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Geothermal Energy

Program Summary Document

FY 1981

Assistant Secretary for Resource Applications
U.S. Department of Energy

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FOREWORD

The Geothermal Energy "Gold Book" has been prepared by the U.S. Department of Energy's Assistant Secretary for Resource Applications for the purpose of providing the Congress with information to supplement the Department's FY 1981 budget request. The report describes geothermal technology programs currently under the Division of Geothermal Energy as well as those geothermal hydrothermal commercialization programs under the Division of Geothermal Resource Management.

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I. PROGRAM OVERVIEW

Geothermal energy is the internal heat of the earth. Much of it is recoverable with current or near-current technology. Geothermal energy can be used for electric power production, residential and commercial space heating and cooling, industrial process heat, and agricultural applications.

Three principal types of geothermal resources are exploitable through the year 2000. In order of technology readiness, these resources are:

- Hydrothermal,
- Geopressured (including dissolved natural gas), and
- Hot dry rock.

In hydrothermal systems, natural water circulation moves heat from deep sources toward the earth's surface. Geothermal fluids (water and steam) tapped by drilling can be used to generate electricity or provide direct heat.

Geopressured resources, located primarily in sedimentary basins along the Gulf Coast of Texas and Louisiana, consist of water and dissolved methane at high pressure and moderately high temperature. In addition to recoverable methane, geopressured resources offer thermal energy and mechanical energy derived from high fluid pressures. The methane, however, has the greatest immediate value.

Hot dry rock (HDR) resources are geologic formations at accessible depths with abnormally high heat content but little or no water. Usable energy is extracted by circulating a heat transfer fluid, such as water, through deep wells that are connected by manmade fractures in the rock. Like hydrothermal energy, HDR can be used for electric power production or direct heat applications.

Of the three types, hydrothermal resources are most ready for commercialization, since much of this resource can be used economically now. Rapid commercial development of the Nation's hydrothermal resources is a major

objective of the federal geothermal program. The program approach for development of hydrothermal resources for electric and direct heat applications is to: (1) complete, with the cooperation of state and local government entities and the private sector, site-specific commercialization plans for each known hydrothermal area; (2) identify technical, economic, and institutional barriers to development at each prospect and plan actions to overcome or alleviate impediments to development; (3) conduct cost-shared demonstrations and operate experimental facilities where necessary to stimulate commercial development; (4) encourage greater participation in the Geothermal Loan Guaranty program; (5) continue resource assessment and reservoir confirmation activities to provide for the expansion of the resource base and reserves necessary to support the future growth of the geothermal industry; and (6) maintain a vigorous supporting research and development program to provide new and improved technology for finding the required resources, reducing energy conversion costs, and controlling potential environmental impacts. In this approach, the Hydrothermal Commercialization program is supported by the Hydrothermal Resources program and the Geothermal Technology Development program.

Commercial development of geopressured energy may begin in the mid 1980's. Economic feasibility will depend on the amount of methane that a given well can produce, a highly uncertain factor at present. The Geopressured Resources program is supported by many of activities in the Geothermal Technology Development program.

Hot dry rock is currently seen as a longer-term possibility. Significant improvements in drilling and fracturing technology are necessary to bring about commercial use of this potentially large resource. Commercialization may occur by the mid 1990's. The hot dry rock activities are a major component of the Geothermal Technology Development program.

The following sections describe each of the four geothermal program areas: (A) Hydrothermal Resources, (B) Hydrothermal Commercialization, (C) Geopressured Resources, and (D) Geothermal Technology Development. The Division of Geothermal Resource Management (DGRM) has responsibility for the Hydrothermal Commercialization Program, while the Division of Geothermal Energy (DGE)

carries the responsibility for the Hydrothermal Resources, Geopressured Resources, and Geothermal Technology Development programs.

A. Hydrothermal Resources

Objectives of the Hydrothermal Resource program are to define and confirm high-temperature reservoirs suitable for electric power generation; to demonstrate such power generation; to identify low-and moderate-temperature prospects with potential for direct heat applications; to assess environmental, health, and safety factors affecting geothermal development; and to develop appropriate control technology.

The Resource Definition subprogram includes the assessment of U.S. hydrothermal reservoirs and the confirmation of hydrothermal prospects through selective drilling and testing projects. DGE participates in regional and national assessments of hydrothermal resources in cooperation with the U.S. Geological Survey (USGS). Low- to moderate-temperature reservoirs are identified through a cooperative program with state agencies. These low-temperature resources are confirmed through user-coupled drilling programs. In addition, DGE conducts exploratory drilling programs in cooperation with industry to confirm high-temperature reservoirs with near-term commercial potential.

The objectives of some 22 demonstration projects administered under the Non-Electric Applications subprogram are to provide evidence of the viability of geothermal non-electric applications in a number of geographical regions and to obtain technical and economic data under field operating conditions.

Assessing environmental, health, and safety concerns affecting geothermal development and developing ways of monitoring and ameliorating them are the primary objectives of the Environmental Control subprogram. The release of hydrogen sulfide to the atmosphere, land surface subsidence caused by the withdrawal of fluids from geothermal reservoirs, and seismicity induced by geothermal fluid extraction and injection are examples of geothermal environmental concerns.

The Facilities subprogram supports field facilities for testing and demonstrating new techniques, equipment, and systems. This support includes the construction and operation of commercial-scale 50-megawatt geothermal electric power plants employing different energy conversion technologies. A major program objective is to demonstrate the economic feasibility and environmental acceptability of producing electric power from geothermal resources. These and other facilities provide a foundation for subsequent commercial development of hydrothermal resources.

B. Hydrothermal Commercialization

The Hydrothermal Commercialization program seeks to accelerate commercial utilization of hydrothermal resources for electric power and for direct heat applications, thereby displacing fossil fuels.

Activities of this program include formulation of geothermal commercial development plans, development of a national geothermal progress monitoring system, assessment of the market penetration potential for hydrothermal resources, and identification of direct heat markets suitable for early penetration. Further activities are development planning in cooperation with local and state officials and potential users, support for economic and engineering feasibility studies, continuing interagency coordination and policy development under the aegis of the Interagency Geothermal Coordinating Council (IGCC), and outreach programs to acquaint potential users with the availability and competitive cost of hydrothermal energy and with the availability of financial assistance through various federal development programs.

C. Geopressured Resources

The Geopressured program seeks to resolve key technical and economic uncertainties now impeding commercial development of geopressured resources. Major questions concern the size of the resource base, the amount of

economically recoverable methane contained in geopressured aquifers, the production capacities and lifetimes of individual reservoirs, the economic feasibility of using the thermal and hydraulic energy obtainable from these reservoirs, and possible environmental effects of energy production from geopressured reservoirs.

A major thrust of the program is the determination of reservoir characteristics of geopressured aquifers on the Texas and Louisiana Gulf Coast by means of production tests of new and existing wells. Several successful short-term tests of existing wells, originally drilled for oil and gas, have been conducted under the Wells-of-Opportunity subprogram. Long-term tests to define characteristics of large reservoirs and to monitor environmental effects require drilling of new wells. A new well was drilled successfully in Texas in FY 1979. Three new wells will be drilled in FY 1980 and three more in FY 1981.

Environmental assessment activities are conducted concurrently with well site selection and well drilling and testing activities. Monitoring efforts and experimental programs at well sites yield information on the environmental effects of sustained high-volume production of geopressured brines.

Engineering activities focus on conceptual design of surface facilities, production cost analysis, and well drilling and completion technology development. The Geopressured program is developing equipment and production techniques in response to the particular temperature, pressure, and salinity regimes characteristic of geopressured reservoirs.

Finally, DGE is working with agencies at various levels of government and with the private sector to analyze the legal, institutional, economic, and technological factors affecting geopressured resource development.

D. Geothermal Technology Development

The objective of the Geothermal Technology Development program is to reduce geothermal costs by improving technology, thus expanding the economically recoverable

resource base. The two major subprograms are Component Technology Development and Hot Dry Rock.

The Component Technology subprogram is carrying out R&D in the five areas summarized below.

The Drilling and Completion Technology subprogram emphasizes improvements in drill bits, downhole motors, and drilling fluids in order to achieve a 25 percent reduction in well costs by 1983 and a 50 percent reduction by 1986.

The Energy Conversion Technology subprogram seeks to reduce geothermal electric power generating costs. The subprogram is directed primarily toward performance improvements and cost reductions in energy conversion system components, particularly heat exchangers.

The Reservoir Stimulation subprogram is developing new explosive and hydraulic fracturing techniques to increase the fluid productivity of geothermal wells. By increasing well productivity, stimulation technology can reduce the number of wells required to exploit a reservoir.

The Geochemical Engineering and Materials subprogram pursues technical solutions to problems associated with the handling and disposal of geothermal fluids. This work focuses on development of economical materials durable enough to be used in hostile geothermal environments.

The Geosciences subprogram activities include exploration technology, reservoir engineering, logging instrumentation, and log interpretation. Exploration technology is designed to improve the accuracy of pre-drilling reservoir assessments. Reservoir engineering is concerned with accurate prediction of reservoir productivity and longevity. Other geosciences activities include the development of measuring devices that can survive geothermal environments and of geothermal well log interpretation to determine reservoir characteristics from borehole information.

The second major subprogram is Hot Dry Rock. The hot dry rock resource requires a major technology advance if its commercial exploitation is to start before the end of the century. Recent operation of a five-megawatt HDR thermal loop at Fenton Hill, New Mexico, has improved the prospects for eventual technical success. In addition to

the Fenton Hill work, DOE is continuing regional and national activities to assess the HDR resource.

Funding levels for each of the programs and subprograms described above are presented in Table I-1.

The following four sections, structured along the lines of the FY 1981 budget, present detailed program descriptions. Each program description contains a general discussion of relevant technical aspects, a summary of project status and plans, a milestone chart presenting major decision points through FY 1985, and funding levels for FY 1979 through FY 1981.

A section which describes the nature and extent of DOE's participation in international geothermal projects and activities follows the program descriptions. The final section describes DOE geothermal program management functions at headquarters and in the field.

TABLE I-1
Funding Levels for Geothermal Energy Programs
FY 1979 through FY 1981

	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)			
	ACTUAL FY 1979	ESTIMATE FY 1980	ESTIMATE FY 1981	INCREASE (DECREASE)
GEOTHERMAL ENERGY				
HYDROTHERMAL RESOURCES				
Resource Definition	26,163	13,406	19,398	5,992
Non-Electric Applications	10,238	12,200	16,000	3,800
Environmental Control	1,859	1,300	2,600	1,300
Facilities	22,968	33,694	15,002	(18,692)
Capital Equipment	1,232	800	0	(800)
Total Hydrothermal Resources	62,460	61,400	53,000	(8,400)
HYDROTHERMAL COMMERCIALIZATION				
Planning and Analysis	5,239	5,000	5,040	40
Private Sector Development	4,410	4,860	4,960	100
Total Hydrothermal Commercialization	9,649	9,860	10,000	140
GEOPRESSURED RESOURCES				
Program Coordination	1,192	882	2,200	1,318
Resource Definition	24,455	32,329	31,000	(1329)
Engineering Applications	72	839	900	61
Environmental Control	551	1,650	1,700	50
Facilities	0	0	0	0
Capital Equipment	111	300	200	(100)
Total Geopressured Resources	26,381	36,000	36,000	0
GEOTHERMAL TECHNOLOGY DEVELOPMENT				
Component Technology Development				
Drilling and Completion	5,432	7,000	8,250	1,250
Energy Conversion	9,344	7,100	12,800	5,700
Reservoir Stimulation	4,442	3,000	4,500	1,500
Geochemical Engineering and Materials	7,071	3,600	5,005	1,405
Geosciences	8,477	4,200	7,835	3,635
Subtotal Component Development	34,766	24,900	38,390	13,490
Hot Dry Rock	15,077	14,000	13,500	(500)
Capital Equipment	1,479	2,100	1,110	(990)
Total Geothermal Technology Development	51,322	41,000	53,000	12,000
TOTAL GEOTHERMAL ENERGY	149,812	148,260	152,000	3,740

II. HYDROTHERMAL RESOURCES

Hydrothermal resources consist of hot water and steam trapped in porous or fractured rocks beneath overlying geologic formations. A specific hydrothermal system is classified as 'vapor' or 'liquid' according to the principal state of the subsurface fluid. Different energy conversion systems are used to recover the energy found in each of these types of hydrothermal resources. Electricity is generated from dry-steam deposits by passing the steam directly through turbines. Liquid-dominated deposits are exploited for power either by partially flashing the hot liquid into usable steam at the surface (flash-steam system) or by transferring its heat to a secondary working fluid, such as freon, which in turn is passed through the turbines (binary-cycle system).

Energy derived from hydrothermal resources also can be used for direct thermal applications. These nonelectric applications, primarily space and process heating, are feasible at temperatures suitable for electric power generation and at lower temperatures. Hot water is piped directly from the geothermal reservoir to the point of use.

Thirty-seven states contain hydrothermal resources; several western regions contain known major resources. Substantial electric power and direct use capacity is expected to be realized by 1984. Projections of approximately 2600 megawatts of electric power generating capacity and nearly 300 megawatts of thermal power by 1984 reflect the potential for this resource.

The Hydrothermal Resources program provides research, development and demonstration (RD&D) support to hydrothermal commercialization activities. This support includes:

- Assessment and confirmation of geothermal reservoirs in cooperation with the USGS, state agencies, and industry.
- Field experiments to demonstrate the engineering and economic aspects of direct heat uses of geothermal resources. The participants are selected by competitive solicitation of cost-shared projects.

- Experimental facilities constructed and operated to perfect new geothermal equipment and process techniques, particularly for electric power production. These techniques will reduce the costs of exploiting hydrothermal resources.

- Major demonstration plants to generate commercial quantities (50 MW_e) of electric power from moderate-and high-temperature geothermal fluids. These plants will provide operating experience needed to establish the technical and economic viability of the technology at full commercial scale. They will be built and operated by industry, which will share the cost.

The Hydrothermal Resources program is divided into four major subprograms: Resource Definition, Non-Electric Applications, Environmental Control, and Facilities. Funding levels for these subprograms are presented in Table II-1.

Table II-1
Funding Levels for Hydrothermal Resources Subprograms
FY 1979 through FY 1981

HYDROTHERMAL RESOURCES	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)			
Subprograms	ACTUAL FY 1979	ESTIMATE FY 1980	ESTIMATE FY 1981	INCREASE (DECREASE)
Resource Definition	26,163	13,406	19,398	5,992
Non-Electric Applications	10,238	12,200	16,000	3,800
Environmental Control	1,859	1,300	2,600	1,300
Facilities	22,968	33,694	15,002	(18,692)
Capital Equipment	1,232	800	0	(800)
Total	62,460	61,400	53,000	(8,400)

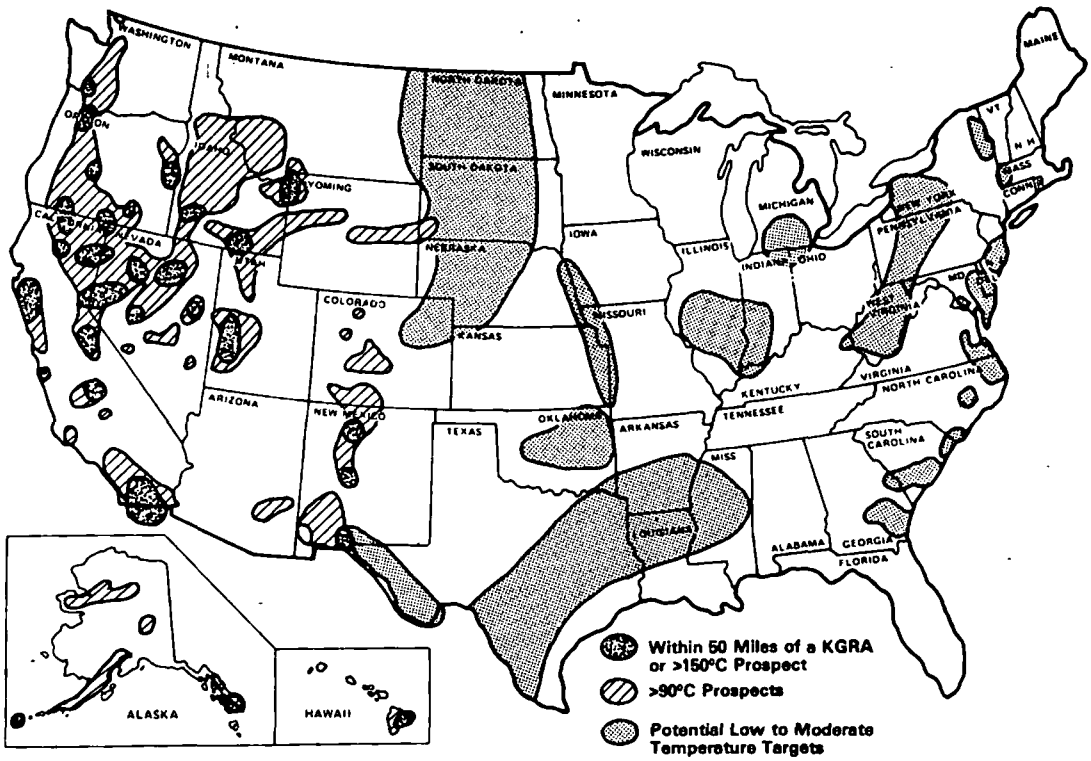
A. Resource Definition

This subprogram provides quantitative assessment of the hydrothermal resource potential and confirms hydrothermal prospects through selective drilling. Other major objectives are to:

- Evaluate the hydrothermal resource potential of the United States,
- Determine the geographical distribution of the hydrothermal resource,
- Confirm the existence and commercial potential of high-temperature reservoirs suitable for both electric power generation and direct heat uses, and
- Identify and confirm low- and moderate-temperature prospects with potential for direct heat application.

In pursuit of these objectives, DGE works with the U.S. Geological Survey in conducting regional and national assessments of hydrothermal resources. Additionally, DGE supports drilling to confirm high-temperature reservoirs with near-term commercial potential under programs cost-shared with private resource developers. Areas of high promise for low- to moderate-temperature reservoirs are the targets of geological and geophysical analyses in projects supported by joint federal and state funding. Further, an exploratory drilling program focuses on several regions with potential for direct heat applications, but without confirmed hydrothermal resources.

The map on the following page illustrates known and potential U.S. hydrothermal resources.



Known and Potential Hydrothermal Resources

Status

- National Geothermal Resource Assessment Update

With DOE support, the U.S. Geological Survey (USGS) has completed a major update of its assessment of U.S. geothermal resources. The results were published in January 1979 as USGS Circular 790. The update reaffirms the existence of large amounts of energy contained within the hydrothermal and geopressured resource bases.

This activity parallels active USGS and state participation in the DOE State-Coupled program. This program is directed at assessment of low- and moderate-temperature geothermal resources for direct heat applications. This relationship will continue to provide new information on low- and moderate-temperature resource areas.

- Industry-Coupled Reservoir Case Study

The objective of the Industry-Coupled Reservoir Case Study is to accelerate confirmation of geothermal reservoirs with apparent commercial potential for producing electricity. The Division of Geothermal Energy (DGE) shares exploratory drilling costs with industry in exchange for publication of reservoir data. In FY 1978, six companies participated in the program. Twenty shallow thermal gradient holes and four deep exploratory wells were drilled in the Roosevelt Hot Springs and the Cove Fort-Sulfurdale areas of south central Utah. In FY 1979, nine companies participated in the program. The program was extended to northern Nevada, where twelve sites are being investigated as candidates for exploratory drilling.

The National Energy Act (1978) provided incentives encouraging the development of geothermal resources, including investment tax credits, expensing of intangible drilling costs, and a percentage depletion allowance. These incentives will facilitate the financial involvement of industry in the exploration for and confirmation of high-temperature geothermal reservoirs, thereby minimizing further direct participation by DOE.

- State-Coupled Program

Low- and moderate-temperature resources for direct heat applications are being defined in a program that involves joint participation by DOE and 30 of the 37 states identified as having hydrothermal resource potential. In Phase I, analysis of existing geological and

geophysical data establishes the probability and distribution of these resources. As promising resources are identified, Phase II is initiated to provide a more detailed assessment of target areas with commercial potential. This phase may include the drilling of deep holes to confirm the existence and nature of the resources. One such project initiated in the Atlantic Coastal Plain region has delineated probable reservoir targets as part of the Phase I activity. Phase II activities are described in the next section.

Geothermal resource maps have been published for Oregon, Nevada and Arizona. Maps for Montana are being prepared. Maps for several other states participating in the State-Coupled program will be published during FY 1980.

- Exploratory Drilling for Low- and Moderate-Temperature Resource Confirmation

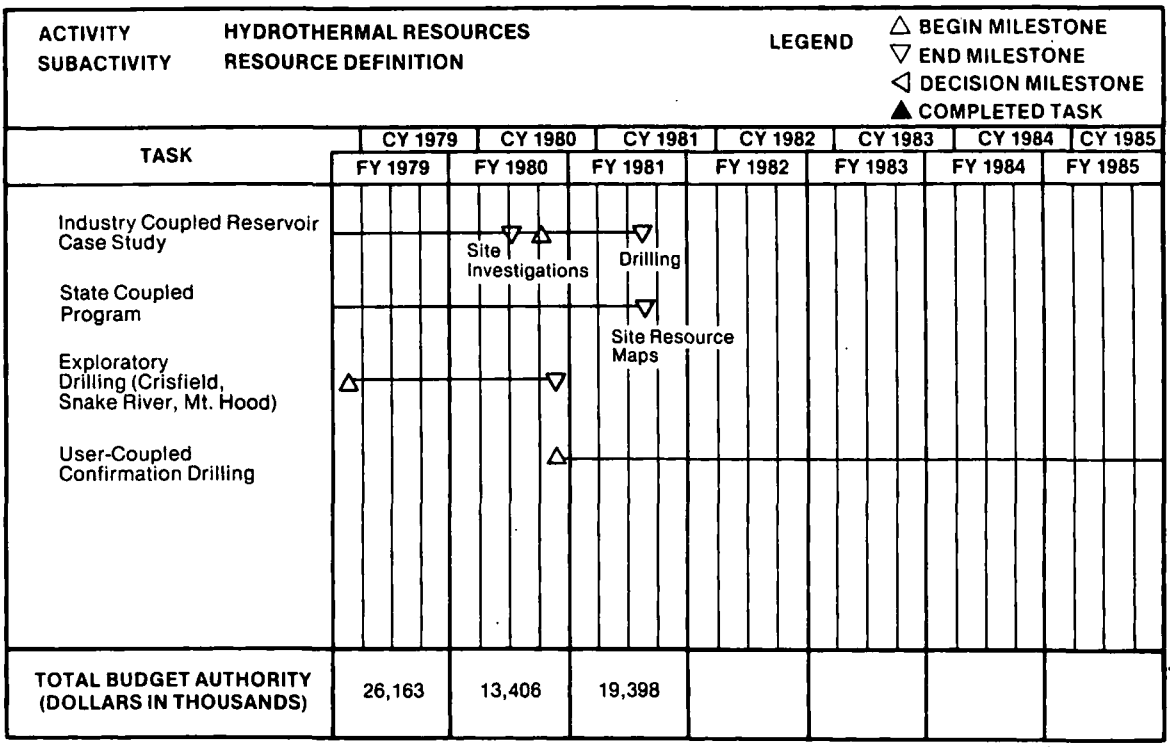
A limited exploratory drilling program has been completed in several regions where there is significant market potential for hydrothermal energy for non-electric purposes and where there are suspected but unconfirmed resources. Examples include the Snake River Plain, the Atlantic Coastal Plain, and the Mt. Hood region. An expanded User-Coupled Drilling program is under consideration. DOE would select a team comprised of a developer and a user to undertake a cost-shared project, consisting of surface exploration and exploratory drilling, to locate and confirm a reservoir suitable for commercial development near the user. Exploratory drilling activities conducted by DOE include the following:

- A 5500-foot deep test well drilled at Crisfield, Maryland recovered 133°F water at a potential flow rate of 325 gallons per minute. One additional exploratory well will be drilled in the Atlantic Coastal Plain during FY 1980.

- A well was drilled to a depth of 10,500 feet in the Snake River Plain to explore the possibility of locating moderate- to high-temperature fluids.

A planned use of the fluids, if located, was to provide a source of heat for a chemical processing plant at DOE Idaho National Engineering Laboratory. The well encountered temperatures of 300°F, but the volume of fluid found was insufficient to meet plant needs.

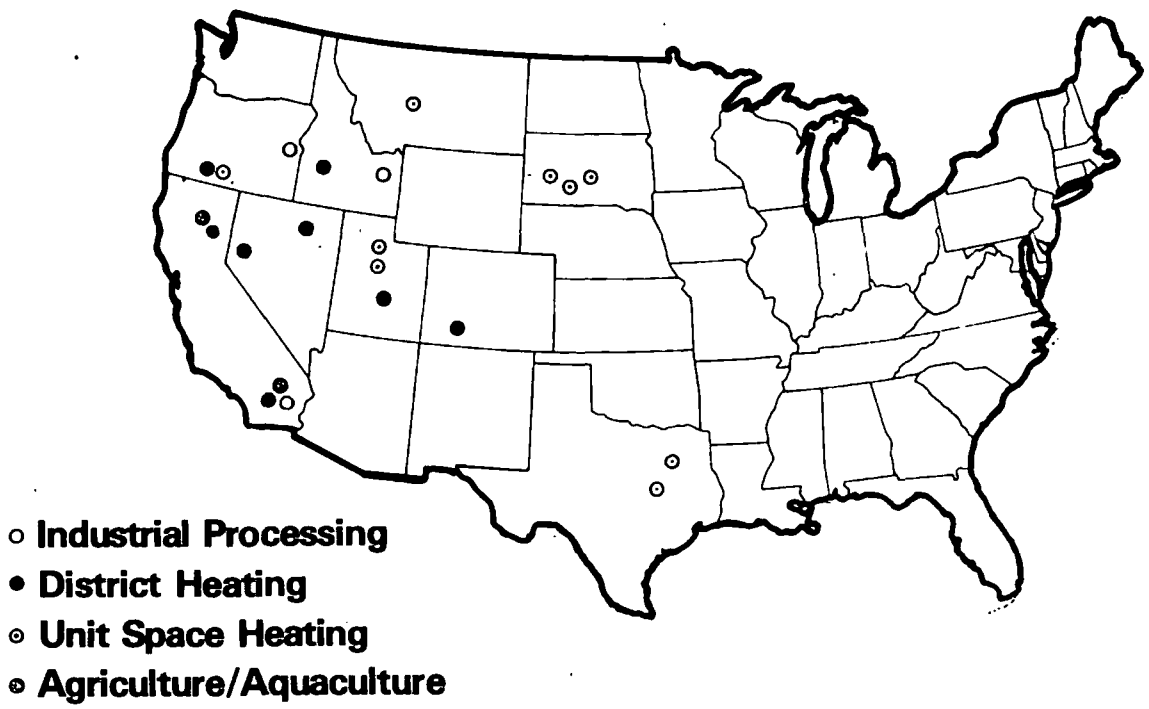
- Two deep wells will be drilled in the Mt. Hood, Oregon, area in FY 1980. Hydrothermal energy at this location might be useful for district heating in the city of Portland and for the space heating of facilities on or near Mt. Hood.



B. Non-Electric Applications

There is a large potential market for geothermal energy for industrial processing, agribusiness, and space and water heating in both commercial and residential buildings. The objectives of direct applications demonstration projects are to provide visible evidence of the viability of geothermal non-electric applications in a number of geographical regions and to obtain definitive technical and economic data under field operating conditions.

The following map indicates the locations of DOE direct heat applications field experiments.



DOE Direct Heat Applications Field Experiments

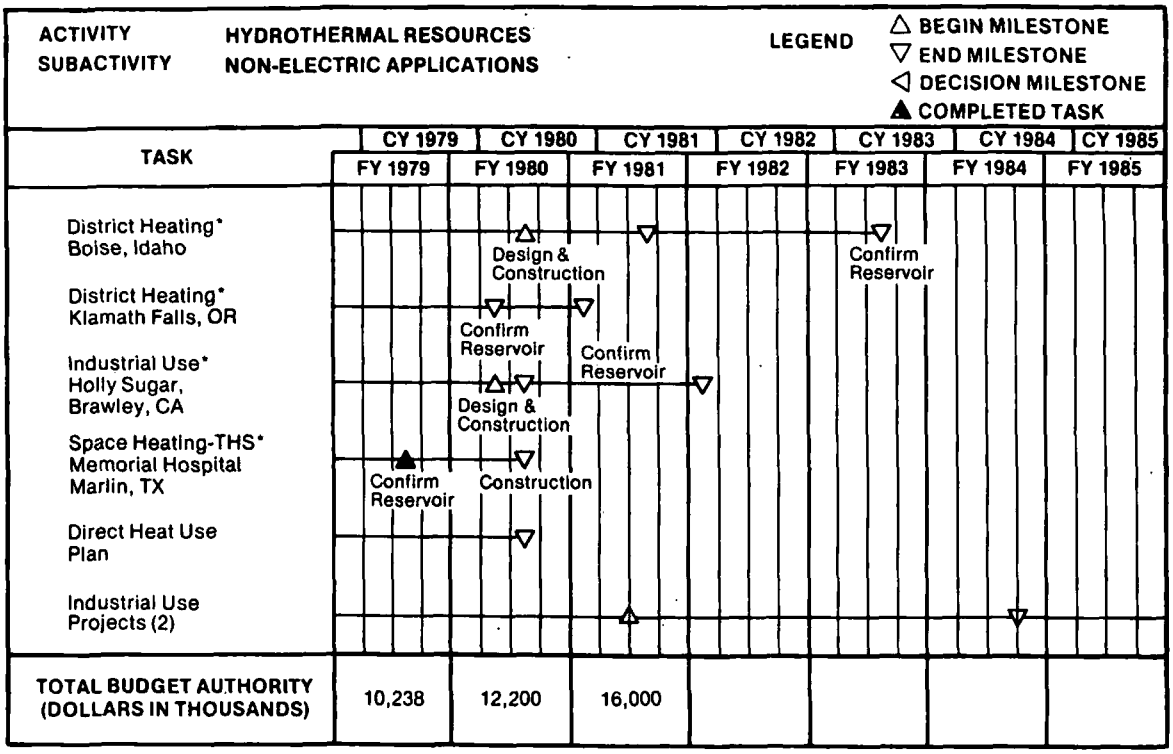
Status

The first solicitation for geothermal direct-use field experiments was issued during the summer of 1977. Twenty-two proposals were received. Eight were selected for subsequent contracts, with the Government's share of the cost varying from 46 to 80 percent. A total of $2.1 million was obligated in FY 1978 for the initial phases of these projects, resulting in commitments of $2.9 million in FY 1979, and $650 thousand in FY 1980 to complete the work.

A second solicitation issued in April 1978 resulted in 40 proposals; 14 were selected for initial FY 1979 funding of approximately $4.9 million. Approximately $10.0 million will be required in FY 1980 and approximately $7.0 million in FY 1981 to complete this group of field experiments. Government cost-sharing amounts to approximately 60 percent of the total project cost.

Of the 22 current projects, the majority are for space heating, while a few are directed at agriculture and aquaculture, and 3 involve industrial processing. Although most of these projects are in the western states, greater emphasis will be placed on locating future demonstration sites in the East as suitable geothermal resources are defined there.

Milestones for Non-Electric Applications are shown on the next page.



*Selected from among 22 active projects

C. Environmental Control

Environmental, health and safety factors affecting geothermal development were identified and discussed in the Environmental Development Plan (EDP) for Geothermal Energy Systems. Although the use of geothermal heat causes less environmental damage than does the use of many competitive energy sources, there are adverse impacts. Release of hydrogen sulfide (H_2S) is a major air quality concern and can cause corrosion of sensitive electrical components. The withdrawal of fluids from geothermal reservoirs may cause land surface subsidence. Additionally, seismic disturbances may result from geothermal fluid extraction and injection processes.

- Air

Some hydrothermal fluids contain dissolved noncondensible gases such as hydrogen sulfide, ammonia, boric acid, and radon. If these are released to the air in large quantities, they could produce toxic effects. Further, hydrogen sulfide has a disagreeable odor which, if emitted in large quantities, could be a nuisance.

- Water

Disposal of those hydrothermal and geopressured fluids which may contain toxic substances is a waste management problem. Care must be taken to assure that ground water quality will not be affected by accidental surface spills or leaks in underground pipes.

- Land

When large quantities of fluid have been extracted from the ground, land subsidence may occur. Earthquakes may be induced by the injection of water into underground fault structures.

- Health and Safety

Well blowouts have occurred during geothermal drilling activities. Excessive noise can result from the drilling of wells during the exploratory and development phases and from venting during the testing and operating phases. These events require appropriate control technology and procedures.

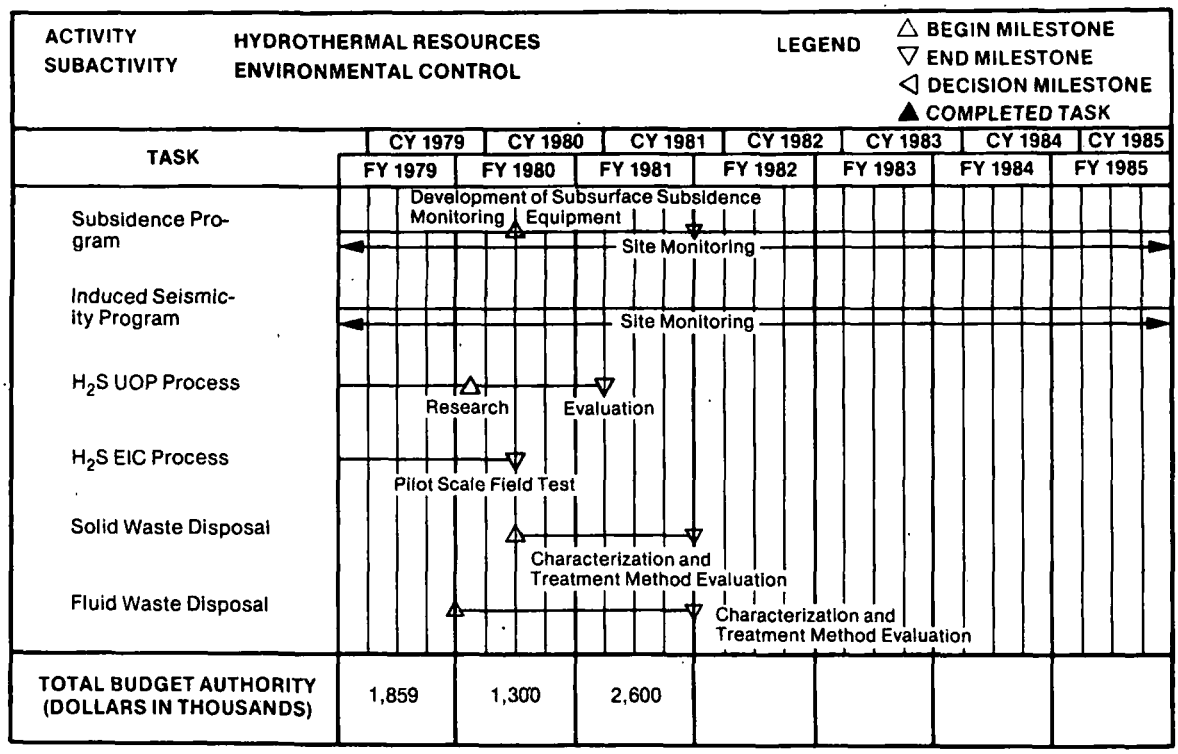
Status

The Division of Geothermal Energy (DGE) has examined each of these major environmental issues and has established environmental control research programs as needed. Experimental impact definition studies of liquid and solid waste disposal and well blowout are underway.

In addition to environmental control studies, DGE sponsors environmental monitoring for each of its major field projects in part to support program preparation of Environmental Assessments/Impact Statements (EA/EIS). To further assist with EA/EIS preparation, DGE has developed guidelines for environmental reports by contractors.

In FY 1980, two research activities in control technology will continue. The Subsidence subprogram will develop a system to monitor subsidence and compaction at depth. The Induced Seismicity subprogram will evaluate the potential for earthquake generation from geothermal activities and will provide seismic monitoring in the vicinity of geothermal fields under development.

A hydrogen sulfide removal system has been successfully tested at The Geysers Geothermal Field in California. Better than 98 percent removal efficiency was achieved. The system was developed by the EIC Corporation of Boston under a cost-sharing contract between DOE and the Pacific Gas and Electric Company (PG&E). The Environmental Protection Agency also participated in the tests.



D. Facilities

Geothermal demonstration plants and other facilities provide technical and economic operating data, hands-on experience for industry, and demonstration of new techniques, equipment, and systems, all at pilot or commercial scale. These facilities foster wider acceptance and use of this alternative energy source. In many areas, industry will construct commercial plants subsequent to successful demonstrations. The following subsections describe DOE hydrothermal experimental facilities.

1. Demonstration Plants

The thrust of this activity is to design, construct, and operate commercial-size geothermal electric power plants based on proven technology. Successful demonstrations will stimulate nonfederal development of liquid-dominated hydrothermal resources for generating electric power.

The plants will demonstrate that production of electric power can be economical, environmentally sound, and socially acceptable. Project objectives are to:

- Demonstrate reservoir performance characteristics of specific liquid-dominated hydrothermal reservoirs,
- Demonstrate the validity of reservoir engineering estimates of reservoir productivity (capacity and longevity),
- Demonstrate commercial-scale energy conversion system technologies,
- Initiate commercial development at resource sites with great potential,
- Reduce unnecessary regulatory requirements and resolve other legal and institutional impediments to geothermal development, and
- Provide the financial community with a basis for estimating the risks and benefits associated with geothermal investments.

Each demonstration plant will generate statistically reliable engineering and cost data on reservoir performance and on plant construction, operation, and maintenance for up to five years. This in turn will demonstrate predictable technical, economic, and environmental performance with acceptable risk on a commercial scale.

For the information derived from the project to be useful, federal involvement must not distort the data from

normal business practices. Therefore DOE delegates management of the demonstration projects to industrial participants to ensure that the projects provide a realistic basis for the private sector to assess commercial feasibility.

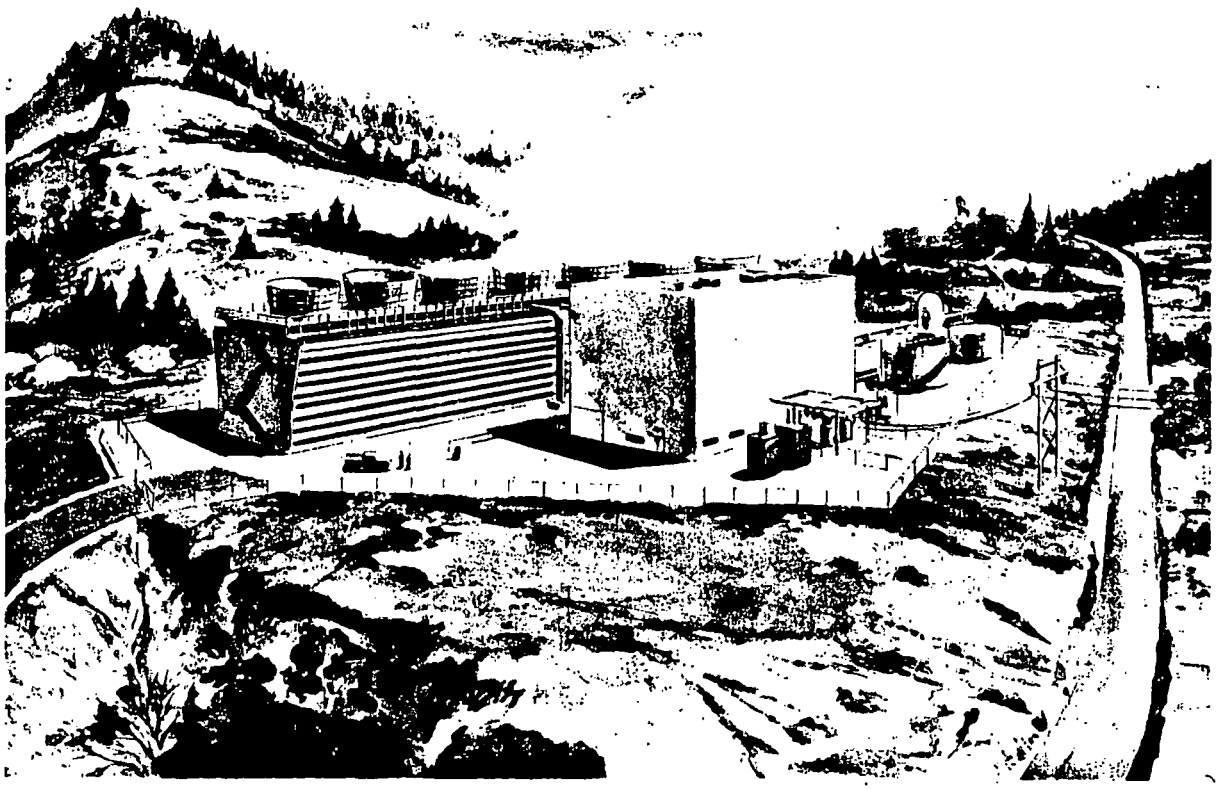
Status

Under a cooperative agreement, both DOE and the competitively selected industrial participants will share the costs of design, construction, and operation of a 50-MW_e commercial-scale geothermal flash-steam demonstration plant at Valles Caldera, New Mexico. The arrangement involves paying back to the Government its portion of the investment from operating revenues.

In September 1977, ERDA issued the Geothermal Demonstration Powerplant Program Opportunity Notice (PON-EG-77-N-03-1717). In July 1978, the DOE Under Secretary determined, following presentation of the Source Evaluation Board findings, that negotiations for the construction and operation of the 50-MW_e commercial-scale geothermal demonstration plant should be initiated with Union Oil Company of California and the Public Service Company of New Mexico, under a cost-shared cooperative agreement. The proposed site is the Baca Ranch in Valles Caldera, New Mexico.

A letter cooperative agreement was executed between DOE, Union Oil, and the Public Service Company of New Mexico on September 29, 1978. The final cooperative agreement was completed on August 6, 1979. The final Environmental Impact Statement was scheduled for publication in early 1980. The plant should be operational by the second quarter of FY 1982.

An artist's conception of the first 50-MW_e demonstration plant is shown overleaf.



50-MW_e Hydrothermal Demonstration Plant

2. Raft River Pilot Plant

This project is a 5-MW_e binary cycle plant that uses a Rankine cycle to convert energy from a moderate-temperature hydrothermal resource (300°F) to electric power. Plant operating data will supply valuable information on the geothermal reservoir and plant equipment, operations, and economics for future commercialization of moderate-temperature resources.

Status

Plant construction is about 80 percent complete. The system is now being fitted with a turbine generator set, and additional well tests are being undertaken. This plant is expected to be operational by the end of FY 1980.

3. Hawaii Geothermal Wellhead Generator

The objective of this project is to evaluate the feasibility of using a wellhead generator to produce base-load electrical power. The 3-MW_e generator will use the geothermal fluid from a well already drilled into the rift zone of an active volcano. The design calls for mounting of the major power plant components, where economically feasible, so that they can be moved to other sites if threatened by lava flows. The project is expected to lead to commercial applications of wellhead generators in remote areas of the western U.S., Hawaii, and other parts of the world.

The construction phase started in the third quarter of FY 1979 and will be completed in the fourth quarter of FY 1980. The wellhead generator is being installed on a geothermal well in the Puna District, Hawaii.

Construction of this facility is on schedule and major equipment has been ordered. The geothermal well, which required recementing in FY 1979, is scheduled to begin production in the first quarter of FY 1981.

4. Geothermal Loop Experimental Facility (GLEF)

This facility, located near Niland, California, was established to evaluate the feasibility of flash-steam and flash-binary systems in the production of electric power from high-temperature/high-salinity resources. The project is cost-shared on an equal basis with the San Diego Gas and Electric Company.

The GLEF was constructed in 1975. The facility evaluated the flash-binary system initially and was later modified to evaluate a two-stage flash-steam plant with redundant flash trains. The latter plant design can increase production efficiency from well below 75 percent to over 85 percent and significantly reduce electricity production costs.

Studies have produced effective pre-injection fluid treatment procedures to eliminate injection clogging problems. Additionally, problems of scaling and corrosion have been solved. The facility completed its testing during FY 1979. The data derived from the facility have prompted Magma Power Company to build a 50-MW_e flash-steam plant on this site. This plant will be operational by late calendar year 1982 or early calendar year 1983.

5. Geothermal Component Test Facility (GCTF)

This facility provides moderate-temperature, low-salinity geothermal fluid and supporting services to experimenters for R&D testing of equipment and components to be used in geothermal systems.

The GCTF, located in East Mesa, California, is currently being used by several industrial firms and DOE contractors. It will be operational until demand diminishes.

ACTIVITY HYDROTHERMAL RESOURCES
SUBACTIVITY FACILITIES

LEGEND
△ BEGIN MILESTONE
▽ END MILESTONE
◁ DECISION MILESTONE
▲ COMPLETED TASK

TASK	CY 1979 / FY 1979	CY 1980 / FY 1980	CY 1981 / FY 1981	CY 1982 / FY 1982	CY 1983 / FY 1983	CY 1984 / FY 1984	CY 1985 / FY 1985
50 MWe Flash-Steam Demonstration Plant	Design △	Construction ▽△		▽△	Operation ▽		
Raft River Pilot Plant	Construction ▽	△	Operation ▽				
HGP-A Geothermal Well Head Generator	Design △	Construction ▽△	Operation ▽				
Geothermal Loop Experimental Facility	Operation ▲	Decommissioning ▽					
TOTAL BUDGET AUTHORITY (DOLLARS IN THOUSANDS)	22,968	33,694	15,002				

III. HYDROTHERMAL COMMERCIALIZATION

The Hydrothermal Commercialization program is designed to enable industry to maximize utilization of the Nation's geothermal resources in an environmentally and socially acceptable manner in the near term.

The major objective of the Hydrothermal Commercialization program is to accelerate the rate of commercial utilization of hydrothermal resources for electric power production and direct heat applications so that geothermal energy will make a significant contribution to domestic energy production. The development of hydrothermal resources will lead to the installation of new electric generating facilities needed to satisfy regional electric power demands, displacing fossil fuel required for this purpose. The Hydrothermal Commercialization program consists of two major subprograms: Planning and Analysis and Private Sector Development.

Funding levels of the Hydrothermal Commercialization program are presented in Table III-1.

Table III-1
Funding Levels for Hydrothermal Commercialization Subprograms
FY 1979 through FY 1981

HYDROTHERMAL COMMERCIALIZATION	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)			
Subprograms	ACTUAL FY 1979	ESTIMATE FY 1980	ESTIMATE FY 1981	INCREASE (DECREASE)
Planning and Analysis	5,239	5,000	5,040	40
Private Sector Development	4,410	4,860	4,960	100
Total	9,649	9,860	10,000	140

A. Planning and Analysis

This facet of the Hydrothermal Commercialization program comprises activities that establish program needs, priorities, and strategies through analyses of the economics of geothermal energy use, market penetration, institutional and legal barriers, and federal policies. To this end, the Division of Geothermal Resource Management (DGRM) prepares commercial development plans on site-specific, regional, and national levels and monitors progress made toward accomplishment of national objectives.

1. Planning

Geothermal commercial development plans at the local, state, and national levels are formulated to promote the rapid and efficient development of major geothermal prospects. State, local, and industrial entities participate in developing these plans.

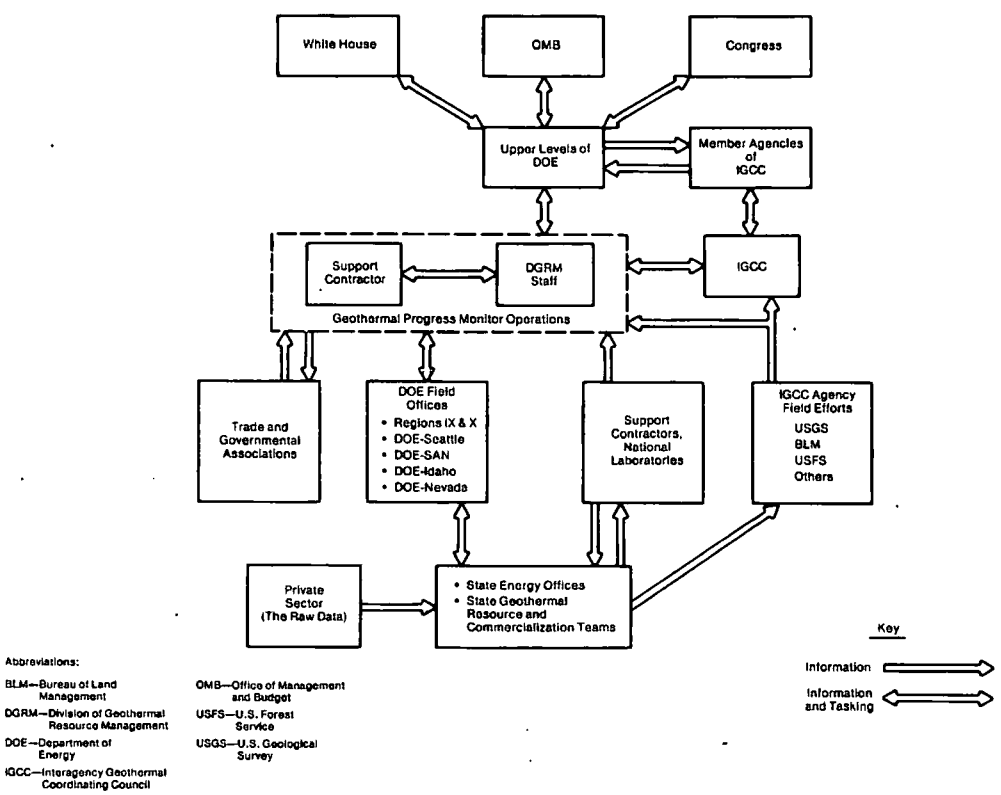
Status

The statewide geothermal development planning projects and site-specific commercialization project planning in 15 Western and 3 Atlantic Coastal Plain states will continue through FY 1980. These cost-shared cooperative projects are targeted for three-year federal financial support followed by state-supported project continuation. Projects in additional states will begin in FY 1981.

2. National Progress Monitoring

The Division of Geothermal Resource Management has initiated the design and implementation of a national geothermal progress monitoring system as a foundation for assessing early indications of success or shortfall in commercialization. This will facilitate the adjustment of geothermal programs and plans. The system will provide periodic reports on status and progress and will maintain selected data bases to support progress evaluations.

The diagram below illustrates the geothermal progress monitoring network.



Geothermal Progress Monitoring Network

Status

The design of the system will be completed in FY 1980 and relevant information will be acquired, analyzed, and published. The system will report the pace of geothermal commercialization and thus measure the impact of the federal geothermal program.

3. Interagency Coordination and Federal Policy Development

The major purpose of this activity is to support the Interagency Geothermal Coordinating Council (IGCC) and to provide an interagency forum for the review of federal policies, regulations, and legislation related to geothermal matters. This activity also coordinates the IGCC annual report to Congress, as required by law.

Status

The panels and working groups of the IGCC continuously review new regulations, coordinate federal cooperative planning, and identify regulatory and legal changes and new policy measures that could affect the achievement of commercialization goals.

4. Economic Evaluation and Barrier Analysis

In this effort, DGRM conducts economic evaluations and barrier analyses to establish the market penetration potential for hydrothermal resources and to support the design of optimum marketing strategies. Further, impacts

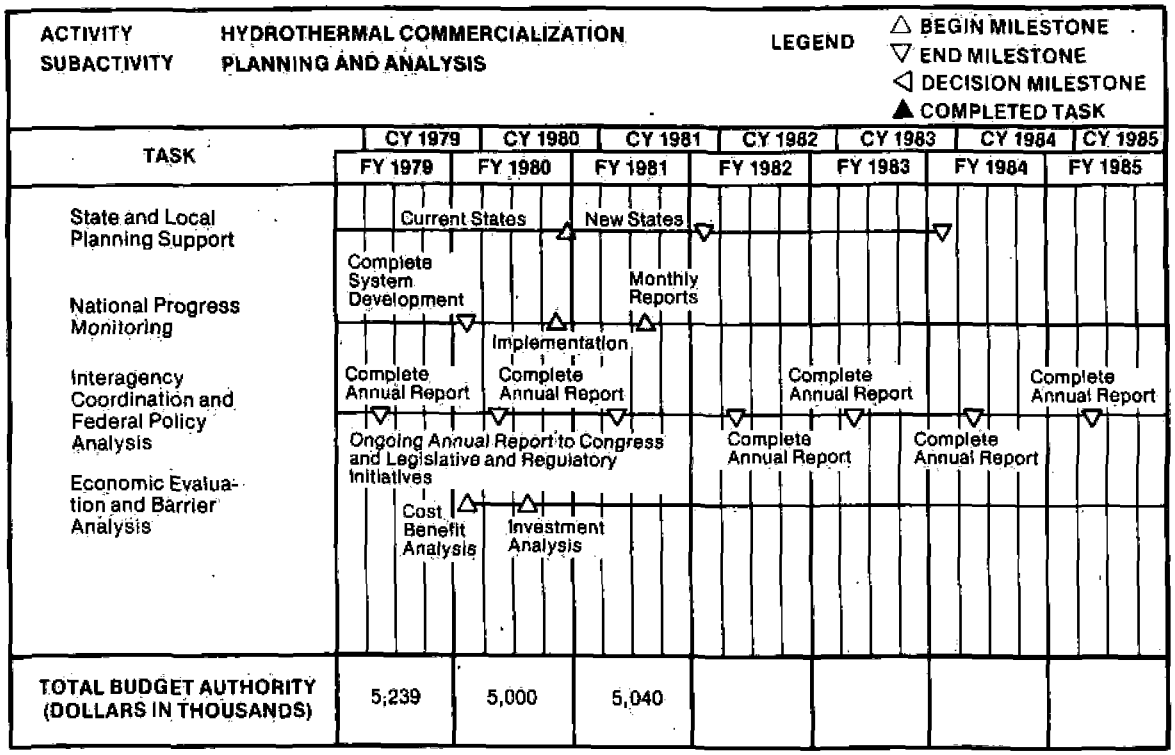
of laws and regulations at the federal, state, and local levels on hydrothermal resource commercialization are evaluated and programs to overcome barriers are implemented.

Status

The market penetration likely in various geographic and industrial sector categories under alternative economic, policy, and technology assumptions will be estimated during FY 1980. Also, a cost-benefit analysis of the effectiveness of present and proposed federal program and policy measures will be conducted.

An analysis of existing federal, state, and local laws and regulations will form the basis for recommendations to enhance commercialization, particularly for direct heat applications. In FY 1980, basic economic data necessary to support DOE analysis and program prioritization will be generated.

Milestones for Planning and Analysis are shown on the following page.



B. Private Sector Development

This aspect of the Hydrothermal Commercialization program seeks to stimulate private sector development through identification of and support for site-specific commercial opportunities for direct heat applications. Funds are provided for site- and application-specific engineering and economic studies of large-scale direct heat applications performed by the private sector. Support of regional community assistance centers is rendered along with technical consultation and information dissemination as part of an information outreach program.

1. Market Assessment

This effort seeks to identify market strategy and specific markets suitable for early penetration on a site-by-site, industry-by-industry, or project-by-project

basis. A further goal is to establish the economic competitiveness of geothermal energy with alternative fuels on a case-specific basis through removal of barriers and provision of incentives.

Status

During FY 1980, market analyses will be performed to define the market according to particular end-uses, size of market, location with respect to resource, density of users within a geographic area, and engineering feasibility. An analysis of energy supply and demand on a site-specific basis will be initiated to predict the degree of market potential and to identify actions and events which would increase market penetration. The potential for market penetration will be assessed through evaluation of the cost of competing energy sources, value of special attributes, and effects of alternative fuel availability.

Environmental, legal, and institutional barriers and financing problems related to specific projects will be addressed in FY 1980. A marketing strategy which considers these constraints at the state and local levels will be developed. Cooperative studies with various industries will be completed to determine the market potential of geothermal energy.

2. Hydrothermal Applications

The aim of this activity is to stimulate private sector interest in development of geothermal direct heat applications through direct developer/user participation and cost-sharing in feasibility analyses and direct heat utilization demonstration projects.

Status

The technical/economic studies concerning institutional uses, district heating, and industrial use of geothermal energy will be completed. Seven to nine additional assessments will be initiated to establish the feasibility of specific direct heat applications. A few selected industrial-scale site-specific pilot projects will be conducted under this program. A number of cost-shared field demonstrations will also be administered under the Program Opportunity Notice (PON) program. The experience gained from these projects will provide actual cost data for a variety of applications (see Section II.B, Non-Electric Applications).

3. Outreach Activities

This aspect of the private sector development effort strives to increase the general level of public and private understanding, interest, and enthusiasm for using geothermal energy as an alternative to imported or depletable domestic resources.

Status

Outreach activities undertaken in FY 1980 will include technical consultation with potential industry, community, and utility end users and public education programs that involve the dissemination of information on geothermal applications. When appropriate, DGRM will function as a broker between the developer and user to facilitate agreements and user commitments for commercial development.

4. Geothermal Loan Guaranty Program

In order to encourage and assist the private sector in accelerating the development and utilization of geothermal resources, DGRM supports a loan guaranty program to minimize a lender's financial risk so that credit can be made available for the construction and operation of geothermal projects, research and development projects, and field exploration. Further goals of the program are to encourage normal borrower-lender relationships and flow of credit to the geothermal industry in time without the need for loan guaranties, to enhance competition, to encourage new entrants into the geothermal market, and to commercialize a wide variety of geothermal resource areas and utilization projects.

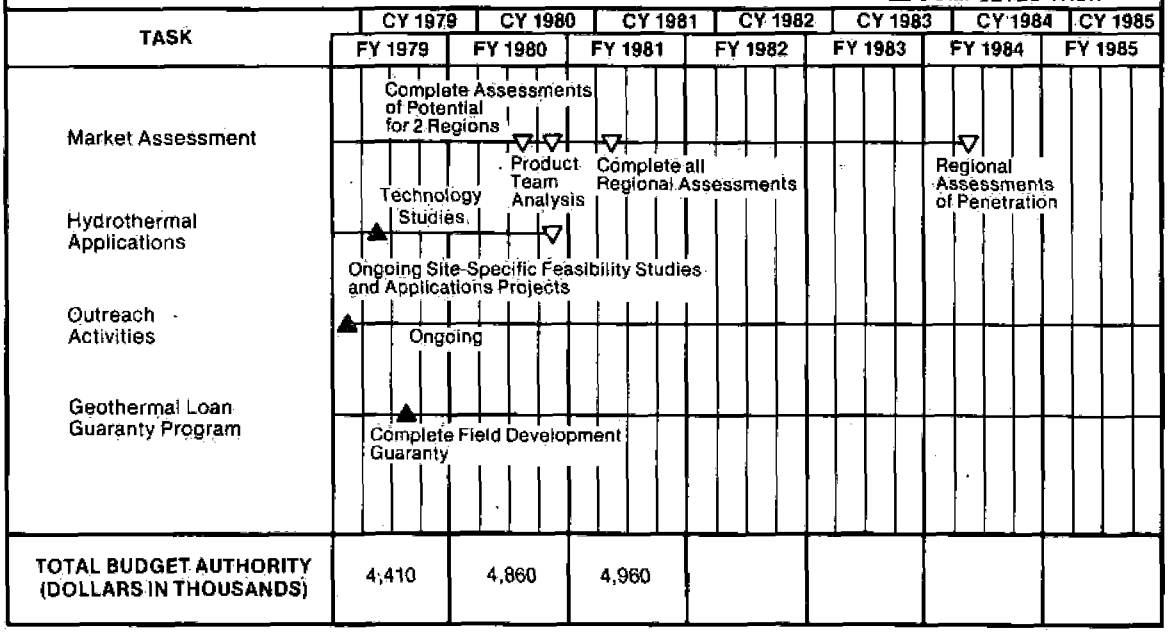
Status

The Geothermal Loan Guaranty program (GLGP), continuing in FY 1980, provides guaranties to lenders on loans made for geothermal projects. Lenders perform traditional loan servicing functions so that experience is gained with each geothermal project. Guaranties are provided for both electric and direct heat projects.

The GLGP presently has guaranteed $43.4 million on four loans totalling $64.4 million. Applications are now pending for guaranties totaling $87.4 million on loans totaling $126.3 million. Three projects will provide an added 77 MW_e to current electricity production, and other projects will provide 117 billion Btu/yr for food processing.

ACTIVITY: HYDROTHERMAL COMMERCIALIZATION
SUBACTIVITY: PRIVATE SECTOR DEVELOPMENT

LEGEND
△ BEGIN MILESTONE
▽ END MILESTONE
◁ DECISION MILESTONE
▲ COMPLETED TASK



TOTAL BUDGET AUTHORITY (DOLLARS IN THOUSANDS)	4,410	4,860	4,960				

IV. GEOPRESSURED RESOURCES

Geopressured resources are high-pressure aquifers that contain dissolved methane gas. Methane is the major target of the energy recovery process, although thermal and mechanical hydraulic energy may also be obtained from the geopressured fluids. Recovery of the latter two forms, however, will be contingent on economical recovery of methane.

Geopressured aquifers, 12,000 to 20,000 feet deep, occur in the U.S. primarily in two broad zones parallel to the Texas/Louisiana coastline. Reservoir modeling and mapping of the Gulf States have identified numerous candidate sites for exploration. Extensive data from thousands of deep wells, drilled originally for oil and gas, prove the existence of these high-temperature, high-pressure zones and identify the geologic conditions under which they occur. The resource is estimated to contain between 3,000 and 50,000 quads of energy and thus constitutes a major U.S. energy target. Geopressured energy utilization goals are 2000 megawatts thermal (MW_t) and 3 quads per year methane production by the year 2000.

The objectives of the Geopressured program are to determine:

- The magnitude of the resource base,
- The amount of methane that is technically feasible to produce,
- The probable production lifetimes of the individual reservoirs,
- The economics of methane production,
- The economics of developing the associated thermal and mechanical energy, assuming that methane recovery is economical,

and to resolve environmental and institutional issues associated with developing the geopressured resource.

The existing Gulf Coast oil and gas production industry is expected to undertake rapid commercial development

of geopressured resources, provided that the resource base is shown to be sufficiently large and that its energy content can be tapped economically without adverse environmental effects.

The Division of Geothermal Energy supports resource definition and environmental assessment activities at the University of Texas, Austin and the Louisiana State University, Baton Rouge.

The program focuses on production tests of wells drilled into geopressured reservoirs. The results will reveal reservoir characteristics and the basic drive mechanisms that cause fluid and gas production, thereby allowing reservoir productivity and longevity to be estimated. Because the characteristics of geopressured aquifiers vary widely, and because reservoir performance under production conditions is a complex phenomenon, a substantial number of tests will be required before the potential of the total resource can be estimated reliably.

After the geopressured fluid has been brought to the surface, the associated methane can be recovered with existing technology. Although some improvements in well completion technology and in methods for managing reservoir production may be required, the conversion of thermal and mechanical energy to electric power (or the direct use of the thermal energy) apparently does not present significant technical barriers. Another issue to be considered is disposal of the brine, which would be produced in large volumes. The most practical method appears to be injection into subsurface formations, but the long-term effects of such operations have not yet been firmly established.

The Geopressured program is divided into four major subprograms: Program Coordination, Resource Definition, Engineering Applications, and Environmental Control.

Funding for each of these components is presented in Table IV-1.

Table IV-1
Funding Levels for Geopressured Resources Subprograms
FY 1979 through FY 1981

GEOPRESSURED RESOURCES	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)			
ACTIVITIES	ACTUAL FY 79	ESTIMATE FY 80	ESTIMATE FY 81	INCREASE (DECREASE)
Program Coordination	1,192	882	2,200	1,318
Resource Definition	24,455	32,329	31,000	(1329)
Engineering Applications	72	839	900	61
Environmental Control	551	1,650	1,700	50
Facilities	0	0	0	0
Capital Equipment	111	300	200	(100)
Total	26,381	36,000	36,000	0

A. Program Coordination

The purpose of this activity is to determine the economic, environmental, institutional, and technological viability of developing the geopressured resource and to provide overall program planning. Policy options and technical programs are being assessed in coordination with federal, state, and local government agencies, industries, utilities, field operators, and public interest groups. This coordination of regional planning activities is organized through Louisiana State University and the University of Texas.

Status

Under these projects, resource characterization data are currently being gathered. These data will be used to identify impediments to geopressured resource development. This information, along with analyses of social and institutional factors that may affect geopressured energy use, will help identify impediments to commercial development of these resources.

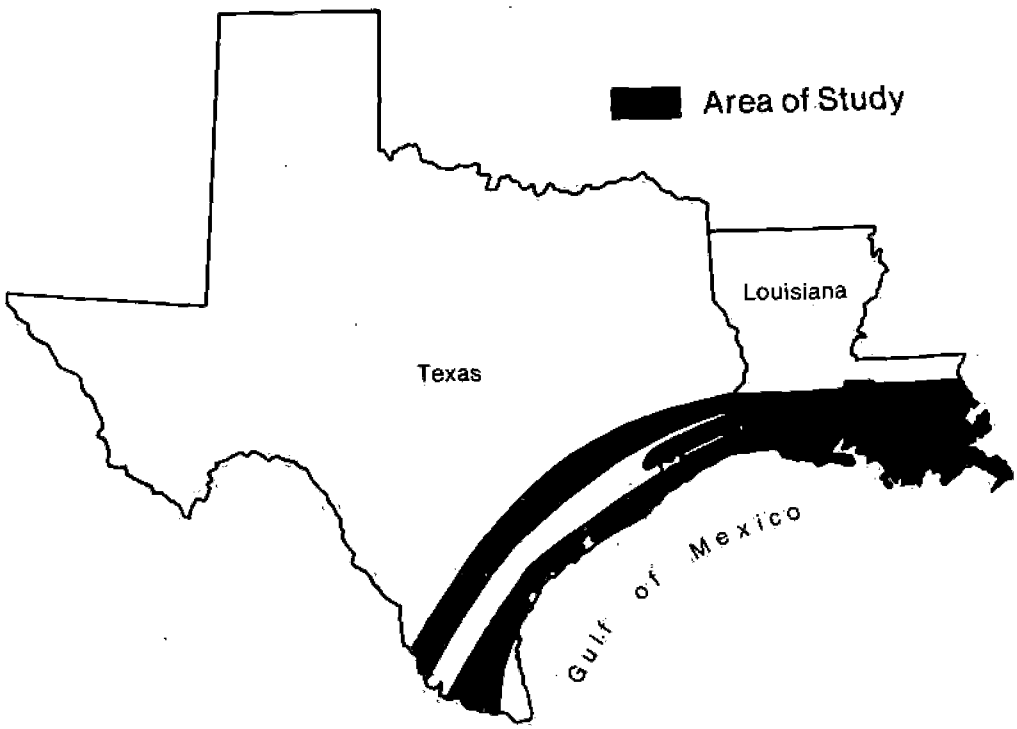
In addition, studies focusing on the legal issues surrounding geopressured resource development have been carried out by Louisiana State University and the University of Texas.

DGE is also cooperating with the Gas Research Institute in the investigation of the potential for recovery of methane from geopressured resources.

B. Resource Definition

The purpose of the Geopressured Resource Definition subprogram is to determine location, size, temperature, pressure, methane content and production characteristics of geopressured sandstone aquifers along the Texas and Louisiana Gulf Coast. This complex analysis is based on geophysical log data from thousands of existing wells (originally drilled for oil and gas), on seismic surveys and core analyses, and on production testing of both new and existing wells.

The location of Gulf Coast geopressured sandstone aquifers is shown on the facing page.



Gulf Coast Geopressured Zones

Status

Detailed examination of geopressured aquifers is continuing in FY 1980. The resulting data allow estimation of the resource base and aid in selecting sites for well drilling and teting projects.

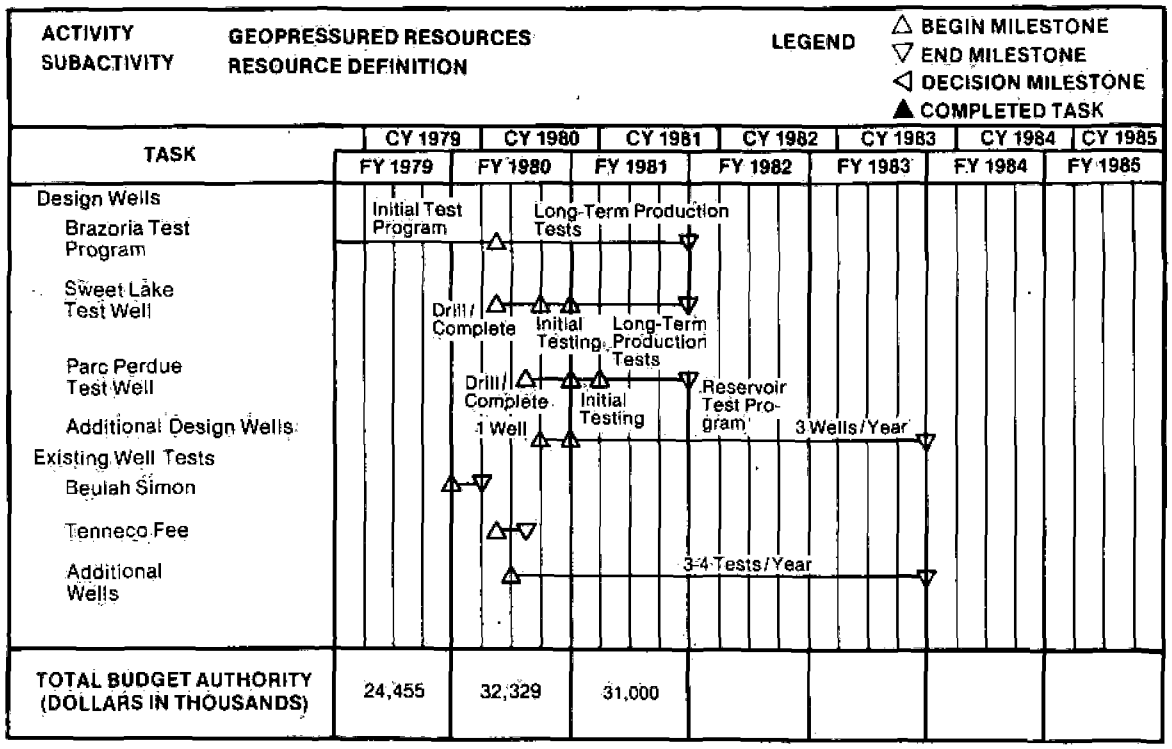
Testing of existing wells, originally drilled to explore for oil and gas, is a means of obtaining geopressured aquifer data at moderate production rates in tests lasting only a few weeks. Tests of existing wells under the Wells-of-Opportunity subprogram will help define

requirements for development of the geopressured energy source. The first successful test of a geopressured aquifer, conducted in Vermillion Parish, Louisiana in 1977, produced methane-saturated brine. Additional tests in a well located in St. Mary's Parish were conducted in FY 1979. Existing well tests will continue in FY 1980 and FY 1981.

Though existing wells are suitable for short-term testing, these conventional oil and gas wells are not appropriate for long-term tests of fluid production at high flow rates. Long-term tests are needed to define properly the production capacities and longevities of large geopressured reservoirs, to determine the technical and economic aspects of brine disposal, and to define the probability of land surface subsidence and other environmental effects.

In 1979, DOE successfully drilled the Pleasant Bayou geopressured test well in Brazoria County, Texas, which is currently undergoing tests. Tests on this well will continue through FY 1981.

Approximately fifteen new geopressured wells will be drilled and tested through 1984 (about three per year) and about the same number of existing wells will be subjected to short-term tests.



C. Engineering Applications

Efforts in this area are directed toward reducing the cost of developing and using geopressured resources. The program is carried out under the following basic categories: (1) surface technology and resource utilization and (2) well drilling and completion.

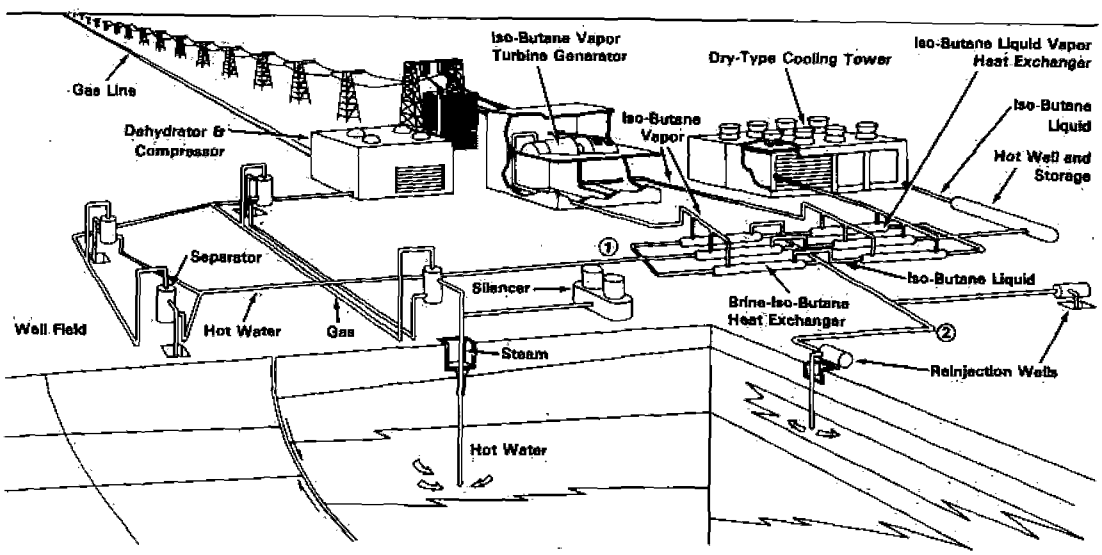
Status

Surface technology and resource utilization activities have been conducted in the areas of methane fuel

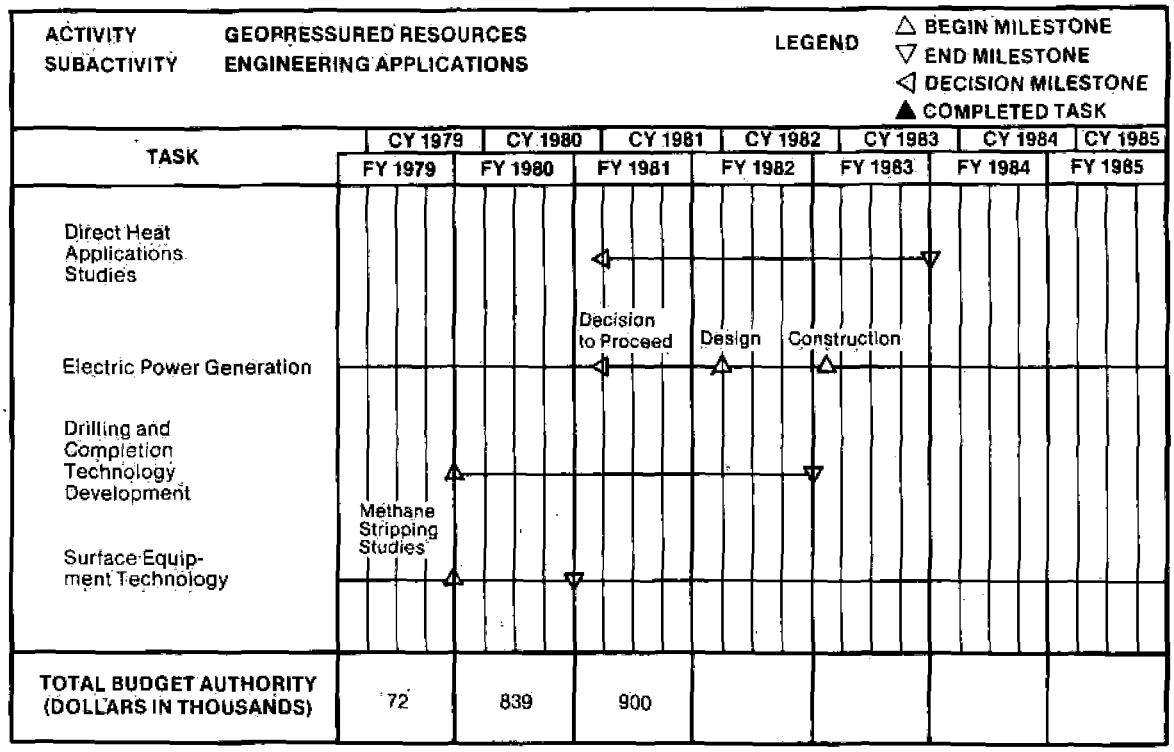
production, direct heat utilization, and electricity production. This work includes the conceptual design of facilities and preliminary economic analyses related to production costs. When the preliminary results of market analyses and well production tests become available in FY 1981, a decision will be made whether to support experimental facilities for electric power generation and direct heat applications from geopressured resources. Appropriate experiments would be undertaken in FY 1982 and FY 1983. Methane stripping studies will take place in FY 1980.

Well drilling and completion technology development will focus on problems related to the high temperature, pressure, and salinity associated with geothermal wells. A program to develop and demonstrate equipment and production methods suitable to geothermal geopressured resources will be carried out in the FY 1980-FY 1982 time period.

The diagram below conceptualizes a geopressured binary-cycle power plant installation.



Geopressured Binary-Cycle Power Plant



D. Environmental Control

The Geopressured program also includes support for continued research on possible environmental effects of sustained high volume production of geopressured brines. Land subsidence is the principal concern addressed by environmental research. The environmental implications of disposing of geopressured well fluids are also being observed through test well monitoring.

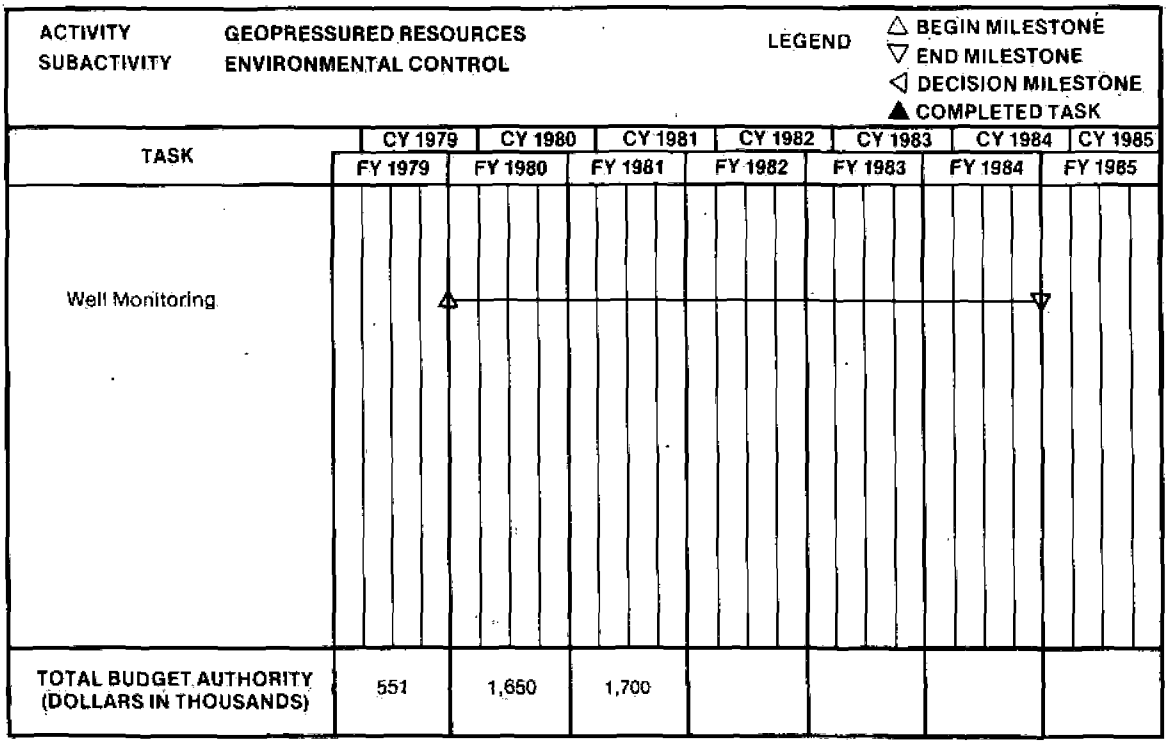
Status

The Pleasant Bayou Test Well in Brazoria County, Texas has been instrumented to measure all environmental parameters, including subsidence, micro-seismicity, and air and water quality. Data obtained from the monitoring of

the well tests will be used to assess the potential impact of geopressured aquifer development.

The disposal of large volumes of brine by reinjection is also under study. The predictive capability of mathematical reservoir models will be tested against well performance data to confirm their reliability.

Environmental assessment and monitoring of well sites in Texas and Louisiana will be accelerated to keep pace with the drilling. Appropriate environmental documentation (Environmental Assessments) will be prepared as necessary in connection with well testing activities conducted under the Resource Definition subprogram.



V. GEOTHERMAL TECHNOLOGY DEVELOPMENT

Geothermal energy can be exploited with technology similar to that used for oil and gas exploration and production. Oil field and water well equipment can be used safely and economically for some low-temperature geothermal applications, but conditions associated with moderate- and high-temperature geothermal resources often exceed the design capabilities of existing techniques, materials, and equipment.

The objective of the Geothermal Technology Development program is to provide improved technology in order to maximize early geothermal exploitation and to expand the economically recoverable resource base. Further, industry is encouraged to develop and market equipment and technology suitable for all geothermal environments. The program is divided into two major subprograms: Component Technology Development and Hot Dry Rock. Funding for Geothermal Technology Development is shown in Table V-1.

Table V-1
Funding Levels for Geothermal Technology Development Subprograms
FY 1979 through FY 1981

GEOTHERMAL TECHNOLOGY DEVELOPMENT	BUDGET AUTHORITY (DOLLARS IN THOUSANDS)			
ACTIVITIES	ACTUAL FY 79	ESTIMATE FY 80	ESTIMATE FY 81	INCREASE (DECREASE)
Component Technology Development				
Drilling & Completion	5,432	7,000	8,250	1,250
Energy Conversion	9,344	7,100	12,800	5,700
Reservoir Stimulation	4,442	3,000	4,500	1,500
Geochemical Engineering & Materials	7,071	3,600	5,005	1,405
Geosciences	8,477	4,200	7,835	3,635
Subtotal Component Development	34,766	24,900	38,390	13,490
Hot Dry Rock	15,077	14,000	13,500	(500)
Capital Equipment	1,479	2,100	1,110	(990)
Total	51,322	41,000	53,000	12,000

A. Component Technology Development

The Component Technology subprogram is organized to correspond to the activities associated with discovery and exploitation of a geothermal resource.

Drilling and well completion technology improvements could reduce the cost of geothermal wells 25 percent by 1983 and 50 percent by 1986. These technology improvements would affect the cost of the projected 10,000 wells that must be drilled in order to bring 25,000 MW_e of geothermal power on line.

The Conversion subprogram is developing pumps, heat exchangers, and systems for use with moderate-temperature geothermal fluid for economical production of electricity.

The Reservoir Stimulation subprogram is working on ways to increase production from individual wells, thereby reducing the number of wells required to exploit a reservoir.

The Geochemical Engineering and Materials subprogram addresses the special character of geothermal fluids and their interaction with other materials. Program efforts focus on developing materials and methods to combat problems of scaling, corrosion, injection well plugging, and materials failure.

The Geosciences subprogram concentrates on improving the technologies for exploration, reservoir engineering, logging instrumentation, and log interpretation.

1. Drilling and Completion Technology

This subprogram supports the development of advanced drill bits, downhole motors, drilling fluids, well completion methods, and advanced drilling systems that could reduce the cost of geothermal wells by as much as 25 percent by 1983 and 50 percent by 1986. The projected 10,000 wells that must be drilled in order to achieve the year 2000 target of 25,000 MW_e of geothermal electric power capacity would be affected by these economies.

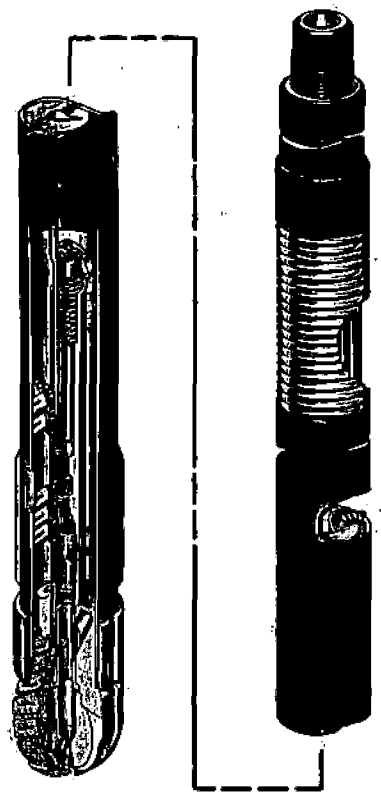
In the initial stage, emphasis is placed on improvements in drill bits, downhole motors, and drilling fluids. Such improvements are necessary to demonstrate technology to meet the 25 percent cost reduction goal. The second stage includes the development of a new drilling system which would be required in order to achieve the 1986 cost reduction goal of 50 percent.

Status

An improved unsealed geothermal roller cone bit was developed and commercialized. This improved bit was designed specifically for drilling hot, hard fractured rock and was field tested at The Geysers Geothermal Field in California. The bits drilled 30 percent longer than conventional bits drilling the same formation at similar temperatures. Use of this new bit can save a minimum of four percent of the total well costs.

A successful field test of the downhole replaceable chain drill bit, developed by Sandia Laboratories, was conducted. This test confirmed the cost benefit of changing the cutting surface of the bit downhole. Commercialization efforts are presently underway. The figure on the next page shows the components of this "continuous chain" drill bit.

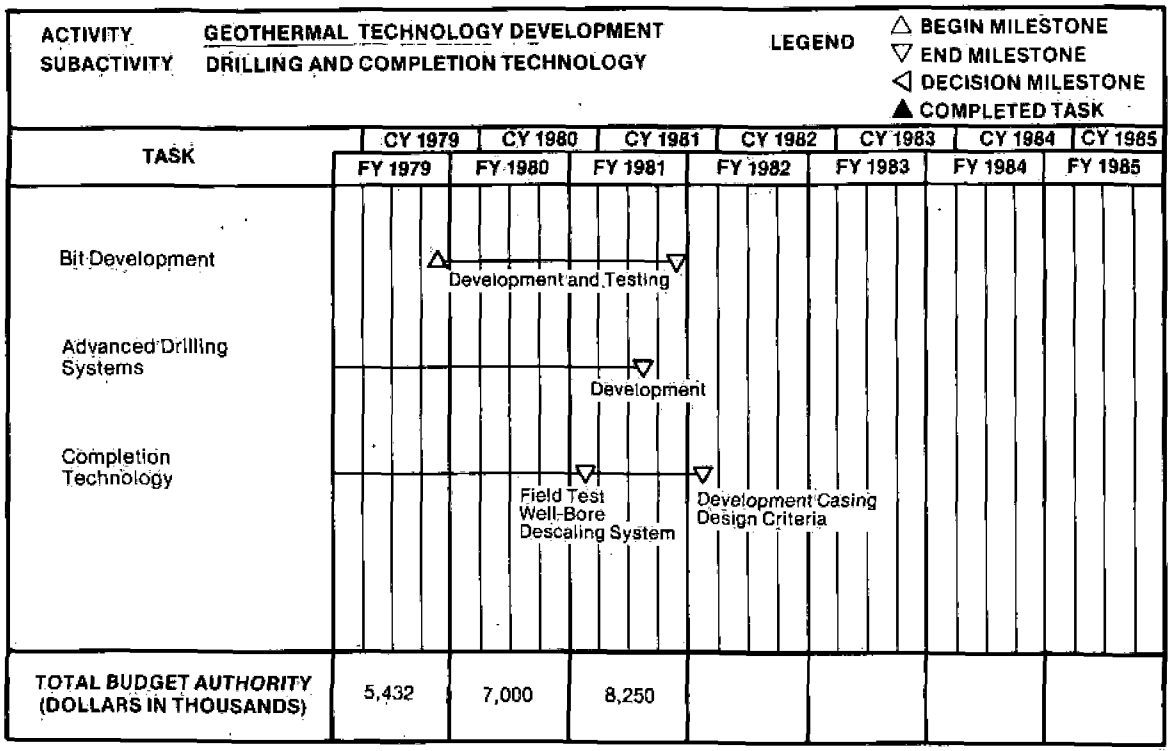
A new technique for removing scale from pipe was demonstrated. This new cavitating descaling system is a critical element in overall geothermal development, because it provides a nondestructive and efficient method for cleaning heat exchangers. The basic technology also will be applied to removing scale from geothermal production and injection wells.



Continuous Chain Drill Bit (Prototype II)

Plans for the development of an advanced drilling system were formulated. A workshop including fifty participants from industry, universities, and government was held to provide recommendations on the development of advanced geothermal drilling systems. Concepts suggested for development include high speed motors and bits, percussion drilling systems, and jet drilling systems.

The FY 1980 program is expected to bring about the commercialization of the continuous chain-drill bit, advances in the use of manmade diamond materials for drill bits, and the evaluation of candidate technology for advanced drilling systems.



2. Energy Conversion Technology

Electricity derived from geothermal resources can serve a wide range of energy markets. The objective of the energy conversion technology program is to reduce geothermal electric generating costs. The program emphasizes conversion technology for moderate temperature resources, which have a much larger resource base than high-temperature resources but are inherently more expensive to exploit.

Binary conversion systems, which offer the greatest potential for reducing electric power generating costs, are a major focus of the program. Conversion technology seeks to improve performance and reduce costs of heat exchangers, which now account for 50 to 70 percent of binary plant costs.

Status

Major accomplishments and plans of the Conversion Technology subprogram include the following:

- The one-MW_e helical screw expander, a rugged, easily transportable wellhead generator system, was refurbished after a successful field test in Utah and made available under a cooperative agreement to the International Energy Agency (IEA) for testing at geothermal fields in Mexico, Italy, and New Zealand.

- A 500-KW_e skid-mounted binary power system employing direct contact heat exchangers has been installed at East Mesa and has undergone preliminary testing.

- A 100-KW_e transportable power system utilizing direct contact heat exchangers has been constructed and installed at a test site near El Dorado, Arkansas. Two months of preliminary shakedown and test runs have been completed. This mobile power plant is pictured on the next page.

- The preliminary design of components for the 5-MW_e gravity head binary cycle system was completed and major components and subsystems were ordered for assembly and installation in a test well in the Imperial Valley of California. Additional phases of the test program, including drilling of a large diameter well and final design, construction, and operation, will occur in FY 1980 through FY 1982.

- Several months of unattended continuous operation of the 60-KW_e binary plant at Raft River have provided new data on the reliability of binary system operation with low-temperature geothermal fluids.

100-KW_e Mobile Power Plant

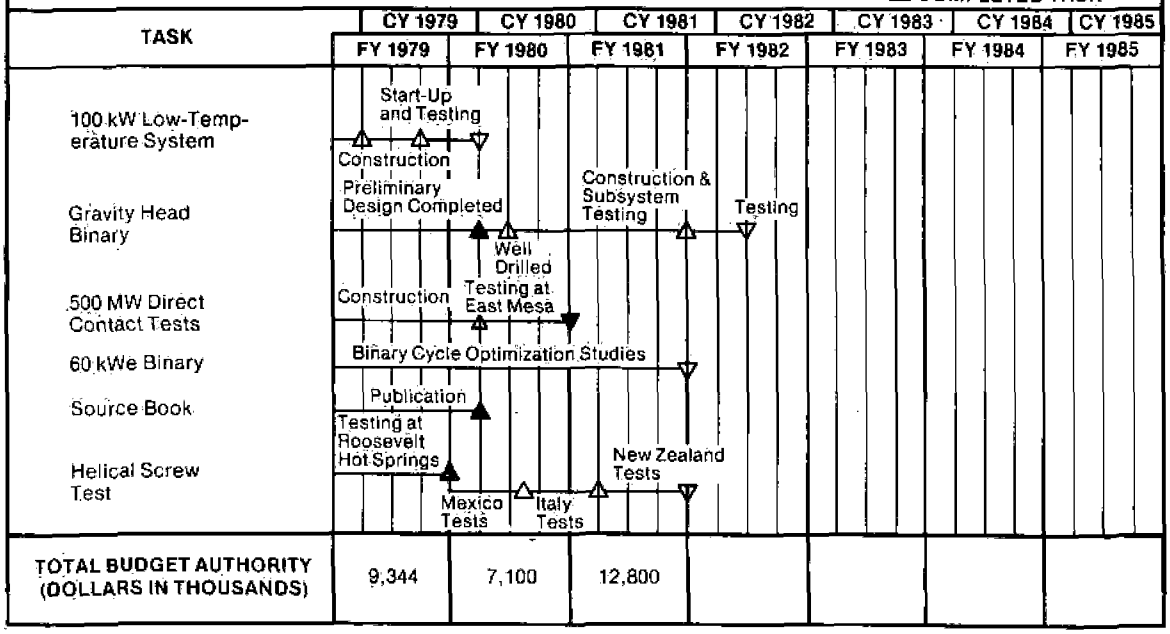
- Joint DOE/Electric Power Research Institute (EPRI) heat exchanger equipment tests have begun at the East Mesa geothermal component test facility.

- A comprehensive source book on the utilization of geothermal energy for electric power production will be published in FY 1980.

Milestones for the Energy Conversion Technology subprogram are shown on the next page.

ACTIVITY: GEOTHERMAL TECHNOLOGY DEVELOPMENT
SUBACTIVITY: ENERGY CONVERSION TECHNOLOGY

LEGEND
△ BEGIN MILESTONE
▽ END MILESTONE
◁ DECISION MILESTONE
▲ COMPLETED TASK



TOTAL BUDGET AUTHORITY (DOLLARS IN THOUSANDS)	9,344	7,100	12,800				

3. Reservoir Stimulation

Stimulation technology is used to increase fluid productivity of wells. Methods for stimulating geothermal wells include chemical treatment, hydraulic fracturing, and explosive fracturing. Geothermal stimulation methods can reduce the number of wells required to exploit a reservoir, thereby decreasing costs. Because of the high temperatures and the geologic conditions found in geothermal reservoirs, requirements for geothermal well stimulation technology differ from those for oil and gas wells. Under the geothermal well stimulation program, new equipment and techniques are being developed to function in the geothermal environment.

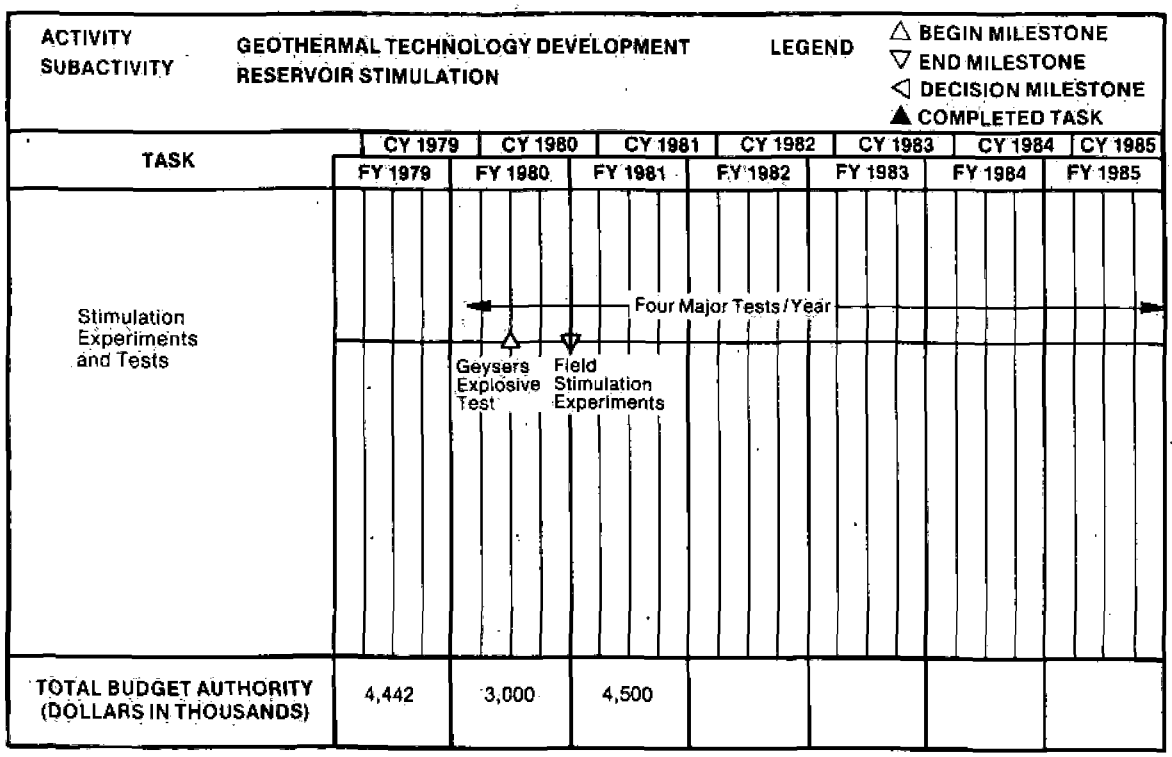
Status

An active geothermal well stimulation program was started in FY 1979 with the stimulation of wells at Raft River, Idaho. Stimulation resulted in a significant increase in production from one well and no discernable change in production from the second.

New tools and techniques for performing explosive stimulation of a well at The Geysers Geothermal Field in California have been developed. Newly developed high temperature explosives will be used in an attempt to increase fracture permeability. Explosive tests will be carried out in March 1980.

The Stimulation subprogram will carry out at least four field stimulation experiments by the end of FY 80. High-temperature equipment will be developed for use in the field experiments. The interactions between hot geothermal formations and various acids used to dissolve calcium carbonate and silica in the well bore and formation will be evaluated.

Milestones for this subprogram are shown on the next page.

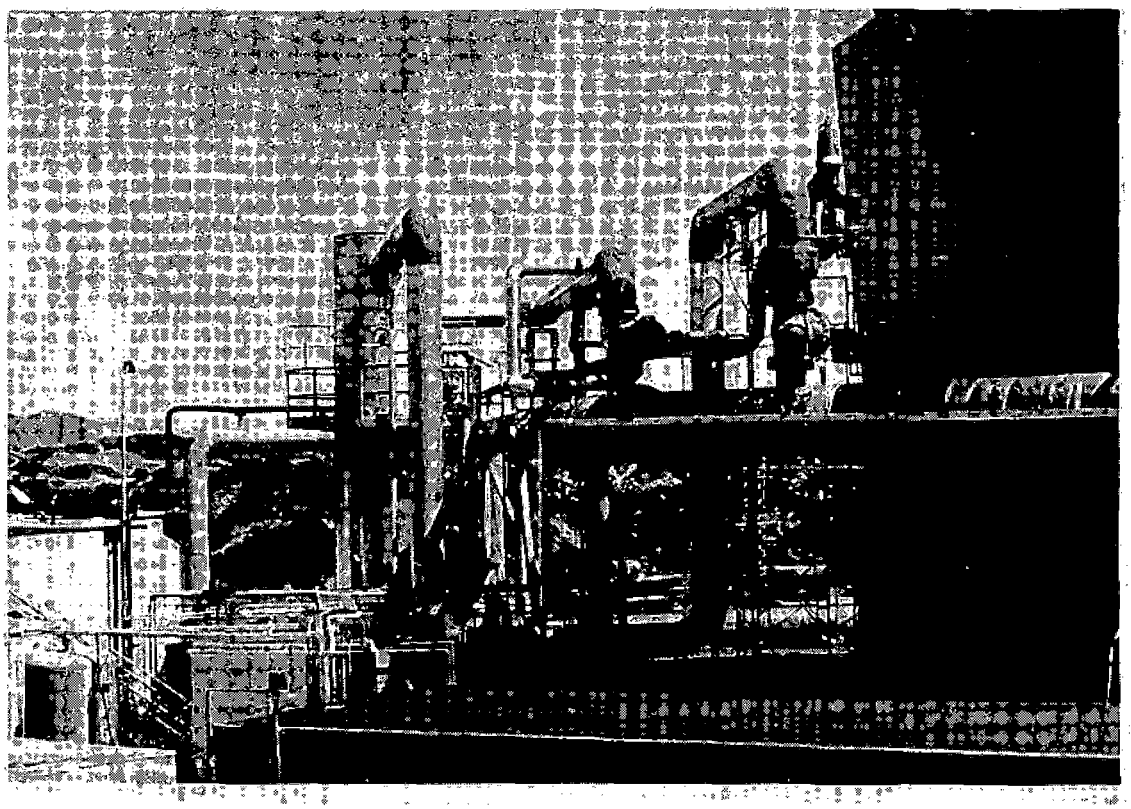


4. Geochemical Engineering and Materials

The Geochemical Engineering and Materials subprogram seeks technical solutions to problems associated with the handling and disposal of geothermal fluids. The subprogram addresses two main areas of interest: scale control and materials durability.

Materials and chemistry considerations are closely related to individual resource characteristics. To achieve overall economy in materials of construction, operation, and maintenance of geothermal systems at a wide variety of sites, durable materials resistant to localized corrosion and catastrophic failure are required.

The objective of fluid chemistry activities is to increase plant efficiency through improved fluid management techniques. Fluid disposal procedures and high-temperature chemical probes are being developed to control waste by-product removal and to optimize the potential for beneficial use of these wastes. A pilot system for controlling emission of hydrogen sulfide gas is pictured below.



Hydrogen Sulfide Removal System at The Geysers Geothermal Field

Materials development efforts seek to advance more economical construction materials and to develop elastomers, metals, and non-metallics for use in the geothermal environment. Major subprograms are developing materials for use in logging tools, cable drill bits, and downhole pump bearings. Polymer concrete is being developed to replace expensive stainless steel and titanium for pipes and

pressure vessels. Steels that resist localized corrosion in well casing, drill pipe, and energy conversion equipment are under development.

Status

Major achievements and plans are described below:

- An analysis of available materials for use in geothermal applications has been completed. The work, presented in handbook form, will aid in the design of geothermal electric power plants. The handbook is now being updated to include materials for geothermal space heating and industrial process systems.

- Polymer concrete, high-temperature elastomers, and casing materials have been developed with 15 to 20 percent improvements in durability and corrosion resistance for geothermal environments. Polymer concrete lined pipes were tested at Niland, California, and East Mesa, California.

- The manufacture of commercial prototype polymer concrete pipe and the technology transfer of new high-temperature elastomers were initiated in September 1978. Two miles of the pipe and a non-destructive evaluation technique for prediction of drill pipe failure will be field tested in FY 1981.

- An industry cost-shared program to instrument the Magma Power Company binary plant at East Mesa, California has been initiated. DOE will provide instrumentation and data interpretation and will gain information on fluid characteristics.

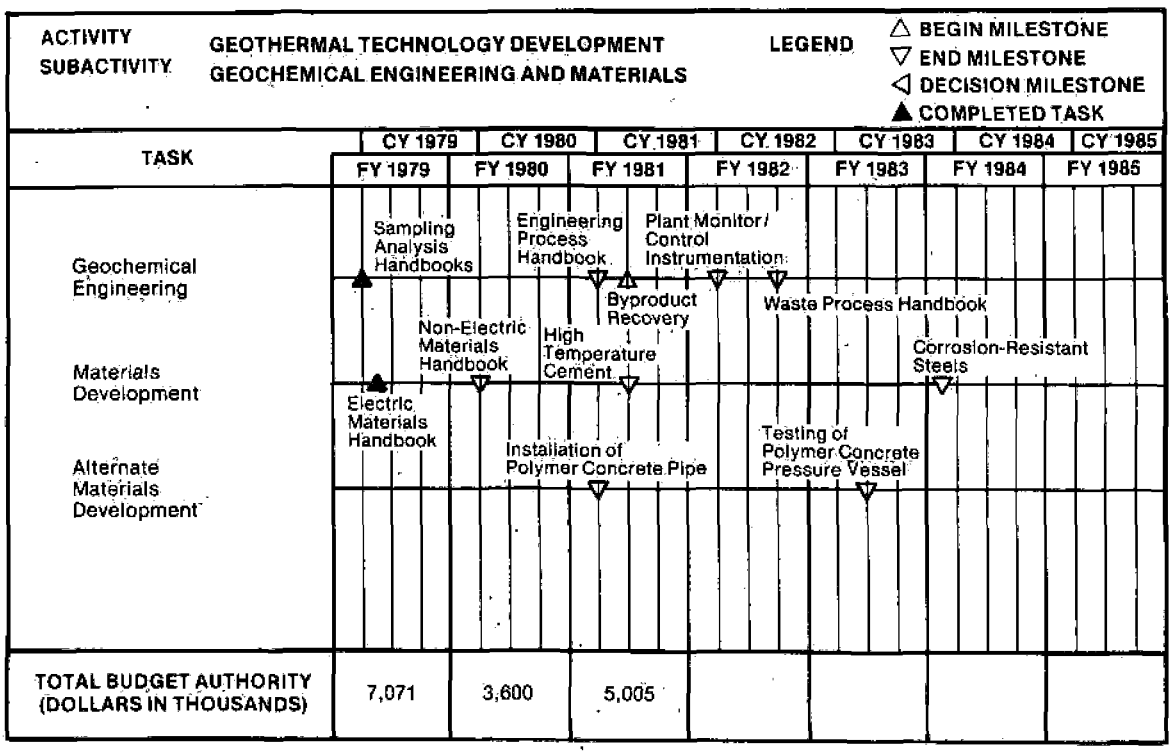
- An American Society for Testing and Materials Committee (E-45) was initiated to standardize materials-related geothermal field test procedures.

- A series of high-temperature well cements has been developed and is being tested at the National

Bureau of Standards as part of an American Petroleum Institute Task Group effort for geothermal well cement standards development.

Geothermal materials work in FY 1981 will emphasize development and testing of elastomers, metals, and cements for geothermal use that are durable at high temperatures and resistant to localized corrosion, wear, fracture, and fatigue failures. Improvements in these materials are essential for the success of downhole pumps, cables, and motors, and for greater longevity of surface, well, and drilling equipment.

Efforts will continue to field test and demonstrate alternate geothermal materials in non-electric as well as electric power systems.



5. Geoscience Technology Development

The Geosciences subprogram, which is aimed at removing technical and economic barriers to geothermal development, includes activities in exploration technology, reservoir engineering, logging instrumentation, and log interpretation. The objectives of these components are detailed below:

- Exploration technology - to improve surface exploration equipment and techniques in order to reduce the number of dry holes drilled in the search for geothermal resources;
- Reservoir engineering - to predict reservoir volumes and productivity accurately over time;
- Logging instrumentation - to develop downhole measuring devices that can survive the geothermal environment; and
- Log interpretation - to determine the characteristics of geothermal reservoirs from borehole information.

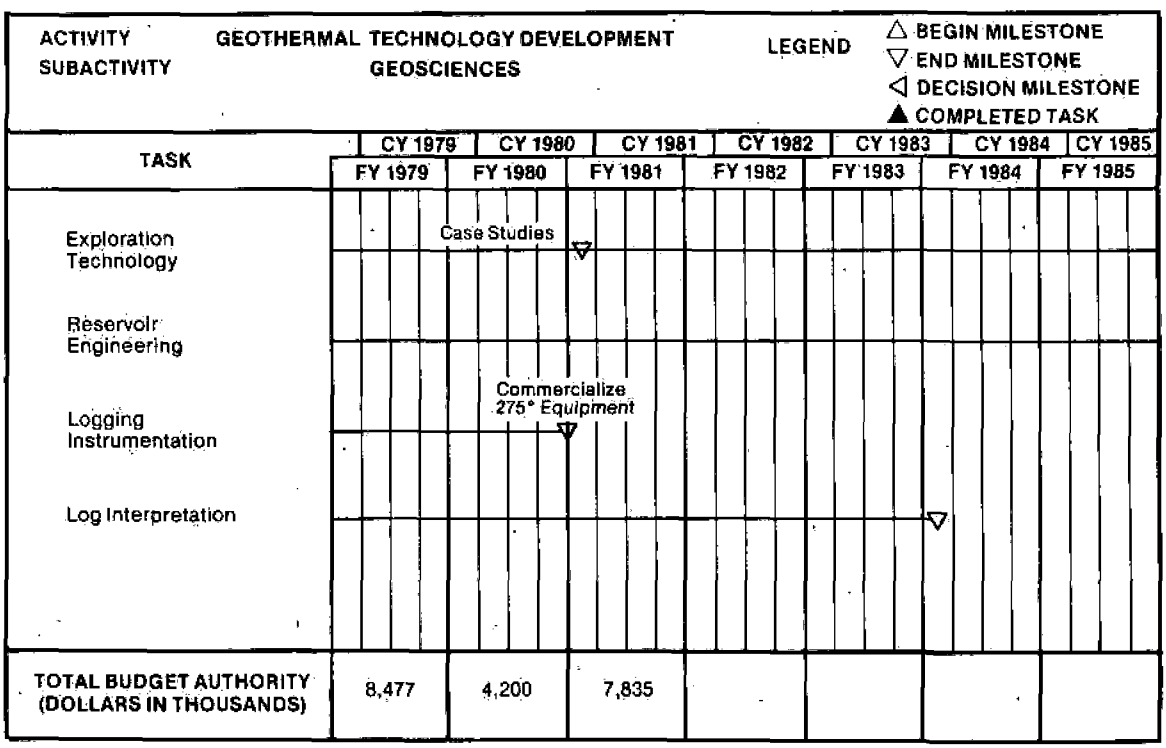
Status

Exploration technology activities seek to overcome key technical problems identified by industry. These activities are undertaken to improve the accuracy of predrilling reservoir assessments, to reduce the number of dry holes drilled, and to reduce the cost of exploration and assessment. This effort seeks solutions to near-term problems as well as developing methods for finding "hidden resources".

The principal objective of reservoir engineering activities is to improve the capability for predicting longevity and productivity of reservoirs. This effort is systematically addressing improvements in technical areas such as well testing, rock and fluid properties, reservoir performance analysis and prediction, and economics. Research in these areas is important since the performance

of most hydrothermal reservoirs has typically been unpredictable due to unknown subsurface conditions. Case histories of producing geothermal fields are being prepared as a basis for modeling.

Logging instrumentation activities are aimed at upgrading tool capabilities from the present rating of 180°C to typical geothermal temperatures up to 275°C. Log interpretation activities seek to analyze problems in data interpretation caused by significant differences between hydrocarbon and geothermal wells. The well logging services presently available are often unsuitable for the hostile environment of geothermal wells, and data essential for reservoir engineering are difficult to acquire. Calibration facilities for industrial facilities will continue to be provided as part of this effort. Both activities work closely with industry in an effort to test and evaluate new concepts.



B. Hot Dry Rock

The hot dry rock (HDR) geothermal resource is defined as the heat stored in rocks that contain little or no water. The lack of sufficient water to transport heat distinguishes HDR from hydrothermal resources. HDR has an extremely large resource base.

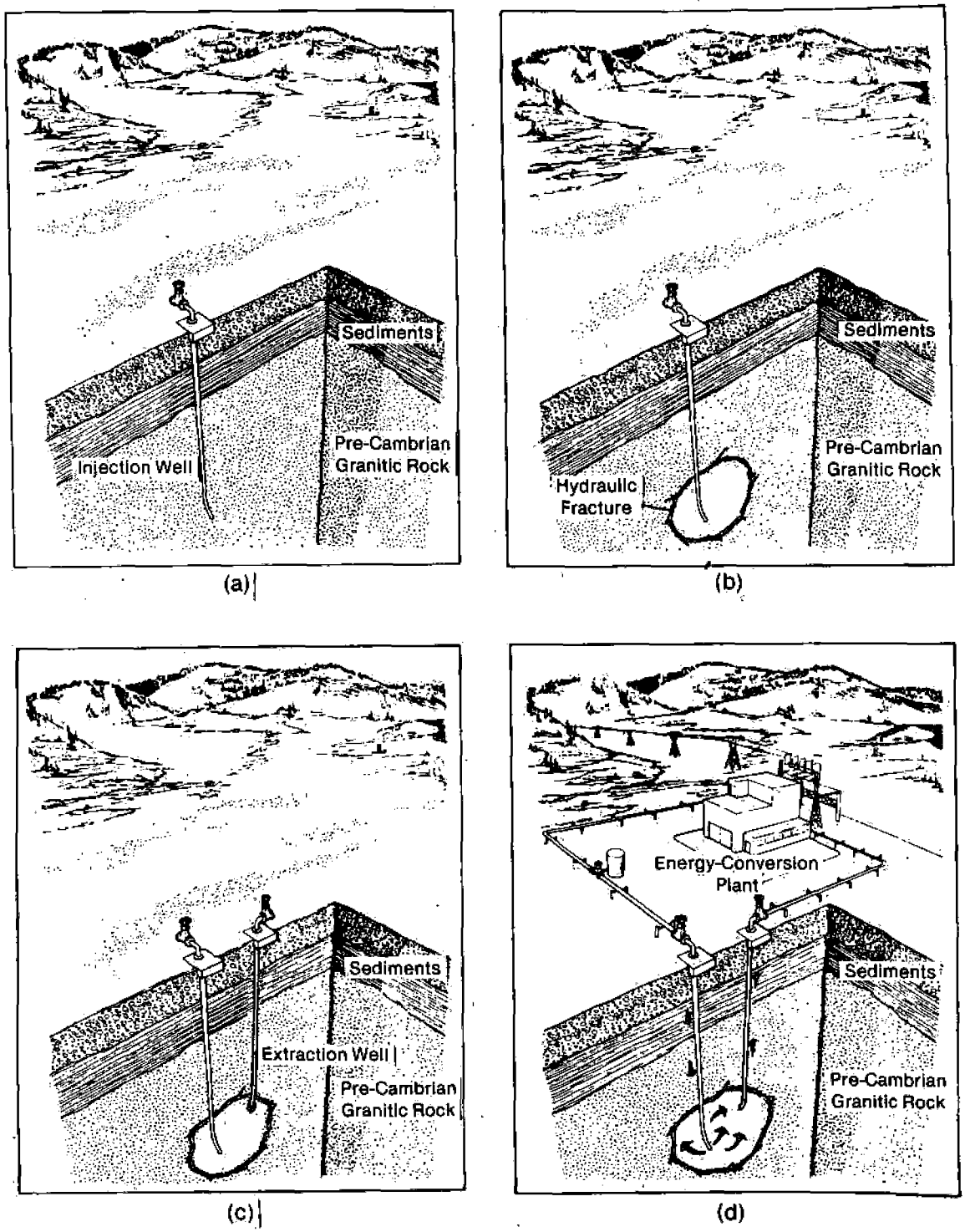
Energy is extracted from hot dry rock by drilling two wells, fracturing the rock between the wells to provide a large heat exchange surface, then establishing a circulating fluid loop. Commercialization will depend on significant improvements and cost reductions in drilling and fracturing technology. The hot dry rock geothermal concept is depicted on the following page.

The Hot Dry Rock subprogram assesses the potential of the HDR resource and supports development of new technical approaches for extracting energy from HDR. Although HDR research began in 1972, the present HDR program was formally instituted at the beginning of FY 1979 after successful operation of a five-megawatt thermal loop at the Fenton Hill HDR site in New Mexico in 1978. General program objectives are (1) to determine the potential of the HDR resource, (2) to verify that the requisite technology for developing the resource exists, and (3) to bring about commercial exploitation of HDR before the end of the century. A major program decision point will occur in FY 1986, when a review of technical and economic feasibility will determine whether the subprogram should be continued.

Status

Since initiation of the HDR program, DOE has established a program office at Los Alamos Scientific Laboratory (LASL), prepared a draft HDR Program Plan, established the National HDR Program Development Council, and prepared the draft FY 1980 Operating Plan.

The Fenton Hill project, the largest single program element at present, is progressing on schedule. The project is a multi-phase effort. Phase I, which is nearing



Hot Dry Rock Site Development

successful completion, is an initial feasibility investigation of LASL's HDR heat extraction technique. Phase II involves creating and testing a commercial-scale 20-50 MW_t thermal loop. In addition, one of the Phase I wells will be deepened to become a permanent downhole equipment test facility. Drilling of the new wells for the Phase II loop has begun. As a possible third phase, the Fenton Hill site could be developed for electric power generation. Although such site development is currently not part of the DOE Fenton Hill project, a local electric cooperative has shown interest in building a small power plant if the large thermal loop proves successful. Environmental surveillance at the Fenton Hill site continues to give evidence of HDR as one of the most environmentally benign energy sources.

Technology development activities associated with the Fenton Hill project have focused on development and testing of high-temperature materials, equipment, and downhole instrumentation and upgrading of commercial drilling equipment.

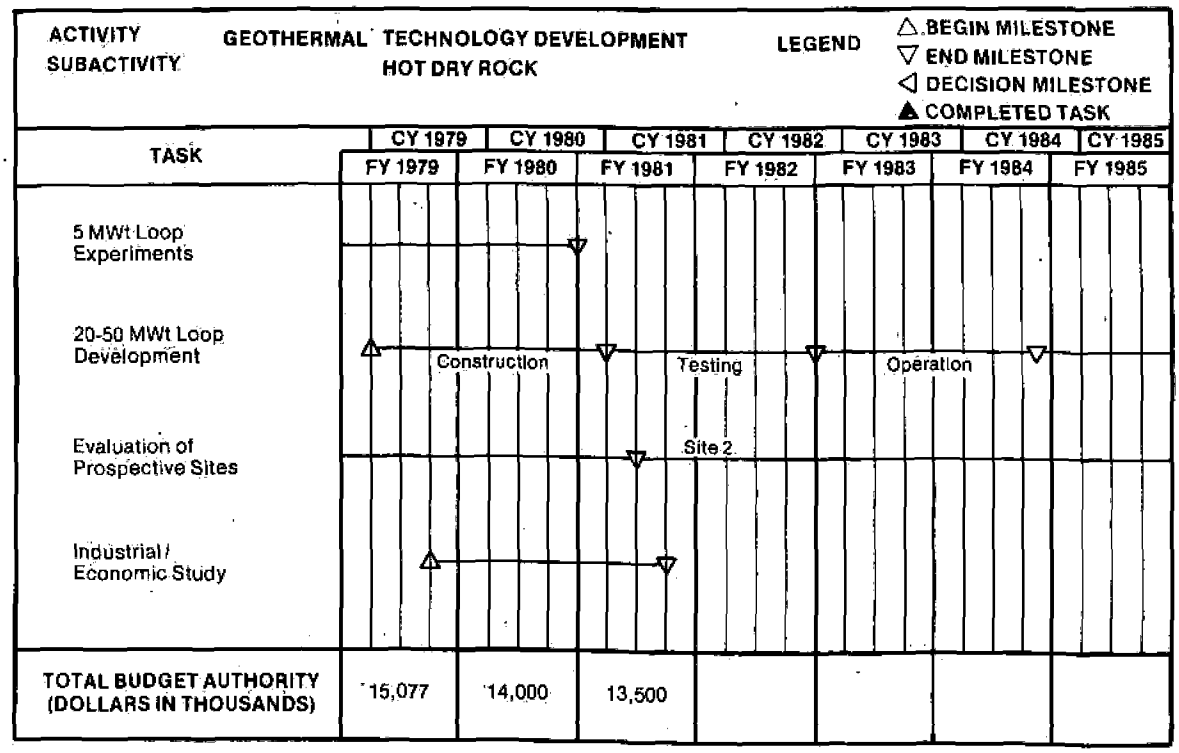
In addition to the Fenton Hill work, DOE is continuing regional and national activities to assess the HDR resource. In FY 1979, DOE cooperated with USGS to determine HDR resource potential and conducted geological and geophysical studies in 34 states. Sites for detailed resource investigations have been selected near Boise, Idaho and on the Delmarva Peninsula. In addition, a catalog of potential HDR sites for commercial and industrial development is being prepared.

In anticipation of HDR commercialization, a preliminary legal study has been published and a two-year industrial/economic study has been initiated.

In accordance with the program objective of proving the general availability of the HDR resources, a second HDR site in a different geologic setting will be selected by the end of FY 1981. Plans for FY 1980 include:

- Increased acquisition of resource potential data and publication of a geothermal gradient map,
- Completion of Fenton Hill Phase I system experimentation,

- Construction of a 20-50 MW thermal loop at Fenton Hill, and
- Continuation of instrumentation development and testing activities.



VI. INTERNATIONAL GEOTHERMAL ENERGY ACTIVITIES

Geothermal resource potential has been identified in over 20 countries. Existing worldwide installed capacity is 1978 MW_e, with planned additional capacity of 3641 MW_e.

The United States participates in international geothermal energy programs through multilateral and bilateral agreements with other nations. These agreements, which can enhance domestic commercialization, cover both exchanges of information and cooperative research and development efforts. Information exchange facilitates expansion of the geothermal data base and helps ensure that experience gained elsewhere is available to U.S. developers.

Status

In FY 1979, the United States and the Federal Republic of Germany signed an agreement providing for participation of German scientists in the Los Alamos Scientific Laboratory (LASL) HDR program. The Federal Republic of Germany will fund 25 percent of the Fenton Hill project, up to a maximum of $2.5 million per year. The agreement will be effective for an initial period of four years. In addition, a cooperative agreement under the International Energy Agency (IEA) was signed for overseas testing of a U.S. manufactured wellhead generator unit, the helical screw expander. Participating countries in this agreement are Mexico, New Zealand, and Italy.

The U.S. also has major bilateral agreements with four countries. Activities carried under these agreements are summarized below:

- The U.S. and Italy have exchanged information on drilling techniques and materials. Exchange of reservoir data has led to initial selection of wells for possible stimulation. Reservoir assessment activities have included testing of a computer model at Lardarello, Italy. In addition,

the U.S. has provided environmental monitoring equipment and cooperated in seismic studies.

- The first meeting of an executive coordinating committee for U.S.-Japan cooperation was held in 1979. Possible cooperative projects relevant to binary conversion systems and the LASL hot dry rock program were discussed.

- Cooperative investigations between the U.S. and Mexico on the geophysical and hydrological characteristics of the Cerro Prieto field continued in FY 1979. Bilinguial proceedings of the First Symposium were published. The Second Symposium was held in December 1979. Discussions are underway to extend cooperation under the bilateral agreement to other geothermal areas.

- A Memorandum of Understanding between the U.S. and New Zealand is under negotiation. Areas of cooperative study will include drilling and completion, logging instrumentation, chemistry and materials, stimulation, reservoir engineering, two-phase flow studies, and brine disposal.

Future international activities include the following:

- A conference in Paris to review recent international geothermal developments,

- Observation of stimulation activities at The Geysers by Italian scientists,

- Expansion of U.S./Italian brine technology and materials testing activities,

- Continued reservoir assessment and engineering activities by the U.S., Italy, and Mexico,

- Continued exchange of drilling and environmental information between the U.S. and Italy,

- Continued exchange of information between the U.S. and Japan, and

- Continued meetings to review progress of the IEA/Manmade Geothermal Energy Systems (MAGES) Implementing Agreements.

VII. PROGRAM MANAGEMENT

The geothermal energy programs described in this report require about $150 million annually in federal funds. These funds are expended via several hundred active DOE contracts involving projects throughout the U.S. Although DOE is designated by the Congress as the lead agency for federal geothermal energy programs, several other federal agencies have substantial geothermal responsibilities. The Department of Interior, for example, has custody of millions of acres of federal land containing geothermal resources and is responsible for leasing them as appropriate for commerical geothermal development. The leasing must be coordinated with DOE reservoir definition and technology development programs if the goals for commercial geothermal development are to be met.

The management of this multifaceted program, from long range planning and policy analysis to the testing of geothermal wells and the approval of loan guaranty applications, is itself a complex challenge. DOE's approach to this task is to concentrate policy, planning, overall budget definition and program defense activities in Washington headquarters, while assigning to DOE Operations Offices, National Laboratories and Regional Representatives the responsibility for project definition, day-to-day project management in the field, and coordination with state and local authorities.

This chapter discusses the organizational structures and their responsibilities in two sections, the first covering DOE headquarters, the other, field organizations.

A. Headquarters Organization

The Interagency Geothermal Coordinating Council (IGCC) serves as a board of directors for federal geothermal programs. This Council, chartered by the Congress (P.L. 93-410), is chaired by the DOE Assistant Secretary for Resource Applications. About 25 federal agencies are represented on the Council at the Assistant Secretary level.

The IGCC, which meets as a body four times a year, accomplishes much of its work through a staff committee and three panels. The Council reviews agency plans for geothermal programs to assure that together they constitute a coherent federal geothermal plan, submits a combined federal geothermal budget request to the President's Office of Management and Budget (OMB), and recommends appropriate changes in national policy and legislation.

In FY 1979, DOE shifted the responsibility for commercialization of hydrothermal resources from the Assistant Secretary for Energy Technology (ASET) to the Assistant Secretary for Resource Applications (ASRA). Most of the DOE geothermal energy programs remained with ASET. Early in FY 1980, as part of a major DOE reorganization, the office of ASET was abolished, and all ASET geothermal program were assigned to ASRA. Therefore, DOE geothermal programs are now conducted under the direction of ASRA, with the exception of some basic research conducted by the DOE Office of Energy Research and environmental research conducted by the Assistant Secretary for Environment.

The geothermal program staff of ASRA is responsible for intitiating the geothermal portions of the DOE annual congressional budget request; defending that request and the program itself within DOE, the Administration and the Congress; developing overall program plans; negotiating management agreements with DOE field offices and providing them with program direction and funding; and conducting periodic program reviews.

B. Field Organization

DOE field offices and some DOE National Laboratories have been assigned major responsibility for the coordination and management of substantial parts of the DOE geothermal program. The Los Alamos Scientific Laboratory (LASL), for example, has been given a lead role in the Hot Dry Rock subprogram. The DOE San Francisco Operations Office conducts the Geothermal Loan Guaranty program, and the Nevada Operations conducts drilling activities under the Geopressured Resource Definition subprogram.

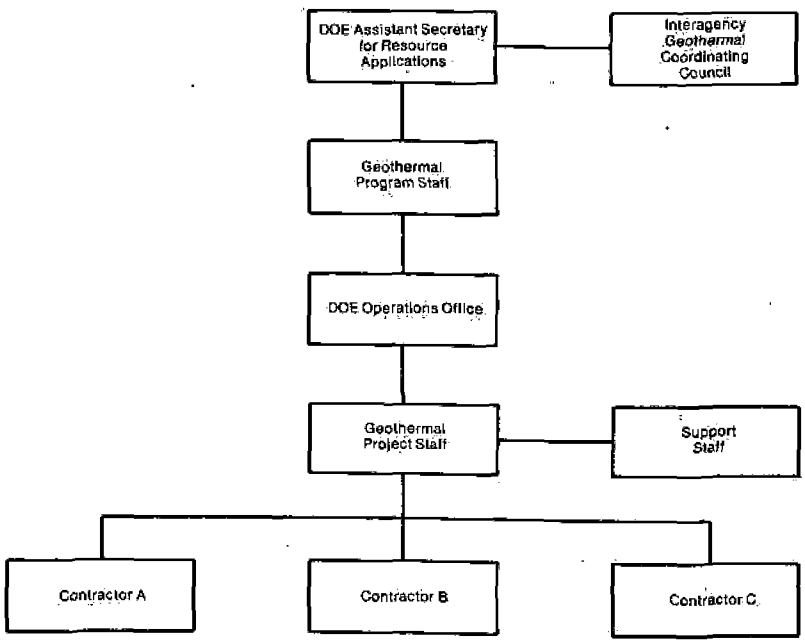
In general, the relationship between each of these offices and headquarters is documented in a formal written

management agreement. Headquarters provides overall planning guidance and financial and manpower resources to the field offices and laboratories. The field offices and laboratories are responsible for project definition, contracting and subcontracting, project management, and reporting. They are accountable for achieving objectives and milestones.

The major management centers for DOE geothermal programs are listed below.

Nevada Operations Office
Idaho Operations Office
San Francisco Operations Office
Chicago Operations Office
Los Alamos Scientific Laboratory
Lawrence Berkeley Laboratory
Idaho National Engineering Laboratory
Sandia Corporation

The organizational relationships of Headquarters, a typical field office, and project contractors are displayed below.



Program Management Organization