land disturbance. Subsequent wells could disturb some land. Since much of the land is Mancos shale which is subject to massive land movements, proposed sites would need to be evaluated prior to selection. However, numerous sites do seem to be available, given the abundant vacant land both inside and surrounding the City.

Water

Water Quality classification B., which has been assigned to the San Juan River is described as follows:

> "a. Bacterialogical concentrations do not exceed a geometric mean of 10,000 total coliform groups or 1000 fecal coliform group per 100 milliliters based on a minimum of not less than five samples obtained during separate 24 hour periods for any 30 day period...

b. The dissolved oxygen concentration is not less than 6 milligrams per liter.
c. A pH rating of not more than 9.0 nor less than 6.0 units.
d. Temperature maintains a normal pattern of diurnal and seasonal fluctuations and does not change abruptly. No warming discharge is permitted in the epilimnion of lakes. Temperature is not increased above 68°F by any other means than natural ones, nor is temperature increased in streams and in the epilimnion of lakes or reservoirs more than 2°F by any discharge.
e. Wastes of other than natural origin does not cause the turbidity of the water to be increased by more than ten Jackson units or its equivalent."

Water Quality Standards and Stream Classification, Colo. Dept. of Health, 1974)

Although development of limited magnitude would probably not significantly change the water quality, any new discharge would require a permit from the Health Department, Water Quality Control Division. Special measures might be needed to remove minerals or heat prior to discharging the waste. Geothermal wastewater and groundwater currently flow into the San Juan River. Concentrations of dissolved solids of 3,300 mg/l from the geothermal fluid and material absorbed from the soil by the ground water do affect water quality.

Plants and Wildlife

Changes in vegetation in the Pagosa Springs area occur when land is disturbed, as shown by Tables 9 and 10, which list the plants growing on the land before and after disturbance. However, none of the plants on the well site in Pagosa Springs were considered endangered or threatened. Within the City, very little, if any of the land has been unaltered from its original state. While sites proposed for land development outside the City might be untouched, an evaluation of the effect upon vegetation at a particular site could only be determined at the time of application for subdivision or zoning permits. Since numerous native plants are currently thriving in thermal brine deposits, no severe effects were predicted even if brines were uncontrolled. Since careful control of brines is expected, the chance of adverse effects from brine on vegetation seems slight (DRI, 1978).

No direct adverse effects upon wildlife are expected from geothermal development. The existing thermal water discharge from the Big Spring into the San Juan River seems to encourage the growth of trout, since the largest specimens are caught near the discharge point. Were large volumes of water containing heat or minerals to be discharged into the surface waters, the effects could be detrimental, but water quality regulations prohibit such discharge. Were geothermal development to encourage additional land development, it could indirectly reduce wildlife habitat. Wild game depends upon vegetation for cover and forage. When this is removed for development, animals may be forced into another area. However, the large percentage of the county which is National Forest provides large areas of wildlife habitat.

TABLE 9

PAGOSA SPRINGS WELL SITE

Vegetation on Undisturbed Land Near the Site

GENUS	SPECIES	COMMON NAME	HABIT	LIFE CYCLE
Pinus	ponderosa	ponderosa pine	tree	perennial
Chrysothamnus	spp.	rabbitbrush	shrub	perennial
Prunus	virginiana	black common chokecherry	shrub	perennial
Amelanchier	alnifolia	serviceberry	shrub	perennial
Artemisia	frigida	fringed sagebrush	herbaceous	perennial
Achillea	millefolium	western yarrow	herbaceous	
Carex	spp.	sedge	grasslike	perennial
Aster	falcatus	heath aster	herbaceous	perennial
Dactylis	glomerata	orchard grass	grasslike	perennial
Helianthus	nutallii	stiff sunflower	herbaceous	perennial
Melilotus	officinalis	yellow sweet clover	herbaceous	annual
Oryzopsis	hymenoides	Indian ricegrass	grasslike	perennial
Salsola	iberica	tumbling russian thistle	herbaceous	annual
Traopogon	pratensis	meadow salsify	herbaceous	biennial
Poa	ssp.	bluegrass	grasslike	perennial
Bromus	tectorum	cheatgrass brome	grasslike	annual
Pteridium	aquilinum	fiddlehead fern	herbaceous	perennial

(Hamilton, private communication)

SOURCE: Denver Research Institute, 1978

TABLE 10
PAGOSA SPRINGS WELL SITE

Vegetation on the Disturbed Land of the Site.

GENUS	Species	Common Name	Habit	Life Cycle
Cirsium	undalatum	wavy-leaf thistle	herbaceous	biennial
Malva	neglecta	commmon mallow	forb	annual
Agropyron	spp.	wheatgrass	grasslike	perennial
Helianthus	nuttallii	sunflower	herbaceous	perennial
Muhlenbergia	minutissima	foxtail	grasslike	annual
Portulaca	oleracea	purslane		annual
Chenopedium	album	lambsquarter	herbaceous	annual
Lactuca	tatarica	wild lettuce	forb	perennial
Plantago	major	plantain	forb	annual

(Hamilton, private communication)

SOURCE: DENVER RESEARCH INSTITUTE, 1978

Ecological Relationships

Depending upon the magnitude of geothermal development in the Pagosa Springs area, some obvious social and economic changes could occur. Population could grow, leading to shortages and higher prices for facilities such as housing, schools, public safety, and services. If the forecast population increase is borne out, improvement and expansion of some of these facilities will most assuredly be necessary (Archuleta County Planning Office). The geothermal development seems unlikely to add to the burden or to create a "boom" effect that would preclude proper planning and development. Jobs, cultural and education opportunities and services would probably increase.

Water Availability

As indicated under institutional considerations, Pagosa Springs has excess water rights that should be sufficient to develop a geothermal system, unless the system is designated non-tributary. This question should be answered soon.

Technical Considerations

Choices are still to be made regarding specific techniques for using the geothermal heat in Pagosa Springs. The geothermal water seems relatively easy to handle, given the endurance of the existing systems. Scaling that has occurred is apparently due to calcium bicarbonate precipitation. Corrosion is probably due to low pH, dissolved calcium dioxide, and hydrogen sulfide and air leakage (Pagosa Springs, 1978).

The chemical contents of the water may require a heat exchanger or chemical additions or possibly only a pressurized, oxygen-free system to preclude corrosion or scaling of the equipment. Prior to a detailed analysis, this decision cannot be made. Whether the system can use the existing well (under 500 feet), is still to be decided following an investigation of the existing well and a cost-comparison (Garing, pers. comm.). Metering may be based upon either the total flow or the total heat obtained by each customer. Retrofitting techniques will vary considerably among structures, depending upon whether they have an existing geothermal system, hot water radiators, forced air, space heaters, or electric baseboard systems. The disposal question must be answered, using reinjection or surface disposal either with or without a cooling pond (Pagosa Springs, 1978).

Economic Considerations

Pagosa Springs' grant application to the Department of Energy (DOE) for their initial heating district indicated a total project cost of $963,200. The total energy requirement of the district was estimated to be 32,800 million Btu per year (Ebeling, 1978). If the project cost is amortized over a period of 25 years, the average cost per million Btu is $1.17 for the initial development, in lieu of operating costs. An economic analysis of a citywide heating district, prepared by the New Mexico Energy Institute, indicated that the energy, including all costs, could be developed for about $1.60 (Cuniff and others, 1979). This compares favorably with the $1.75-$3.75 average energy costs that were indicated in the grant proposal for 1978 supplies. Rising fossil fuel costs make the geothermal energy costs increasingly attractive.

As in other areas, Pagosa Springs has had difficulty financing needed projects. They attempted for some time to locate a source of funding for geothermal development prior to the DOE's announcement of a grant program. Municipalities generally have very limited revenue to meet even basic needs. Those with high unemployment and low incomes are reluctant to incur debt even when a project will be revenue-producing. Communities that are less familiar with the use and dependability of geothermal energy or that are less sure of its availability will be even more reluctant to incur debt for what may seem to be a risky venture.

GEOTHERMAL ENERGY DEVELOPMENT POTENTIAL

Geothermal Resource Characteristics

Investigation of the currently available information about the geothermal resources shows the extent to which they are capable of supplying the energy demand.

As Table 11 shows, the surface temperature ranges between 54 and 56°C, with an estimated subsurface temperature range of 80-150°C. The 1,500 foot well drilled by the Colorado Geological Survey in 1978 obtained a total flow for all zones of about 5,000-6,000 gallons of fluid per minute. However, temperatures dropped from 151°F at 255 feet to 112-120°F in the lower part of the hole (Galloway, 1980). The amount of energy estimated to be contained in the reservoir is 0.0226 quads, with about 0.0013 quads of that available, usable energy (Pearl, 1979). That is about 22 times the amount of natural gas consumed in Pagosa Springs in 1977 and about 5 times the estimated total thermal demand for the Pagosa Springs area. The total dissolved solids content ranges between 3,040-3,310 mg per liter. The chemical analysis is shown on Table 12.

Current Use of Geothermal Energy in Pagosa Springs

Twenty-eight hot water wells are known to be in Pagosa Springs. Ten of these have been abandoned, five are unused, but thirteen are still in use. Most of these are used for space heating, although some are used for melting snow and for swimming pools.

Planned Development of Geothermal Energy

The Town of Pagosa Springs has recently been awarded a grant to assist the financing of a geothermal heating district. The projected total project cost of $963,200 will finance a project leading to and including the construction of a central business district heating system that is planned to include 11 public buildings, 26 businesses and approximately 23 homes, as shown on Figures 7 and 8 and Tables 13 and 14. For these buildings, a total of 32,800 million Btu's of heat is estimated to be required annually. The alternative distribution line routes are shown on Figure 7. Either the existing well No. 1 or a new well nearby will be used as the production well (Pagosa Springs, 1978).

TABLE 11

Resource Characteristics - Pagosa Springs

TDS	ESTIMATED AREAL EXTENT	ESTIMATED THICKNESS	SURFACE TEMPERATURE	ESTIMATED SUBSURFACE TEMPERATURE	ESTIMATED TOTAL BTU'S (10^{15})
3,040-3,310 mg/l	1.00 sq. mi.	200 ft.	54-56°C	80-150°C	0.0226

Existing wells 85-468 feet, producing from the Dakota. CGS well total depth 1500 feet, total flow 6,000 gpm all zones, temperatures hotter in Dakota, isothermal conditions 500 feet from bottom.

Source: Pearl, 1979.

Several alternative sites were proposed for a reinjection well if one is required. Because of the drop in elevation to the sites, gravity flow may be sufficient, eliminating the need for pumping spent fluids into the well. More details were described under Technical Considerations (Pagosa Springs, 1978).

Opportunities for Future Geothermal Energy Development

The proposal from Pagosa Springs for their initial heating district grant describes a marketing activity to encourage additional geothermal energy users. Several groups of future additional users seem probable. Within the proposed initial heating district boundaries are 69 residences. In the proposal, 23 residences were estimated to be customers of the district at its inception. The remaining 46 might be encouraged to do so before the system is completed. Table 15 shows potential geothermal energy users and their estimated energy requirements. Several new buildings are planned for construction in Pagosa Springs outside the initial heating district. These include a bank building and senior citizens housing group. In addition, given the population growth, a new high school will most likely be necessary in the near future. Were these new structures to use geothermal energy initially, heating system costs would be approximately the same as for any system and retrofitting costs would be avoided. An energy demand of this magnitude could help encourage the extension of the heating district to the remainder of the town.

The potential industrial geothermal energy users now seem to be limited, given the current industrial status, plus the limitations of location, climate and transportation facilities. However, since timber has been the primary industry, it seems quite possible that a timber kiln could in the future be heated with geothermal energy. Also, small businessmen have expressed interest in developing greenhouses and aquaculture facilities in Pagosa Springs (Hays, 1979). With a growing grocery and restaurant market because of increases in both permanent residents and tourists, the demand for food products will expand. Additionally, unforeseen industrial uses could be initiated as the population grows.

Finally, since most of the population growth is now occurring and is forecast to occur in the future outside the existing Pagosa Springs boundaries, the market potential of the suburban areas seems promising. The largest

Table 12

Physical Properties and Chemical Analysis of Thermal Waters in Colorado

Pagosa Springs: Big Spring

Location: 37°15'52"N. Latitude: 107°00'37"W. Longitude: T. 35 N., R. 2 W., Sec. 13cd, N.M.P.M., Archuleta County

	Date Sampled			
	8/75	10/75	1/76	4/76
Arsenic (As), UG/L):	120	130	-	-
Boron (B), (UG/L):	1,800	1,700	2,000	2,300
Cadium (Cd), (UG/L):	0	0	-	-
Calcium (Ca), (MG/L):	230	210	240	230
Chloride (Cl), (MG/L):	180	180	190	180
Fluoride (F), (MG/L):	4.3		5	4.8
Iron (Fe), (UG/L):	80	20	20	20
Lithium (Li), (UG/L):	2,900	3,200	-	-
Magnesium (Mg), (MG/L):	25	23	2.6	24
Manganese (Mn), (UG/L):	230	220	220	200
Mercury (Hg), (UG/L):	0.1	0	-	-
Nitrogen (N), (MG/L)	0.02	-	0.01	0.01
Phosphate (PO_4)				
Ortho diss. as P, (MG/L):	0.07	-	0.03	0.07
Ortho, (MG/L):	0.21	-	0.09	0.21
Potassium (K), (MG/L):	90	87	87	85
Selenium (Se), (UG/L):	0	-	-	-
Silica (SiO_2), (MG/L):	54		58	59
Sodium (Na), (MG/L):	790	780	800	730
Sulfate (SO_4), (MG/L):	1,400	1,500	1,500	1,300
Zinc (Zn), (UG/L):	10	20	-	-
Alkalinity				
As Calcium Carbonate, (MG/L):	701	705	707	702
As Bicarbonate, (MG/L):	855	859	862	856
Hardness				
Noncarbonate, (MG/L):	0	0	0	0
Total, (MG/L):	680	620	610	670
Specific conductance (Micromohs):	5,810	4,000	4,200	4,340
Total dissolved solids (TDS), (MG/L):	3,200		3,310	3,040
pH, Field	6.5	6.9	6.6	6.5
Discharge (gpm):	265	226	241	260
Temperature (°C):	58	57	55	54
Remarks:				

SOURCE: Barrett and Pearl, 1976.

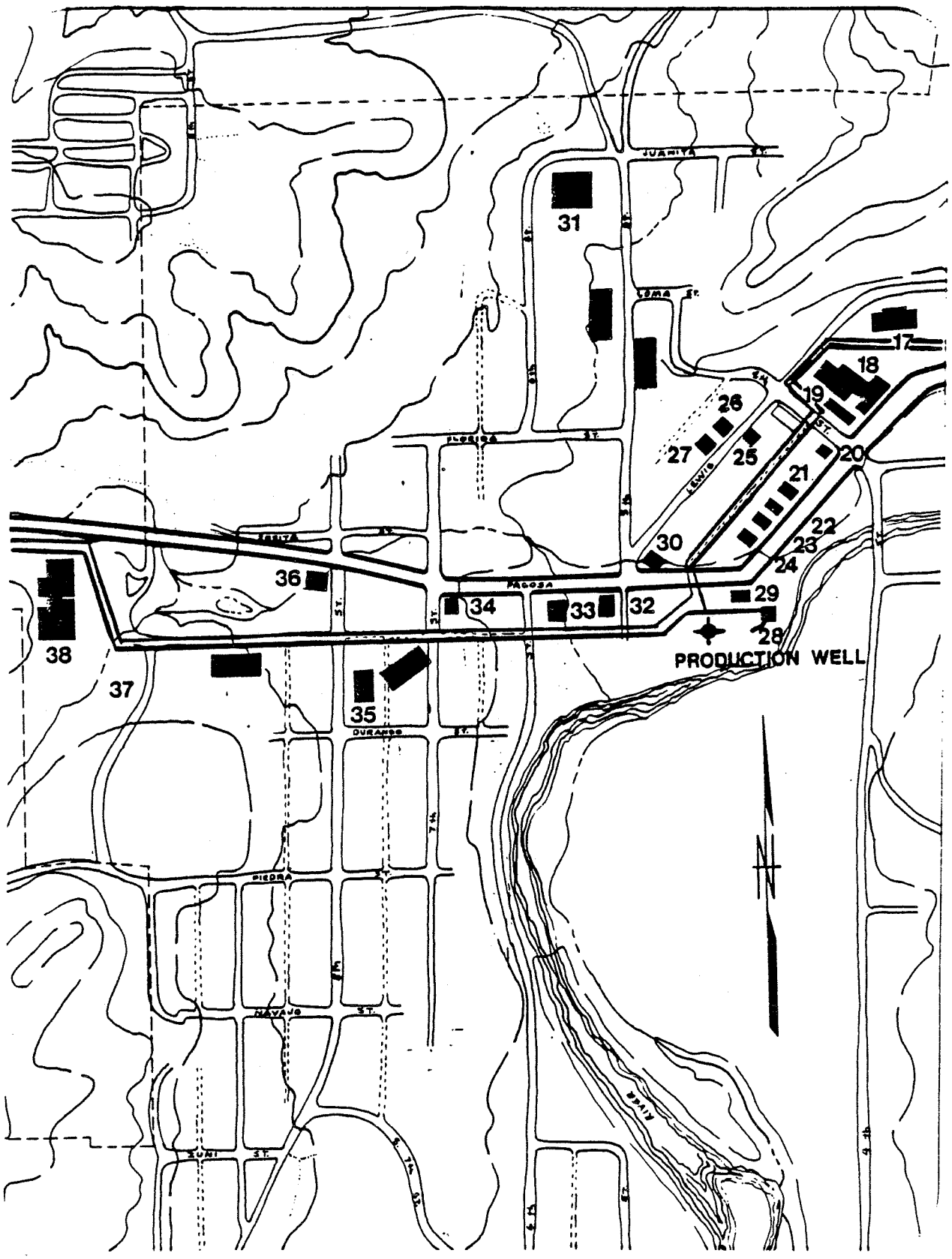


FIGURE 7
DISTRICT GEOTHERMAL HEATING SYSTEM

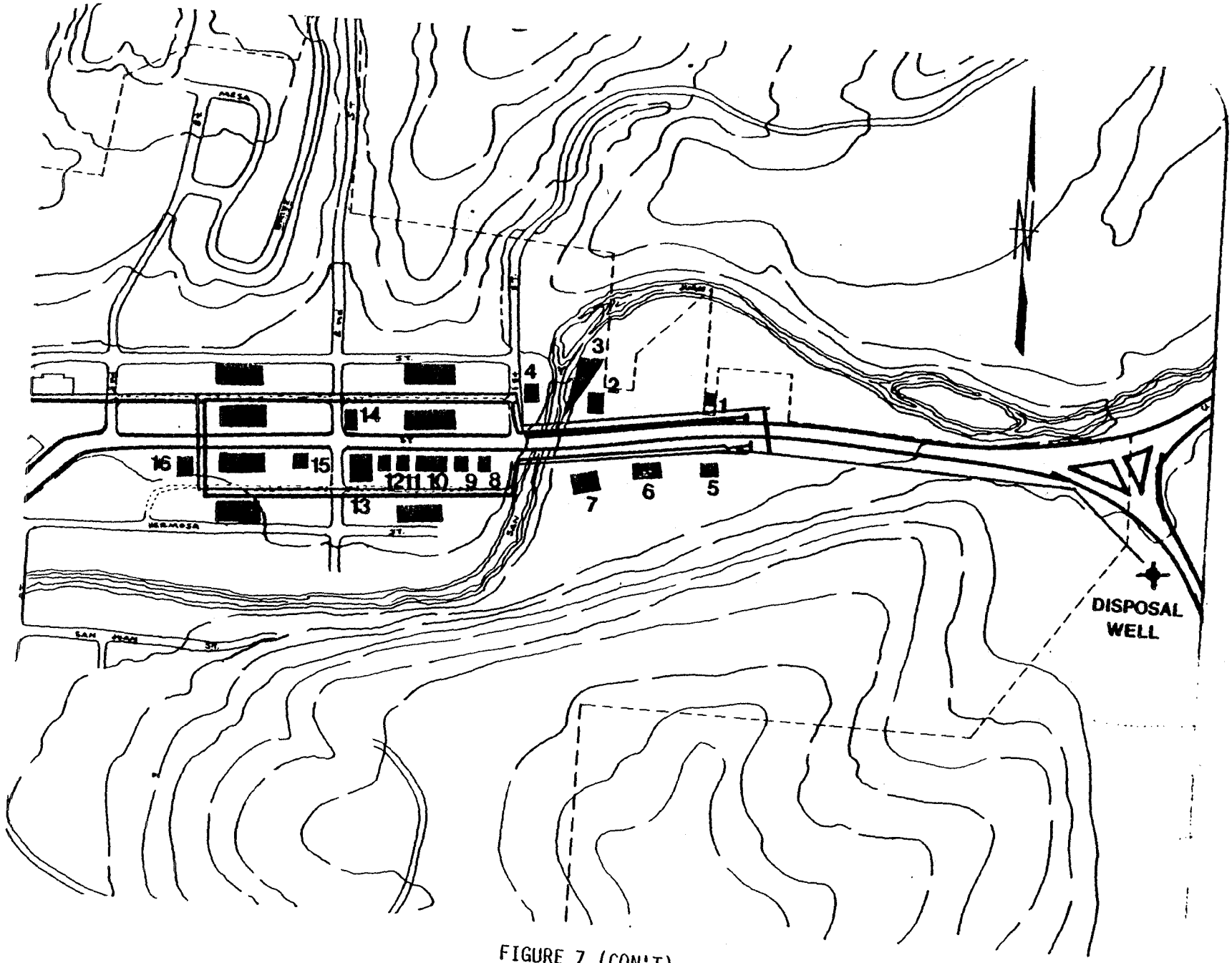


FIGURE 7 (CON'T)

TABLE 13

Projected Users of the Geothermal Space Heating Utility

Public Buildings

No.*	Building	Present Fuel Used	Approximate Annual Fuel Cost	Ownership
4	Old water works and museum	Propane	420	City
14	U.S. Forest Service			
	a. Office Building	Natural Gas	450	U.S. Government
	b. Garage/Shop	Natural Gas	620	U.S. Government
17	Junior High	Natural Gas		School District
18	High School	Natural Gas	14,000	School District
38	Grammar School	Natural Gas		School District
37	Bus Garage	Natural Gas		School District
29	County Courthouse	Natural Gas	563	County
30	Town Hall	Natural Gas	1,357	City
31	Archuleta Housing** Corporation	Natural Gas	7,100	County
35	County shop/garage	Natural Gas	1,480	County
39***	Town shop/garage	Propane	1,436	City
	Established Annual Fuel Cost		$27,426	

* As indexed on Figure 1
** This is part of Alternative 1 on Figure 1
*** Not shown on Figure 1

SOURCE: Pagosa Springs, 1978.

TABLE 14

Projected Users of the Geothermal Space Heating Utility

Private Businesses

No.*	Business	Present	Approximate Annual Fuel Cost
1	Silver Dollar Liquor	Propane	400
2	J's Mart	Propane	1,100
5	Circle K Grocery	Natural Gas	350
6	Al's Cafe	Electricity	900
7	San Juan Motel	Propane/Natural Gas	7,000
8	Dr. Davis (Dentist)	Natural Gas/Elec.	700
9	Jo Ge's Boot Hill and Real Estate	Propane	1,000
10	Harvey's Motel	Propane/Natural Gas	2,000
11	Pioneer West	Electricity	1,000
12	Trading Post	Wood/Propane	200
13	Solar Mall	Solar/Natural Gas	500
15	United Farm Agency	Electricity	1,500
16	Baptist Church	Natural Gas	1,500
19	Pagosa Laundromat and Shopping Area	Natural Gas	1,000
20	Goodman's	Natural Gas/Propane	900
22	Jackish Drugs	Hot Water/Natural Gas	850
23	Total Sports	Propane	1,500
24	La Cantina	Natural Gas	800
25	Universal Telephone	Natural Gas	500
26	Methodist Church	Hot Water	-
27	Alley's	Natural Gas	400
32	Johnson Chevrolet	Natural Gas	4,000
33	Gambles	Natural Gas	3,000
34	Conoco Service Station	Natural Gas	720
40**	Pagosa Hotel Building	Natural Gas	1,200
41***	Spa Motel	Propane/Electricity	2,000
	Estimated Annual Fuel Cost		$ 34,520
	Public Building Fuel Costs		$ 27,426
	Homes		$ 8,050
	Total		$ 69,996

No.	Business	Fuel Used	Comments
21	Trading Post	Natural Gas	Store now empty
3	Shopping Mall -- Proposed for near future		
36	Shopping Mall -- Proposed for near future		

* As indexed on Figure 1

** Not shown on Figure 1; located in group No. 1 to No. 24

*** Not shown on Figure 1; located south of river, on 4th Street

SOURCE: Pagosa Springs, 1978.

subdivision, Eaton Corporation's Pagosa development, 4 miles west of Pagosa Springs, covers 22,000 acres. The planned athletic training center, existing and planned stores and shops, as well as the condominiums and single-family residences could use geothermal energy. In other subdivisions, as well, similar opportunities exist, although on a smaller scale.

Schedule for Geothermal Energy Development

The activities necessary to develop geothermal energy in Colorado, in general have been identified. They are shown on Appendix A.

In the Pagosa Springs area, where the development will most likely take place on private, City or County property, rather than Federal, some of the activities listed are unnecessary. Those activities specific to Pagosa Springs for the proposed and postulated development are listed in Appendix B and

TABLE 15
POTENTIAL GEOTHERMAL ENERGY DEMAND
TO YEAR 2020
IN PAGOSA SPRINGS AREA

USERS	ESTIMATED GEOTHERMAL ENERGY DEMAND MILLION BTU'S	CUMULATIVE ESTIMATED GEOTHERMAL ENERGY DEMAND MILLION BTU'S
1. Current Consumption	13,020	13,022
2. Planned Heating District	30,302	43,322
3. Additional Homes Within District	6,210	49,532
4. Balance of City	89,000	138,532
5. Industrial Users Fish Farms - 50,0001 Greenhouses - 20,0001 Timber Kiln - 18,0001	68,000	206,532
6. Residential and Commercial Growth in City	152,000	358,532
7. Suburban Area	160,000	518,532
8. Industry in Suburban Area	68,000	586,532
9. Residential and Commercial Growth in Suburban Area	1,333,862	1,920,394

1VTN, 1977

described in detail as follows. The total time required for each activity is that indicated in the grant proposal for the activities listed in the proposal. The activities are incorporated into the possible development schedule as shown on the time-phased flow chart, Figure 8, and are described below in the order in which they occur:

PAGOSA SPRINGS HYDROTHERMAL DISTRICT HEATING SYSTEM

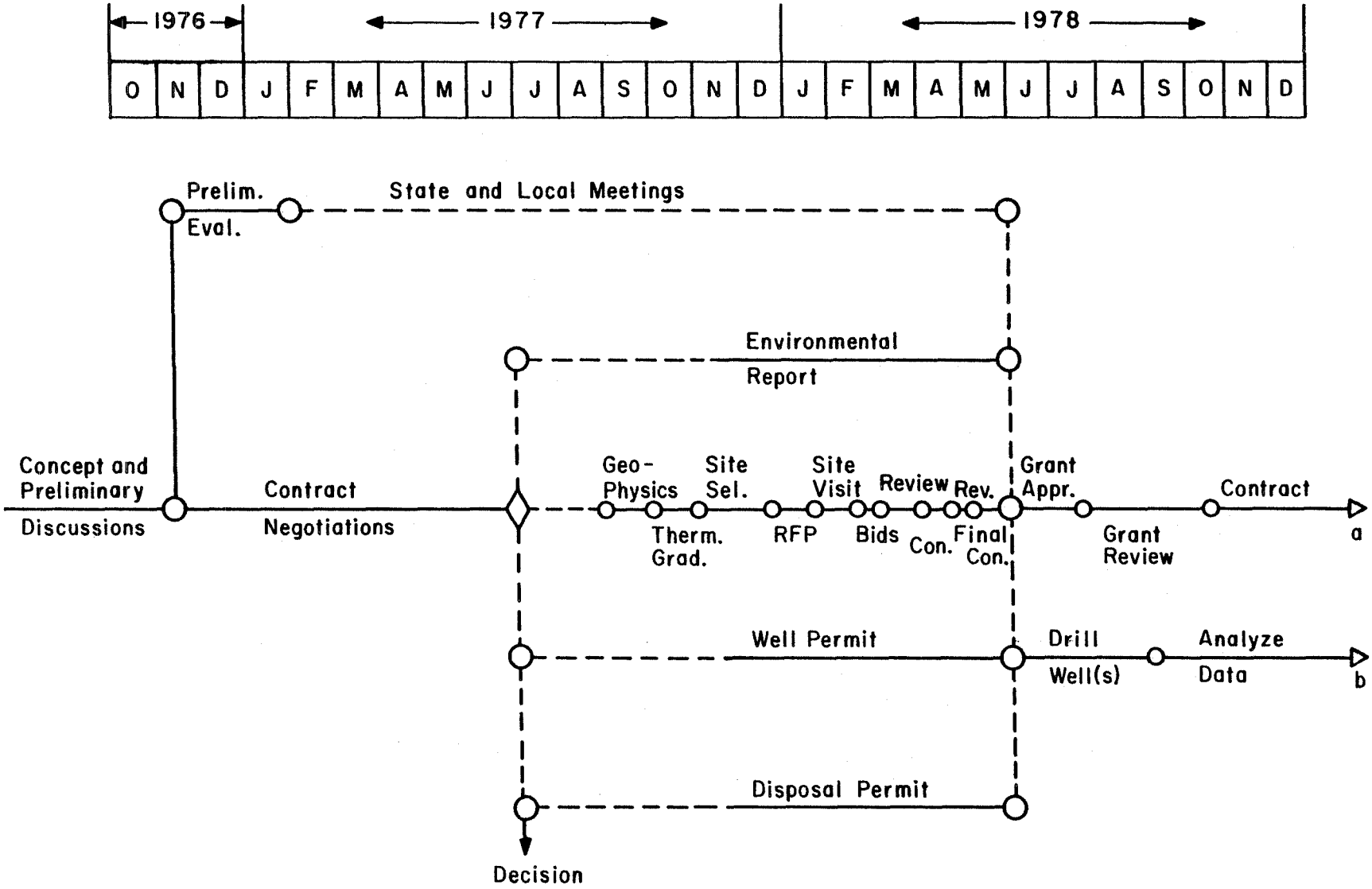


FIGURE 8

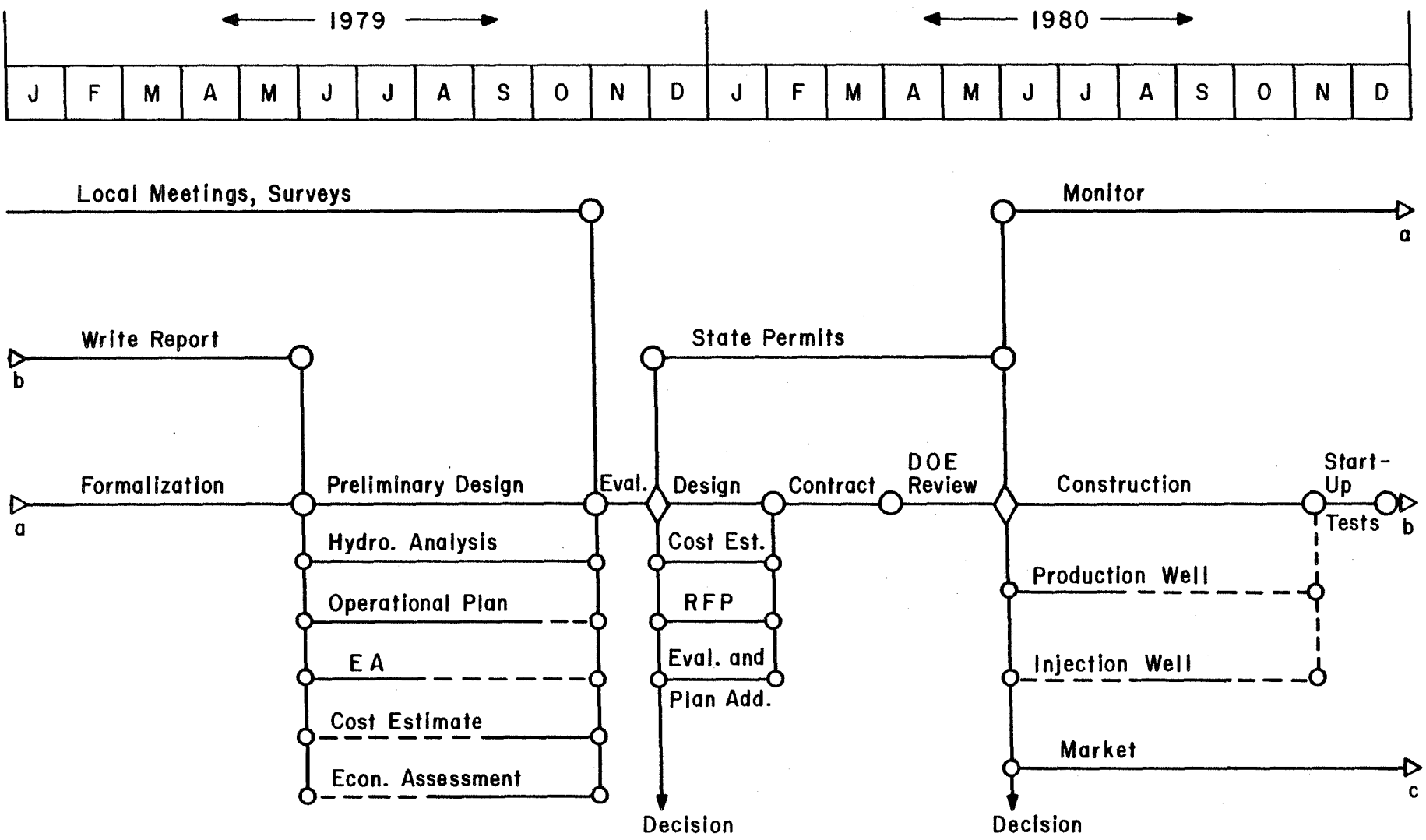


FIGURE 8 (Con't.)

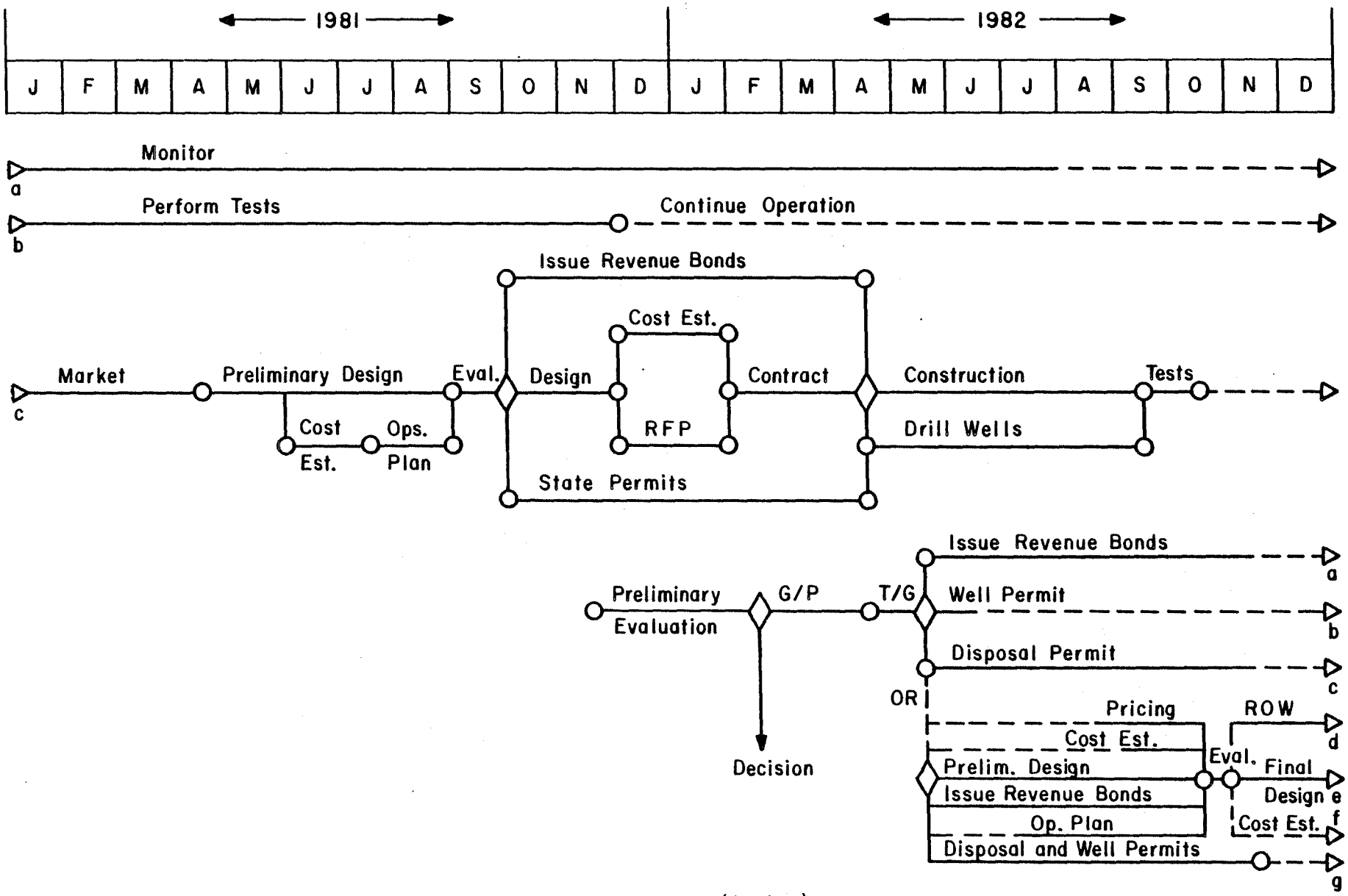


FIGURE 8 (Con't.)

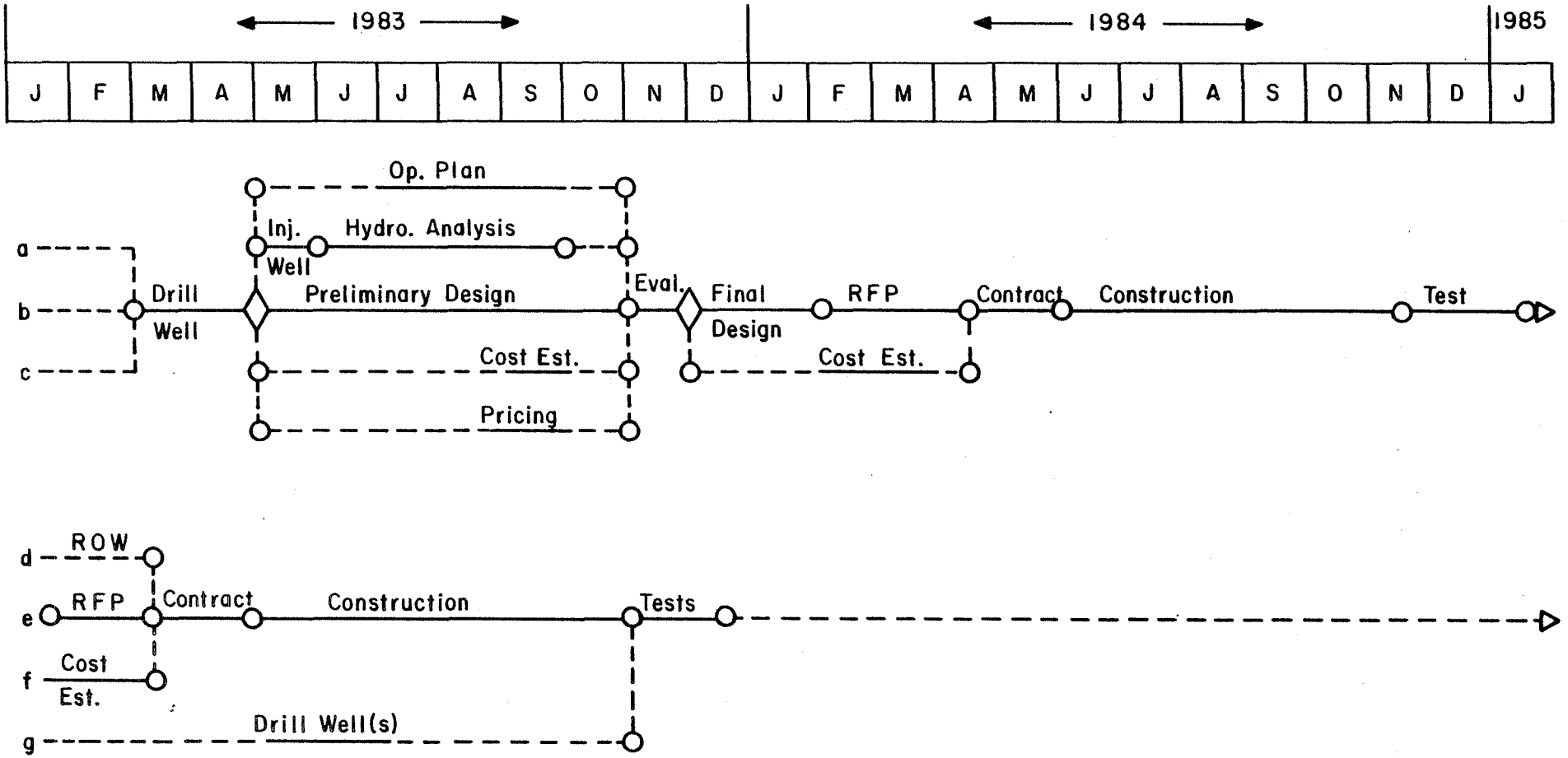


FIGURE 8 (Con't.)

1,2 Concept - The Superintendent of Schools, Abner Hahn, requested from State agencies, EG&G and others information and assistance regarding the use of geothermal heat in the public schools in Pagosa Springs. Prior to these requests, he had undoubtedly considered and discussed with others in the area the geothermal potential. Although this preliminary concept and discussion phase is essential, the beginning date of such germinal stages is difficult to establish. For that reason, the activity beginning is shown to be open-ended. Educational and promotional programs directed toward increasing the incidence and shortening the time of such concept stages can assure that the most basic condition for geothermal development, namely the presence of an idea, is met.

3 A DOE prime contractor, EG and G, Idaho, Inc., was requested to conduct a feasibility study for the conversion of the Pagosa Springs Middle and High Schools back to the geothermal heat that they used originally. The study showed that although more information about the geothermal resource is needed, the probability for successful development of a geothermal systems was very high. Corrosion-resistant materials would be needed as would reinjection into an existing well of the spent fluid, according to the analysis. The cost would be amortized over 20 years or less (Engen, 1977).

4 Meetings with local officials and citizens - some of them called by the Colorado Geological Survey (CGS) were held at intervals to discuss the potential for geothermal energy, the possible uses for the energy in the area and the well drilling and other development activities.

5 Contract with DOE - Because of the interest in geothermal energy in the area, the CGS included the drilling of a test well in Pagosa Springs among the resource assessment activities funded by the U.S. Department of Energy.

6 Geological/geophysical investigations - The CGS performed geological evaluations and contracted with the Colorado School of Mines for geophysics work.

7 Environmental report prepared and approved - prepared by the Denver Research Institute, described the probable effects of drilling the CGS test well.

8 Heat flow holes - The CGS drilled six heat flow holes to a depth of 300 feet to identify the heat flow trends. The results showed the hottest area was near the hot spring.

9 Well permit - The CGS submitted an application for a well drilling permit to the Oil and Gas Conservation Commission. The application was referred to the State Engineer for review to assure that the proposed geothermal well would not interfere with existing water rights. Because the well was a test well only, consideration of the effect on existing water rights was assumed to be inapplicable.

10 Disposal permit - The CGS submitted an application to the Water Quality Control Division of the State Health Department for a permit to dispose of geothermal water into the San Juan River during the well testing period. Officials indicated that because their main concern was the thermal pollution expected from the disposal, a fenced cooling pond would be required in order to cool the water prior to its disposal. The Air Pollution Control Commission of the State Health Department prepared a letter waiving the need for a permit, since no significant emissions or pollutants were expected from the well drilling. As shown on the flow chart, several activities necessary for the exploration program in Pagosa Springs were performed simultaneously.

11 Site Selection - The CGS met with local officials to find an available site that would provide a high probability of success. A site behind the County Court House was chosen. The owner offered the use of the site with no charge except for the use of sufficient water to heat his own buildings. An agreement was signed among the owner and the County, the City and the School District, who jointly would become the well owners. The agreement stipulates that should the well not be used within two years, the ownership will revert to the land owner.

12 Request for proposal-bid documents were prepared by the CGS and sent to contractors solicit bids for drilling a 2,000-foot exploratory well and 2,000-foot and 500-foot observation wells.

13 Site visitation - a visitation to the site allowed interested drillers to review the area to determine drilling conditions.

14 Bids - Bids were submitted in the amounts of $167,000, $250,000, and $500,000.

15 Review of bids - Bids were reviewed to assure their conformance with requirements and to select the lowest bid.

16 Contract preparation - Contract with James Drilling was prepared.

17 DOE review - The CGS contract with James Drilling was reviewed by DOE who requested that certain changes be made.

18 Finalize contract - Contract with James Drilling was made final and signed by CGS and James Drilling and approved by the State Attorney General.

19 Exploratory well was drilled.

20 Analysis of drilling results and reports preparation - Those conclusions that could be drawn from the drilling program were indicated in a formal report soon to be released. As indicated, the hottest water was 151°F at 255 feet, but fluctuated between 112 and 120°F in lower part of hole.

Even though the well will probably not be used immediately, the drilling program was informative as well as being a generator of additional activity.

21 Grant application preparation - The Department of Energy circulated a Program Opportunity Notice requesting the submittal of proposals for development of systems using geothermal in direct applications. When the Superintendent of Schools and others indicated a need for technical assistance in writing the proposal, the Colorado Team discussed the need with private consultants. Both Jay Dick and Coury and Associates, consultants, volunteered to assist, including their services in the work proposed. With City and County officials and residents obtaining and compiling much of the necessary information, a proposal for $700,000 for construction of a heating district to heat 26 businesses, 11 public buildings, and approximately 23 homes was submitted. The proposal showed three phases, a preliminary design and evaluation phase, a final design phase, and a construction phase. After each of the first two phases, evaluation and decision to proceed to the next phase is required.

22 Grant application review - Following their review, the DOE announced in October, 1978, that Pagosa Springs would receive a grant.

23 Finalize contract - Contracts are reviewed to assure they meet requirements prior to final signing.
The contract was received in the Archuleta County Planning Office for signatures on June 15, 1979. The consultant, Coury and Associates, had agreed to begin work earlier.

24 Environmental report - The first contract activity to begin is the environmental report. The report will be a refinement and expansion of the environmental report prepared in advance of the CGS drilling program.

25 Hydrological testing - The amount of well discharge that can be obtained in order to assure the maximum reservoir will be assessed, along with other hydrological data.

26 Public meetings, surveys, following contract finalization - residents will be asked for general information and direction as well as participation in the heating district.

27 Preliminary engineering design - will "develop a detailed preliminary design of the entire system, including production and injection wells location and capacity; brine treatment requirements; distribution line sizes, material, location, and method of installation and burial; brine treatment facilities for usage and injection; retrofit designs for principal users; typical retrofit designs for small users; and heat exchanger design if system requires an isolated working fluid.

28 Preliminary cost estimate - Using drawings prepared as indicated in No. 27, will prepare a preliminary cost estimate for installed system. Although related to task 27, some of this task can be done simultaneously with completion of engineering design.

29 Economic evaluation, including pricing and payback schedule for reimbursing DOE for part of the front-end cost of the development. is part of the town's contribution. As above, requires input from other tasks.

30 Operational plan - including a firm agreement between town and users.

31 Evaluate - before proceeding to the next phase to determine whether system will be less costly than existing fuel.

32 Permits - Water, disposal, well. A permit from the State Engineer may be required in order to divert water rights from their domestic water supply to a new geothermal well. A well permit from the Oil and Gas Conservation Commission will be required to either drill a new geothermal well or reenter and refine the existing Court House well. The most time-consuming permit to obtain is the waste water disposal permit that would be required for either reinjection or disposal to the surface. The disposal method approved by the Health Department will influence the cost and thus the overall economic viability of the project.

33 Final Engineering Design and drawing - As with the last phase, the next four activities can be performed simultaneously with close coordination among them to assure the transference of information from each activity to the others as soon as possible.

34 Cost estimates - more detailed than previous ones, based upon final design information.

36 Finalize contract - among the County, City, School District 50, and users.

37 Construction contract review - includes the review of bids for low, qualified bidder by the district officials and by DOE for compliance with their specifications, as well as an evaluation of continuation of the project.

38 Development well - Some of the activities in this phase may be conducted simultaneously. Either a new well will be drilled or casing, reaming, or other modifications will be made to an existing well.

39 Injection well -If an injection well is needed, it can be drilled following the production well work, to minimize transmission costs for the drilling rig. If injection is the disposal method, an alternative to a new well would be an existing well, such as the High School well.

40 Hydrological tests - Following the drilling of a new well or modification of the old well.

41 Construct facilities - During the drilling, pipelines, retrofitting, and other construction activities can be performed.

42 Start-up performance and acceptance tests - based on predetermined criteria.

43 Accept system.

44 Market expanded system - to attract new users - initially for other areas in the city, then for suburban areas, if reservoir is sufficient.

45 Monitor system - using test plan.

46 Four Performance tests - at three-month intervals, to determine:
- reservoir response to usage patterns, on basis of performance of production and injection wells;
- flow, pressure and temperature distribution throughout system;
- heating effectiveness in various building types under various weather conditions;
- necessity, if any, to use supplemental heat source during coldest weather;
- relationship between user costs, as paid to the town of Pagosa Springs, and previous heating bills under old systems;
- operational costs to the town of Pagosa Springs.

47 Marketing survey of new users - continuation of activity 44.

48 Operational Plan for additional users within initial district - assumes that plan will be developed to include the 46 additional residences within district boundaries, who were not signed up initially.

49 Contract formalization with additional users - those users indicated in 48.

50 Engineering design - for additional users within district - included in activity for initial participants.

51 Cost estimate - for additional users within district.

52 Construction and retrofitting - for additional.

53 Preliminary design for system expansion #2 - remainder of City. Includes estimated growth since 1977. System may be extended in increments, rather than as one project as shown.

54 Cost estimate - for #2 - experience and information value is assumed by reducing estimated time required for this activity below that of the initial district.

55 Operational plan for system expansion.

56 Evaluation - of #2 followed by decision about proceeding with extension

57 Permits - again, need to apply for permits early if construction is to proceed in a timely manner.

58 Issue revenue bonds - assumes that City will have demonstrated the value of a geothermal heating system sufficiently that they will be both willing and able to float revenue bonds to finance the system expansion, or that they could use the geothermal loan guaranty program. Some extensions may, however, be financed privately or cooperatively, without the need for bonds.

59 Final design - for #2

60 Cost estimate - for #2

61 Construction bid document - for #2

62 Finalize contractual agreements - construction contracts for #2. Assumed a shorter time frame because Federal government reviews would presumably not be required.

63 Construct facilities - for #2

64 Drill wells - additional wells for refinement of existing wells can be accomplished during the construction phase. Since the reservoir would be proven by that time, there is minimal risk involved in proceeding with construction before drilling wells.

65 Tests - minimal because of previous testing.

66 Preliminary evaluation of suburban system feasibility - since most of the growth is now occurring and is forecast to occur in subdivisions outside Pagosa Springs' existing City limits, a substantial market is available and forecast to expand.

67 Preliminary resource assessment - geological examination of potential for geothermal resources on or near Eaton's Pagosa.

68 Geophysics - on or near Eaton property.

69 Thermal gradient holes - on or near Eaton property. Following these last three activities, a decision could be made concerning two alternatives for developing a suburban system - namely, extension of the Pagosa Springs system or further exploration on or near the Eaton Development to see whether a second or extended hydrothermal reservoir is present. Nos. 70 through 86 show an exploration and development program at Eaton (or other suburban area) while #70a through 86a describes an extension of the Pagosa Springs system.

70 Well and disposal permits - for a suburban exploratory well.

71 Issue revenue bonds - assumed necessary for funding, if project is part of Pagosa Springs or special geothermal heating district. However, bonds may be very difficult or impossible to sell before a revenue is proven. Alternative forms of financing could include receipts from the existing system in Pagosa Springs, general

obligation bonds, or private financing. Or, the system could be privately developed by a firm such as Eaton Corporation.

72 Drill test well - on suburban location identified through preliminary exploration program. If the well is successful, the following activities through 86 would be required. No elaboration is necessary, since they are the same as above.

73 Injection well - for suburban system

74 Hydrological analysis - for suburban system

75 Preliminary engineering design - for suburban system

76 Preliminary cost estimates - for suburban system

77 Economic evaluation

78 Operational plan

79 Evaluate - decide whether warranted

80 Final engineering design

81 Cost estimates

82 Right-of-way - would be required for suburban system transmission and distribution lines.

83 Contract bid documents

84 Complete contractual agreements

85 Construct facilities

86 Start-up tests or, alternatively;

70a Well and disposal permits - for additional wells in Pagosa Springs to serve suburban areas. Since the reservoir will have been proven by this time, some of the activities shown above are unnecessary for expansion of the Pagosa Springs sytem to suburban areas.

71a Issue revenue bonds for suburban expansion. Should be relatively easy to obtain if system is shown to be adequate. However, issuance might be necessary following economic evaluation rather than simultaneously as shown.

72a Preliminary engineering design

73a Preliminary cost estimate

74a Economic evaluation pricing and payback schedule - a critical evaluation to determine the practicability of a four-mile system expansion.

75a Operational plan with users

76a Evaluation - followed by a decision about whether to proceed with the next phase

77a Final engineering design

78a Cost estimates

79a Right-of-way - includes transmission line from Pagosa Springs

80a Contract bid documents

81a Complete contractual agreements

82a Drill well(s)

83a Construct facilities - including pipelines, retrofitting

84a Start-up tests

By late 1980, Pagosa Springs' initial heating district, by then expanded to include additional homes within district boundaries and the industrial processors indicated, should be on line. About 5×10^{10} Btu's of geothermal energy could be on line. With the expansion of the system to include the remainder of the City, including forecast growth, or about 25×10^{10} Btu's of geothermal energy could be in use in 1982.

Because the value of the geothermal energy will by that time have been sufficiently demonstrated, no additional federal funds are assumed to be needed. Rather, revenue bonds could provide the required front-end financing. Because the City is in favor of such development and the State permits required are apparently reasonable, no severe institutional barriers are anticipated.

If the geothermal energy in the Pagosa Springs area is sufficient, the heating district could be extended to suburban areas. Or, alternatively, wells could be drilled west of Pagosa Springs to feed a separate heating system that could be on line by late 1983 or 1984, providing about 44×10^{10} Btu's of thermal energy. Financing and rights-of-way would be needed, but do not yet seem to be severe problems. If the supply proves to be adequate for the entire Pagosa Springs area, about 189×10^{10} Btu's of geothermal energy could be in use by the year 2020 as shown on Figure 9.

SUMMARY

Pagosa Springs' geothermal development is indeed underway. Although geothermal energy has been used by several residents for years, that energy has not begun to meet its potential. Now, perhaps, that potential can be met.

The steps leading to the development process were time consuming. For some time, Pagosa Springs' actually developing a district heating system must have seemed impossible.

On the one hand, the community had the resource, had demonstrated its ability to use it, and needed financial assistance. Precisely because of economic conditions, the community could neither afford to develop the system itself nor pay someone to prepare the technically-sophisticated proposal that was essential to obtaining federal assistance.

Furthermore, although the development seemed as though it would save residents money, too little economic analysis had been done to assure them that would be the case. Again, funds were not available to pay for a detailed analysis.

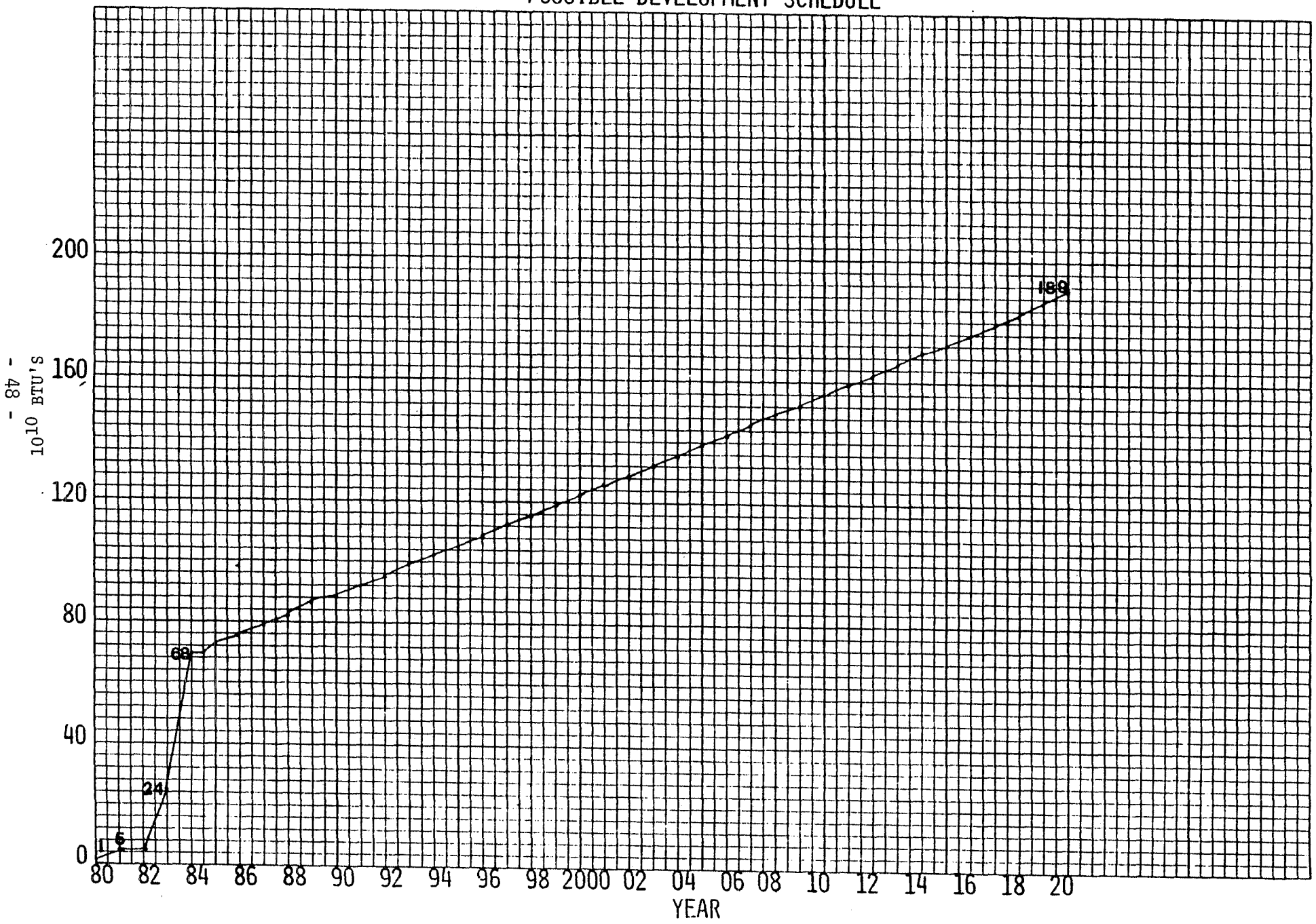
Additionally, no private geothermal production companies seemed eager to develop the energy and sell it to the residents. Perhaps it is not a sufficiently profitable venture, or perhaps the geothermal development industry is simply too immature.

When the Department of Energy solicited proposals for demonstration projects, Pagosa Springs was most interested. When private consultants Coury and Associates and Chaffee Geothermal volunteered to help prepare a proposal, Pagosa Springs then had hope that they might develop a successful proposal. Indeed their hopes and their efforts were rewarded when they obtained a cost-share contract to develop a geothermal heating district demonstration project in Pagosa Springs, Colorado.

For this project to be underway, as it is, financial and expert assistance from outside sources were required. Perhaps at a later date, the cost of conventional energy sources will be sufficiently high to stimulate communities to develop the geothermal energy totally with their own financial resources. But the project also demanded the interest of Pagosa Springs residents as well as the expenditure of much of their time and effort. Such interest and action will never cease to be necessary. If the energy is to be used in the future elsewhere, either users or producers, individual, corporate, cooperative, or governmental, will have to recognize and accept the value of the energy and then take the steps necessary to assure its development.

FIGURE 9

PAGOSA SPRINGS GEOTHERMAL ENERGY
POSSIBLE DEVELOPMENT SCHEDULE



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Appendix A

GEOTHERMAL DEVELOPMENT ACTIVITIES
IN COLORADO

1.0 Regulatory Activities
1.1 Federal

- 1.1.1 Permit for pre-lease exploration
- 1.1.2 Lease - application filed with BLM
  - 1.1.2.1 - Non-competitive
    - 1.1.2.1.1 - Review by BLM
    - 1.1.2.1.2 - Review by USFS
    - 1.1.2.1.3 - Review by BIA and Indian Tribe
  - 1.1.2.2 - Competitive
- 1.1.3 Permit for post-lease exploration, non-surface-disturbing activities
- 1.1.4 Permit for post-lease exploration, surface-disturbing activities
  - 1.1.4.1 Permit for deep exploratory drilling
  - 1.1.4.2 Permit for extended flow test
- 1.1.5 Approval of unit agreement
- 1.1.6 Environmental base line data permit
- 1.1.7 Approval of plan of development
- 1.1.8 Approval of plan of disposal
- 1.1.9 Approval of plan of utilization
- 1.1.10 Approval of plan of production
- 1.1.11 Siting and right of way

1.2 State

- 1.2.1 Well permit from Oil and Gas Conservation Commission and review by State Engineer
- 1.2.2 Appropriation of water
- 1.2.3 Permit from Water Quality Control Division/State Health Department for disposal of wastewater into stream
- 1.2.4 Permit for disposal of wastewater into underground aquifer
- 1.2.5 Permit or waver from Air Pollution Control Division
- 1.2.6 Geothermal leases
- 1.2.7 Right-of-way

1.3 County Permits

- 1.3.1 Rezoning approval
- 1.3.2 Subdivision approval
- 1.3.3 Building permit
- 1.3.4 Geothermal development approval

2.0 Resource Characterization Activities
2.1 Preliminary Investigations:
2.2 Geological/geophysical investigations
2.3 Heat flow hole drilling
2.4 Exploratory drilling

- 2.4.1 Site selection
- 2.4.2 Drill well
- 2.4.3 Analyze results

2.5 Hydrological testing
2.6 Reservoir characteristics
2.7 Environmental Base Line Data
2.8 Reservoir Observation and Monitoring

3.0 Developer Negotiations and Contracting
3.1 Unit negotiations
3.2 Preliminary market and contract negotiations
    3.2.1 Initial negotiations
    3.2.2 Preliminary negotiations
3.3 Pre-design analysis
3.4 Contract negotiations
    3.4.1 DOE
    3.4.2 Construction Contract Bid Document Preparation
    3.4.3 Construction Contract
        3.4.3.1 Site visitation
        3.4.3.2 Bids submitted
        3.4.3.3 Evaluation
        3.4.3.4 Decision
    3.4.4 Construction Contract Review
    3.4.5 Finalize contract
3.5 Financial Negotiations
    3.5.1 Developers' operating capital
    3.5.2 Investors' participation
    3.5.3 Loan
        3.5.3.1 Private institution
        3.5.3.2 Revenue bonds
    3.5.4 Grant
        3.5.4.1 DOE PON
            3.5.4.1.1 Application
            3.5.4.1.2 Grant, review application
        3.5.4.2 User Share
3.6 Geothermal leases
3.7 Right-of-way

4.0 Field Development
4.1 Prepare Plan of Development
4.2 Field Design
4.3 Development wells
    4.3.1 Production well drilling
    4.3.2 Production well testing
4.4 Injection system
4.5 Gathering system
4.6 Field Deliverability test

5.0 Power Plant
5.1 Preliminary Design
5.2 Prepare Plan of Utilization
5.3 Prepare Plan of Injection
5.4 Conduct Siting Study and Prepare ROW Application
5.5 Detailed Design
5.6 Procurement of Power Plant Materials
5.7 Plant Construction

5.8 Power Plant Start-up and Test
5.9 Field Operation

6.0 Power Transmission Line
6.1 Transmission Line Design
6.2 Procurement of Transmission Line Materials
6.3 Transmission Line Construction

7.0 Direct Thermal System Development
- 7.0.1 Concept
  - 7.0.1.1 Preliminary discussions
  - 7.0.1.2 Survey and data collection
  - 7.0.1.3 Preliminary evaluation
  - 7.0.1.4 Public meetings
  - 7.0.1.5 Marketing
  - 7.0.1.6 Proposal preparation
- 7.0.2 Preliminary Design
  - 7.0.2.1 Preliminary environmental assessment
  - 7.0.2.2 Preliminary engineering design
  - 7.0.2.3 Preliminary cost estimate
  - 7.0.2.4 Economic evaluation pricing & payback schedule
  - 7.0.2.5 Operational plan Between town, users
- 7.0.3 Final Design
  - 7.0.3.1 Final engineering design and drawing
  - 7.0.3.2 Cost estimates
  - 7.0.3.3 Contract bid document preparation
  - 7.0.3.4 Construction contract review
- 7.0.4 Construction
  - 7.0.4.1 Construct facilities
  - 7.0.4.2 Construct pipeline
- 7.0.5 Operation and Testing
  - 7.0.5.1 Start-up performance and acceptance tests
  - 7.0.5.2 Accept system
  - 7.0.5.3 Monitor completed system
  - 7.0.5.4 Four performance tests

APPENDIX B

GEOTHERMAL DEVELOPMENT ACTIVITIES IN PAGOSA SPRINGS, COLORADO

Index	Activity	Immediate Predecessors	Immediate Successors	Estimated Duration[1] (Weeks)
1	Concept			
2	Preliminary Discussions	1	3	
3	Preliminary Evaluation	2	4	
4	Meetings with local officials and citizens	3/2	19/21	69
5	Contract with DOE	2	6	26
6	Geological/geophysical investigations	5	8	4
7	Environmental Report prepared and approved	5	19	39
8	Heat flow holes, including temperature logs	6	11	4
9	Well permit	5	19	8
10	Disposal permit	5	19	10
11	Site selection	8	12	5
12	Request for proposal	11	13/14	4
13	Site visitation	12	14	4
14	Bids submitted	12/13	15	4
15	Review of bids	14	16	4
16	Contract preparation	15	17	4
17	DOE review	16	18	2
18	Finalize contract	17	19	3
19	Exploratory well	18	20	18
20	Analysis of drilling results and report preparation	19		32
21	Grant application preparation	18	22	6
22	Grant application review	13	23	13
23	Finalize contract 2	22	24/25/27	17

[1]Through number 23, duration indicated is actual time transpired.
[2]Might be necessary to obtain State permits and/or to complete design prior to contract preparation, in which case project would be delayed.

Index	Activity	Immediate Predecessors	Immediate Successors	Estimated Duration (Weeks)
24	Environmental assessment	23	31	6
25	Hydrological testing	23	31	16
26	Public meetings/surveys	--	30	26
27	Preliminary engineering design	23	31	20
28	Preliminary cost estimate	23	31	10
29	Economic evaluation, pricing and payback schedule	23	31	14
30	Operational plan between town, users	23	31	12
31	Evaluate	24/25/27/28/29/30	32	5
32	Permits, water, disposal, well	31	38/39/41	26
33	Final engineering design and drawing	31	35	9
34	Cost estimates		35	9
35	Contract bid document preparation[3]	31	36	9
36	Finalize contract	35	37	11
37	Construction contract review	36	41	5
38	Development well	32/37	40	4
39	Injection well	32/37	40	4
40	Hydrological tests	38/39	42	2
41	Construct facilities	37	42	24
42	Start-up performance and acceptance tests	41/40	43	4
43	Accept system	42	45	
44	Market expanded	37	48	40
45	Monitor system	37	--	104

[3]Assumes no equipment procurement delays.

Index	Activity	Immediate Predecessors	Immediate Successors	Estimated Duration (Weeks)
46	Four performance tests	43	--	51
47	Marketing survey of new users	37	53	42
48	Operational plan for additional users within initial district	37	49	1
49	Contract formalization with additional users	48	50	2
50	Engineering design	49	51	1
51	Cost estimate	50	52	1
52	Construction and retrofitting (w/initial)	49	42	24
53	Preliminary design for system expansion[4]	47	55	20
54	Cost estimate	53	55	5
55	Operational plan for system expansion	54	56	6
56	Evaluation	53	57/58/59	
57	Permits	56	63	26
58	Issue revenue bonds	56	63	26
59	Final design	56	60/61	9
60	Cost estimates	59	62	5
61	Contract bid document	59	62	9
62	Finalize contractual agreements	61	63	11
63	Construct facilities	62	65	24
64	Drill well(s)	62	65	4
65	Start-up performance tests	63/64	--	4
66	Preliminary economic evaluation of suburban System feasibility	--	68	14
67	Preliminary resource assessment	66	68	4
68	Geological/geophysical tests	67	69	4
69	Gradient holes	68	71	4
70	Well and disposal permits	71	69	26
71	Issue revenue bonds	70	72?	26
72	Drill test well	70	72	8

[4]Assumed initial project would perform as demo project.

Index	Activity	Immediate Predecessors	Immediate Successors	Estimated Duration (Weeks)
73	Injection Well	71	73	4
74	Hydrological analysis	71/72	78	16
75	Preliminary engineering design	71	78	20
76	Preliminary cost estimate	71	78	5
77	Economic evaluation pricing and payback	71	78	7
78	Operational plan with users	71	78	12
79	Evaluate	73/74/75/76/77	78	3
80	Final engineering design	78	82	9
81	Cost estimates	78	83	9
82	Right-of-way	79	84	9
83	Contract bid document	79	84	9
84	Complete contractual agreements	82	84	11
85	Construct facilities	83	85	24
86	Start-up tests	84	--	4
	OR*			
70a	Well and Disposal Permits	69	84a	26
71a	Issue revenue bonds	69	79	20
72a	Preliminary engineering design	69	79	20
76	Preliminary cost estimate	69	79	5
73a	Economic evaluation pricing and payback schedule	69	79	7
	Operational plan with users	69	79	12
76a	Evaluation	71/75/76/77/78	80	3
77a	Final engineering design	79	83	9
78a	Cost estimates	79	84	9
79a	Right-of-way	79	84	9
80a	Contract bid document	80	84	9
81a	Complete contractual agreements	83	85	11
82a	Drill well(s)	70	86	8
83a	Construct facilities	84	86	24
84a	Start-up tests	84a,85	--	4

* First case is for well drilled at a suburban site, second case (a) is for expansion of the Pagosa Springs system.

APPENDIX C

METHODOLOGY

As indicated previously, most of the data used for this study were secondary data. In some cases, these required interpretation, refinement, or supplementation. The following describes the methods used on those occasions:

Population and Energy Demand

An attempt was made to estimate the thermal demand in Pagosa Springs from the mean natural gas consumption per customer. For each customer class, the number of cubic feet per customer was multiplied by .9 to factor out cooking fuel, then by .7, an efficiency factor. Then, a heat content of 850 Btu's per cubic foot of natural gas was assumed, resulting in an estimated 55 million Btu's per customer. Because this was much lower than averages for areas of less extreme cold, it was believed to be underestimated because supplementation with wood stoves is common. Therefore, the following method of estimating the energy demand found in Rules of Thumb (EG&G) from geothermal direct applications was used:

> Annual Heat Load: HLa = 20,000 [for average efficiency] x 8417 [degree days] = 135 million Btu's/year per residence.

To account for commercial use, this amount was doubled. The total estimated energy demand was then calculated by multiplying by the estimated and forecast dwelling units.

Actual number of dwelling units in Pagosa Springs was used for 1976, with the existing occupancy rate of 2.7 used for forecasting. The population forecast by the Archuleta County Planning Office for the year 2000 was extrapolated to the year 2020. For the Pagosa Springs area, assumed to be within approximately a ten-mile radius of Pagosa Springs, the 83 percent of the population residing in the area that was estimated by the Archuleta County Planning Office was used. This was assumed to increase to 91 percent of the county population by the year 2000.

The future industrial facilities were postulated from the criteria described, including historical patterns and the resources, geographic and environmental conditions in the area. The estimated energy demand for indicated industries was obtained from published reports.

Geothermal Energy Available

Estimated geothermal energy available was obtained from a report by R. H. Pearl (in preparation), which estimated reservoir and extractable energy. By using a factor of .25, the usable energy was then estimated.

Possible Development Schedule

To postulate a possible development schedule for the Pagosa Springs analysis, judgements were made about the possible uses and the rate at which system