FINAL REPORT
THE SIXTH ANNUAL INTERAGENCY GEOTHERMAL COORDINATING COUNCIL REPORT
FISCAL YEAR 1981

OCTOBER 18, 1982

1.0 INTRODUCTION

Geothermal energy is the natural heat of the earth, and can be tapped as a clean, safe, and economical alternative source of energy. Figure 1 presents a map of the United States indicating known and potential hydrothermal resources. Since much of this energy resource is recoverable with current or near current technology, it could make a significant contribution both to increasing domestic energy supplies, and to reducing the United States' dependence on imported oil. Moreover, it can be used for various purposes: electric power production, residential and commercial space heating and cooling, industrial process heat and agricultural process applications.

Although not intended as a statement of goals or targets, energy projections were prepared in conjunction with the National Energy Policy Plan of 1981*. With a midrange total U.S. energy consumption in 1990 and 2000 of 87 and 100 quads, respectively, geothermal electric production of 0.2 and 0.4 quads and direct-heat, of 0.07 and 0.2 quads were estimated. Although less than one percent nationally, regional contributions (particularly in California) are expected to exceed several percent. Thus geothermal represents one of several alternate energy systems which will play an increasingly important role in the U.S. energy future.

The Federal government has been actively involved in the development of geothermal energy since 1970, when the Geothermal Steam Act was passed. Since then it has undertaken numerous research, development, and demonstration programs to investigate the use of geothermal energy. This report summarizes the accomplishments of the Federal government during fiscal year 1981, and describes Federal geothermal energy programs. Table 1 presents a chronological history of significant geothermal energy developments.

In 1981, the overall objective of the Federal geothermal program was to respond to the needs of private industry, thus enabling it to undertake commercial development of geothermal resources; it provided an appropriate level of assistance while removing barriers to exploration and development. Private industry's leading role in the direct planning and construction of geothermal energy systems reflected a policy decision to rely on the market place for geothermal energy industrialization activities.

The efficient and timely development of geothermal resources depends on the coordinated efforts of Federal, state, and local governments, industry, consumer and environmental groups and private citizens. Federal responsibilities and programs are divided among a number of agencies, whose activities are coordinated through the Interagency Geothermal Coordinating Council (IGCC), which was established in 1974 by PL 93-410. The IGCC brings together all of the

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* "Energy Projections to the Year 2000," Office of Policy, Planning and Analysis, U.S. Department of Energy. DOE/PE-0029, July 1981.

FIGURE 1

Known and Potential Hydrothermal Resources

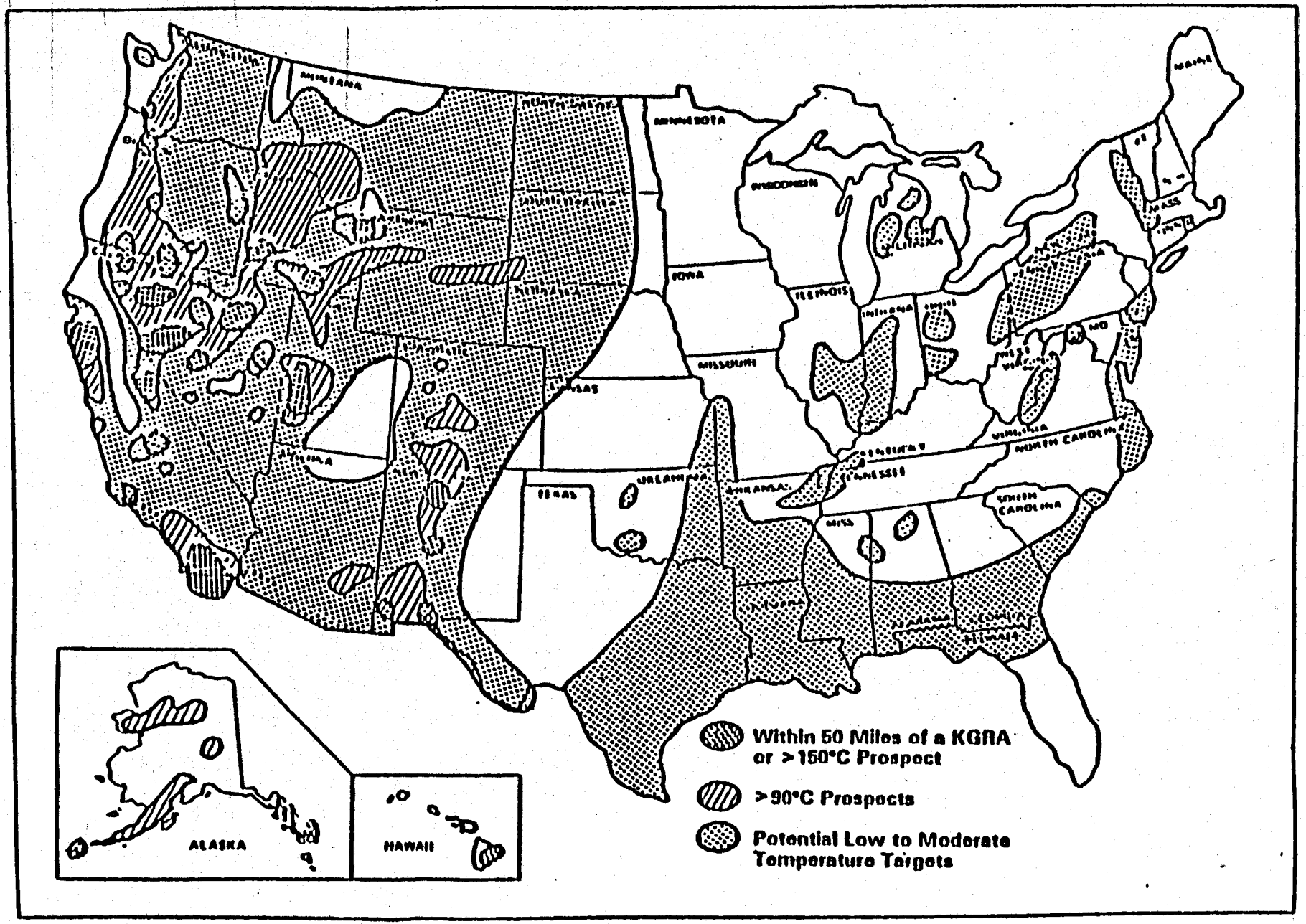

Table 1. SIGNIFICANT EVENTS IN THE DEVELOPMENT OF GEOTHERMAL ENERGY IN THE UNITED STATES

1894	District heating implemented in Boise, Idaho
1900	Hot water provided to homes in Klamath Falls, Oregon
1916	Power generation at The Geysers resort
1927	First exploratory geothermal wells were drilled in Imperial Valley, California by Pioneer Development Company
1959	Small pilot plant operated near Niland, California on Sinclair No. 1 well
1960	Commercial electricity generated from dry steam at The Geysers, California
1970	Geothermal Steam Act Passed (PL 91-581)
1972	NSF became lead agency for Federal Geothermal Programs
1973	USGS, AEC, NSF prepared the first Federal Geothermal Program
1974	Geothermal RD&D Act passed (PL 93-410)
1975	ERDA formed; Division of Geothermal Energy formed primarily from NSF, AEC staff
	USGS released first national geothermal resource estimates and inventory
1977	DOE formed; DGE kept intact
1978	Energy Tax Act passed (PL 95-618)
	EPA issued pollution control guidelines for geothermal energy development
	Successful Hot Dry Rock experiment conducted in New Mexico
	First geothermal crop-drying plant built in Nevada
1979	USGS released updated national geothermal resource estimates and inventory
	Streamlining task force recommended measures to speed Federal leasing to IGCC
	First geothermal electricity produced from Federal lands, at The Geysers, California

Table 1. SIGNIFICANT EVENTS IN THE DEVELOPMENT OF GEOTHERMAL ENERGY IN THE UNITED STATES (Concluded)

	World's first commercial binary cycle plant (10 MWe) built by industry at East Mesa, California
1980	World's largest single geothermal power unit (129 MWe) generated electricity at The Geysers, California
	10 MWe flash-steam plant built by industry at Brawley, California
	First electric power from a Hot Dry Rock resource produced at Fenton Hill, New Mexico
	First geothermal ethanol plant began production at La Grande, Oregon, under private funding
	First 5 DOE-sponsored field demonstrations of direct heat applications became operational
	First deep geothermal reservoir confirmation well drilled in Atlantic Coastal Plain, near Crisfield, Maryland
	Crude Oil Windfall Profits Tax Act passed, providing tax credit increase for geothermal equipment (PL 96-223)
	Energy Security Act, containing Title VI, "The Geothermal Energy Act of 1979", passed (PL 96-294)
1981	DOE reorganization merged DGE into the Geothermal and Hydropower Technology Division
	First U.S. geothermal electric generation plant outside the 48 contiguous states brought on-line in the Puna resource area in Hawaii
	The Insurance Company of North America began offering insurance against the financial risk of reservoir failure
	The practical demonstration of generating electricity from moderate-temperature geothermal fluids was accomplished at Raft River, Idaho
	At Roosevelt Hot Springs, Utah, 1.6 MWe was generated by a mobile well-head generator

Federal agencies with responsibilities related to geothermal energy development, and serves as a forum for interagency program coordination and information exchange.

The IGCC consists of the Federal agencies which participate in the geothermal program and is responsible for supervising and coordinating the activities of the Federal government community. This responsibility is spelled out in the Geothermal Research, Development, and Demonstration Act of 1974 (PL 93-410); specifically it is "...to coordinate those Federal plans, activities, and policies which are related to or impact on geothermal energy, including auxiliary activities of agencies not represented in the council membership". The Council, through the Chairman, may make recommendations to the appropriate agencies and the President with regard to alternative policies or action considered necessary or desirable to expedite the development and utilization of geothermal energy resources. Member agencies include the Departments of Energy, Commerce, Defense, Interior, Housing and Urban Development, Treasury and Agriculture, and the Environmental Protection Agency. The Federal Geothermal Program Budget of the member agencies is presented in Table 2.

2.0 LEASING

The goal of Federal geothermal leasing activities is to make lands available to industry for exploration and development. Leasing responsibilities are divided between the Bureau of Land Management, the Forest Service, and the Conservation Division of the United States Geological Survey (USGS).

During FY 81, the Federal government issued leases for 626,588 acres, well above the expectation of the Leasing Policy Development Office (500,000 acres per year). Federal leases are issued either through the competitive or non-competitive leasing program.

Competitive Leasing

The Bureau of Land Management (BLM) conducts competitive geothermal lease sales several times each year. At the lease sale, parcels of land located in Known Geothermal Resource Areas (KGRAs) are offered to the public. Typically, a lease sale involves several tracts of land; each tract is bid on separately. The highest qualified bidder receives rights to explore and develop the geothermal resources, conditioned on compliance with applicable laws, regulations, and lease terms of the sale.

During 1981, the Federal government leased 114,053 acres through the competitive leasing process. Although in years past it was generally recognized that the acres leased were not the areas with the most geothermal potential, this may now be changing. The majority of land now being offered is in higher potential areas, particularly California, as shown in Table 3. Table 4 presents a break-down of the average winning bonus bids by location for 1981.

Table 2
FEDERAL FUNDING FOR GEOTHERMAL ENERGY ($000)*

ORGANIZATION UNIT	Actual 1979	Actual 1980	Actual 1981	Estimated 1982	Requested 1983
Department of Agriculture					
U.S. Forest Service	780	750	700	600	600
Department of Defense					
Navy	300	230	930	850	1160
Air Force	0	200	1010	100	500
DOD Total	300	430	1940	950	1660
Department of Energy					
Conservation & Renewable Energy (Formerly Resource Applications)	152990	149870	142521	55004	9810
Office of Energy Research	2100	3102	3305	3000	3200
Environment	2820	1950	723	0	0
GLGP (Administrative Expenses)	0	181	193	200	75
DOE Total	157910	155103	146742	58204	13085
Department of Interior					
National Park Service	**	**	**	120	10
Fish & Wildlife Service	200	200	70	100	0
Bureau of Land Management	2590	2550	2650	2233	2822
Bureau of Mines	1050	800	400	384	384
Bureau of Reclamation	550	910	60	60	30
USGS, Geothermal Research Program	12043	10047	7889	7606	6053
USGS, Geothermal Evaluation & Lease Regulation	750	860	898	1822	1855
DOI Total	17183	15367	12024	12325	11154
Environmental Protection Agency	920	850	1550	0	0***
TOTAL FEDERAL GEOTHERMAL PROGRAM BUDGET	177093	172500	162956	71479	26499

* Operating expenses rounded to nearest thousand.

** Not known.

*** While the FY 83 EPA budget does not target resources specifically for geothermal, other R&D at EPA (e.g., disposal of liquid effluents) may be applicable to geothermal energy.

Table 3

COMPETITIVE LEASING BY STATE, TOTAL ACREAGE LEASED, BY YEAR

STATE	1974 - 1976	1977	1978	1979	1980	1981	Total
Nevada	120,996	36,663	9,322	24,298	20,419	15,304	227,002
Utah	76,539	12,788	1,658	-0-	-0-	-0-	90,985
New Mexico	32,564	48,065	8,767	7,063	-0-	13,835	110,294
Oregon	68,872	-0-	5,818	-0-	32,630	-0-	107,320
California	36,937	2,856	4,395	6,959	10	84,914	136,071
Idaho	24,903	6,985	-0-	-0-	-0-	-0-	31,888
Colorado	5,036	-0-	-0-	-0-	-0-	-0-	5,036
Total Acres Leased	365,847	107,357	29,960	38,320	53,059	114,053	708,596

Source: USGS, Conservation Division, Office of Deputy Conservation Manager for Geothermal, Menlo Park, Calif.

Table 4

Average High-Bid Price Per Acre

1981

State	Site	Average Price Per Acre
California	Imperial Valley KGRA	$ 12.45
	Randsburg KGRA	99.35
	Mono-Long Valley	83.76
	Coso Hot Springs	158.51
Nevada	Ruby Valley	5.00
	Dixie Valley	7.14
	Stillwater Mountains	1.00
New Mexico	Baca Location One	8.79
	Lightning Dock	4.96
	GRAND TOTAL AVERAGE:	$ 84.41*

* The acreage leased at each site is accounted for in this weighted average.

Acres: 1,147,053 x 84.41/9

With the exception of 1974 and 1978, when land at The Geysers was offered, 1981 saw the highest average price per leased acre. Between 1980 and 1981, the average price per acre increased from $32.52 to $84.41. While no firm conclusions should be drawn from this dramatic increase, contributing factors include:

1) the parcels offered for lease in 1981 were in more desirable areas;

2) the average price of fossil fuels increased during 1981;

3) there is a better understanding of the nature and occurrence of geothermal systems as a result of research studies.

Although all these factors had some bearing on the increase, the single greatest contributing factor was probably that the parcels offered for lease in 1981 were in more desirable areas.

Non-competitive Leasing

Non-competitive leases are issued by the Federal government on land not located within a KGRA. During FY 81, 512,535 acres were leased through this process. Table 5 details cumulative noncompetitive lease totals for 1976 - 1981; Table 6 presents noncompetitive geothermal leasing applications and issuances.

3.0 ENVIRONMENT

The Federal Geothermal Environment Program focuses on characterization of the environmental impacts from the development of geothermal energy sources and the development and evaluation of control methods to mitigate or eliminate environmental or health concerns. The coordination between the private sector, the research community, and Federal and State Government Agencies is provided by the IGCC's Environmental Controls Panel. The Environmental Controls Panel successfully completed its effort to refocus and integrate Federal environmental research programs, with EPA, DOE and DOI being the principal actors in the environmental program. The panel also completed an effort to identify highest priority geothermal environmental research needs at the project level. The program has included acquisition of baseline data, monitoring, and research related to air quality, surface and ground water quality, hydrological alterations, ecology, solid residuals, noise, subsidence and seismicity, health effects and socioeconomic problems; regional and site specific assessments of the environmental, health, and socioeconomic impacts of geothermal resource development; and development and evaluation of environmental control technologies. Budgeted research activities have been reduced in FY 1981 for the geothermal environmental program within all member agencies of the IGCC Environmental Controls Panel.

Table 5

CUMULATIVE NONCOMPETITIVE LEASE TOTALS, 1976 - 1981

Year	Filings	Withdrawn, Rejected, & Refused	Awaiting Action (not cumulative)	Leases Issued	Acreage Leased (cumulative)
1976	5,432	2,734	2,012	656	1,141,980
1977	6,043	3,232	1,831	904	1,500,005
1978	6,655	3,673	1,806	1,117	1,930,163
1979	7,315	4,027	1,956	1,332	2,314,670
1980	8,243	4,457	2,111	1,675	2,933,901
1981	8,708	4,824	1,807	1,958	3,446,436

Source: USGS, Conservation Division, Office of Deputy Conservation Manager for Geothermal, Menlo Park, Calif.

Table 6

NONCOMPETITIVE GEOTHERMAL LEASING, 1981

	APPLICATIONS							
	FILED			INACTIVE			AWAITING ACTION	
STATE	BLM	FS	SUBTOTAL	WITHDRAWN	REJECTED	REFUSED	BLM	FS
Alaska	0	0	0	0	0	0	0	0
Arizona	108	73	181	25	35	8	39	61
California	856	536	1,392	510	314	11	251	275
Colorado	91	128	219	93	15	5	55	11
Idaho	683	369	1,052	317	173	47	57	213
Montana	38	66	104	64	28	0	0	6
Nevada	2,196	24	2,220	773	430	78	72	7
New Mexico	695	42	737	361	90	22	129	0
Oregon	692	686	1,378	292	310	0	51	468
Utah	701	113	814	235	169	23	36	21
Washington	0	434	434	167	71	0	0	52
Wyoming	26	139	165	141	16	0	1	2
Eastern States	0	12	12	0	1	0	0	0
TOTALS	6,086	2,622	8,708	2,978	1,652	194	691	1,116

Table 6 (Cont'd.)

STATE	LEASES ISSUED BLM	ISSUED FS	ISSUED SUBTOTAL	ACRES BLM	ACRES FS	ACRES SUBTOTAL
Alaska	0	0	0	0	0	0
Arizona	12	1	13	19,621	1,920	21,541
California	56	0	56	92,986	0	92,986
Colorado	42	8	50	52,064	10,433	62,497
Idaho	213	1	214	375,222	2,560	377,782
Montana	6	0	6	10,687	0	10,687
Nevada	859	7	866	1,581,888	11,502	1,593,390
New Mexico	140	0	140	252,145	0	252,145
Oregon	233	28	261	361,895	42,871	404,766
Utah	321	14	335	580,130	18,170	598,300
Washington	0	2	2	0	5,120	5,120
Wyoming	0	4	4	0	7,448	7,448
Eastern States	0	11	0	0	19,774	19,774
TOTALS	1,882	76	1,958	3,326,638	119,798	3,446,436

Source: USGS, Conservation Division, Office of Deputy Conservation Manager for Geothermal, Menlo Park, Calif.

Activities conducted during FY 81 include:

- A DOE study of the applicability of the EIC-CUPROSOL advanced H_2S removal process to geothermal resources and the recovery of salable by-products from that process.
- A DOE investigation of the UOP SULFOX process for the removal of H_2S from geothermal steam.
- A DOE study of the use of high voltage electron beams to strip H_2S from geothermal fluids.
- An EPA study on electrochemical oxidation of hydrogen sulfide (H_2S) for saline resources.
- An EPA assessment of potentially harmful non-H_2S air emissions from geothermal sites.
- An EPA assessment of the feasibility and acceptability of large scale subsurface spent fluids injection.
- A DOE project to examine concepts for the monitoring of injected fluids to protect groundwater.
- An EPA/DOE project to identify hazardous components of geothermal wastes.
- A Fish and Wildlife Service/EPA report which developed criteria for properties of effluent water for viable wetlands ecosystems.
- A DOE review of environmental aspects of direct use of hydrothermal energy.
- A DOE review of environmental aspects of Hot Dry Rock energy.

4.0 HYDROTHERMAL RESOURCE IDENTIFICATION, ASSESSMENT, AND EXPLORATION

The United States Department of Energy and the United States Geological Survey have several programs to establish the extent and to identify the location of geothermal resources in the United States. These programs are geared to: (1) characterize the geological nature of each type of geothermal resource; (2) estimate distribution and energy content of all geothermal resources of the United States; (3) evaluate geothermal energy potential in the U.S. through inventory of the identified portion, and prediction of the undiscovered portion of the nation's resources, and (4) contribute to the confirmation of selected specific geothermal reservoirs. USGS activities emphasize geothermal resource inventory and assessment work; DOE activities focus on more detailed study of specific resource areas.

Major accomplishments as a result of these efforts in FY 81 included:

- A variety of maps and reports produced by USGS detailing reservoir temperatures and other vital characteristics about several promising geothermal areas.
- Completion of test drilling at Mt. Hood and Newberry Volcano, Oregon.
- Publication of a new geologic map of the Coso Volcanic field.
- Discovery of hot springs on the floor of Crater Lake, Oregon, and an area of anomalously high heat flow near Brawley, CA.
- Publication of resource maps for California, Colorado, Idaho and Utah and final stage of preparation of maps for Montana, Nebraska, Oregon, South Dakota, and Texas.
- Drilling under the Industry-Coupled Program of three high temperature exploratory wells by Getty Oil at Brady Hot Springs and in the Stillwater area of Nevada.
- Selection of four low- to moderate-temperature projects for DOE funding: (1) Honey Lake, CA, (2) Alamoso, CO, (3) Wine Valley, CA, (4) Magic Hot Springs, ID. Planning and drilling activity proceeded during FY 81.

5.0 HYDROTHERMAL TECHNOLOGY DEVELOPMENT

Although many of the procedures used in the exploration and exploitation of geothermal resources have been adapted from conventional energy technologies, the nature of geothermal resources presents unique challenges. New exploratory procedures are needed to identify potential resources. The very essence of geothermal energy, namely, high temperature, presents difficulties not confronted in oil and gas production. In addition to the problems inherent in the handling of high temperature brines, some of this nation's highest temperature brines contain extremely high concentrations of dissolved minerals. These dissolved minerals tend to precipitate and create scaling problems in utilization systems. Technological solutions to these obstructions to utilization must be found if the nation's geothermal resources are to be fully and efficiently exploited.

Highlights of the FY 81 accomplishments include:

- Development of a new methodology to assess geothermal resources of less than 90° C.
- Development of a radiogenic model to locate hydrothermal anomalies based on buried radioactive plutons identified by the examination of gravity measurement data.

- Cost reductions in the use of an existing magnetotelluric model which has the potential for defining deeply buried geothermal systems.

- Successful testing of improved drill bits, downhole motors, improved drilling fluids, and new well completion equipment and techniques.

- Continuation of a study on heat transfer and flow rates associated with thermally induced cracks in the rock formations of hydrothermal reservoirs.

- Development of improved high-temperature seals and lubricants for well drilling and field development.

6.0 HYDROTHERMAL TECHNOLOGY TRANSFER

The goal of the Hydrothermal Technology Transfer Program is to provide an appropriate level of Federal support to industry so that development of geothermal resources can proceed on a schedule determined by market forces. The program focuses on low- to moderate-temperature resources for direct applications and high-temperature geothermal resources for electric power generation. Hydrothermal resource development is impeded by the private sector's perception of economic and technical risk, reservoir performance uncertainties, and a variety of legal and institutional barriers. By responding to private sector requirements, it has been the role of the Hydrothermal Technology Transfer Program to help establish the economic, technical, and environmental acceptability of hydrothermal resource applications, and to assist in streamlining regulatory procedures and alleviating legal constraints.

DOE's Hydrothermal Technology Transfer Program in FY 81 consisted of technical assistance and information dissemination; legal and regulatory reform and streamlining; site-specific direct heat feasibility studies and field demonstrations; construction and operation of pilot and commercial-scale electric power demonstration facilities; and administering existing geothermal loan guaranties. Program emphasis will be placed on the analysis of the general characteristics and performance of geothermal reservoirs and on energy recovery from moderate-temperature resources, which contribute about eighty percent of the resource base. Program accomplishments during FY 81 included:

- Technical assistance to 39 interested parties, including 5 residential/space heating applications, 7 commercial space heating applications, 6 agricultural, and 1 industrial process.

- DOE/HUD jointly funded district heating feasibility studies for 28 communities, which includes several geothermal energy sources.

TABLE 7

GEOTHERMAL RESOURCES DEVELOPMENT FUND AND GUARANTY AUTHORITY*

	FY 81	
	FUND	AUTHORITY
Interest Differential	$ 277,382	
Unexpended Appropriations, Carried Forward from FY 80	$ 43,123,767	
FY 81 Guaranty Authorization		$136,000,000
Value of Loans Guaranteed		$ 91,048,000
Uncommitted Guaranty Authorization Carried to FY 82		$364,000,000
Administrative Expenses Incurred** (FY 81)	$ 739,339	
Guaranty Fees Collected in FY 81	$ 416,806	
Unexpended Appropriation Carried to FY 82	$ 20,819,234	
Guaranty Fees Collected in FY 81 and Deposited in GRDF	$ 416,806	
Appropriation Rescinded by Congress	$ 21,982,000***	

*This financial information is included in the Sixth Annual Report to satisfy the requirements of PL 93-410, Section 204(C).

**Contractor and consultant costs necessary to assist in evaluating technological, geophysical, financial, marketing, management and legal data submitted with guaranty applications and to assist in monitoring guaranteed projects.

***Rescinded from the Guaranty Reserve Fund, as requested by the Administration.

- Initiation of operations of a 3 MWe power plant which utilizes a wellhead generator.

- Monitoring the Geothermal Loan Guaranty Program. (Table 7 presents the FY 81 status of this fund).

Financial and economic incentives for private sector development are also provided by other Federal agencies. The Departments of Commerce and Housing and Urban Development offer financing opportunities for geothermal development in their grant programs. Communities may choose to utilize their HUD Community Development Block Grant (CDBG) funds for this purpose, and may request Urban Development Action Grants (UDAG's) provided that private sector leveraging and other requirements are met.

7.0 FEDERAL USE OF GEOTHERMAL ENERGY

Where economically appropriate, the Federal government has been involved in the utilization of geothermal resources. In particular, the Department of Defense has been active in the development and use of geothermal energy at several military installations throughout the U.S. and the world. Significant accomplishments during FY 81 included:

- Construction of a geothermal heating system at the U.S. Naval Station at Keflavik, Iceland which will equip the base for using geothermal energy.

- At China Lake Naval Weapons Center, California, drilling of production wells was begun as well as the initiation of plans to construct a 75 MWe plant.

- The preparation of a request for proposals to develop the geothermal resource at the Naval Air Weapons Training Complex, Falon, Nevada, was initiated.

- Technical and economic feasibility studies for using geothermal energy were conducted for Navy and Marine Corp sites in Hawaii, Twenty-Nine Palms, in California, in the Imperial Valley and for Air Force bases in Texas and Arizona.

- DOE continued its efforts to assist other Federal agencies in identifying buildings and facilities that could use geothermal energy for heating and cooling.

Although the primary emphasis has been on DOD, contacts have also been established with the U.S. Postal Service and other agencies.

8.0 GEOPRESSURED RESOURCES

The development of geopressured resources has been undertaken in three major program areas: resource assessment, reservoir definition,

and environmental research. Along the Gulf Coast, tens of thousands of wells have penetrated geopressured aquifers in search of oil and gas. The extent of the geopressured resource in this area is being defined based on logs from these wells. These results, in conjunction with seismic surveys and core analysis, have identified 70 areas with excellent potential for geopressured production. Programs to test Wells of Opportunity (unsuccessful oil and gas wells penetrating geopressured formations) and design wells drilled by DOE have been undertaken to test geopressured aquifers. In addition, preparation of energy recoverability estimates has been undertaken by USGS.

During FY 81, significant accomplishments within the Geopressured program included the following;

- Completed drilling of the design wells Gladys McCall No. 1 (Cameron Parish, Louisiana), Sweezy No. 1 (Vermilion Parish, Louisiana), and Amoco Fee No. 1 (Cameron Parish, Louisiana).
- Initiated long term testing of the Pleasant Bayou No. 2 (Brazoria County, Texas) design well.
- Completed the testing of six wells of opportunity.
- Completed the mapping of several promising geopressured reservoir areas along the Gulf Coast.
- Improved the accuracy of predicting methane in saline solutions based on log data.

9.0 HOT DRY ROCK RESOURCES

DOE established its Hot Dry Rock (HDR) Program after the successful demonstration of the technical feasibility of extracting HDR energy with a 5 megawatt thermal (MWt) loop at Fenton Hill, New Mexico. The program goal is to demonstrate the commercial feasibility of HDR energy by undertaking high-risk, high-payoff R&D activities. These activities include a wide variety of projects which are progressing simultaneously. The most extensive HDR project now underway is the 30 to 50 MWt commercial-scale loop at Fenton Hill.

Accomplishments during FY 81 have included:

- Drilling on a deeper production well (EE3) was initiated, and by late August, completed. The well was caged and shut-in at a depth of 13,933 ft. Fracturing of the rock to complete the loop between the injection well (EE2/FY 80) and production well (EE3) has begun.

- A thermal gradient map of the United States was published based on logging records from abandoned wildcat oil and gas wells. The map shows high gradient areas due to conductive flow of heat.

- In New Hampshire, a heat-flow hole was drilled by an experimental "flame jet" process. Sunk to a depth of 1,086 feet, this process worked exceptionally well, at times penetrating at a rate approaching 100 feet per hour.

10.0 GEOSCIENCES RESEARCH

The Geoscience Research Program is concerned with basic R&D. The majority of the geothermal research under the Geoscience Research Program is conducted in the area of energy resource recognition, evaluation and utilization. During FY 81, accomplishments have included:

- A demonstration of the scientific feasibility for extraction of energy from magma bodies. This project was conducted by Sandia Labs at Kilauea Iki Lava Lake in Hawaii. After much study it was determined that the extraction of energy from molten magma bodies is scientifically feasible.

- Development of a new downhole seismic source. This seismic source is a vibrator system which goes down the borehole to create seismic activity with minimal borehole damage.

- Development of a mathematical code to evaluate volcanic gases and fix rock histories. This code gives scientists greater insight into the energetics of the volcanic system and may provide information on the potential for geothermal energy extraction.