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Geothermal Energy

Program Summary Document

FY 1982

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

January 1981

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1 PROGRAM OVERVIEW

Geothermal energy is derived from 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)
- Hot dry rock.

In hydrothermal systems, natural water circulation moves heat from deep internal 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 of Louisiana, consist of water and dissolved methane at high pressure and at moderately high temperature. In addition to recoverable methane, geopressured resources provide thermal energy and mechanical energy derived from high fluid pressures, although methane offers the greatest immediate value. Commercial development of geopressured energy may begin in the mid-1980s. Economic feasibility will depend on the amount of methane that a given well can produce, a highly uncertain factor at present.

Hot dry rock (HDR) resources are geologic formations at accessible depths with high heat content and little or no water. Usable energy is extracted by circulating a heat transfer fluid, such as water, through deep wells connected by manmade fractures in the rock. Like hydrothermal energy, HDR can be used to generate electric power or provide direct heat. Commercial use of HDR is currently seen as a longer-term possibility (by early 1990s), although significant improvements in drilling and fracturing technology must be made before this potentially large resource can be fully realized.

Rapid commercial development of the nation's hydrothermal resources is a major objective of the federal geothermal energy program, which consists of a six-fold approach for developing hydrothermal energy resources for electric and direct heat applications:

1. Work with state and local government entities, to provide information and technical assistance to the private sector

2. Identify technical, economic, and institutional barriers to development, and plan actions to overcome or alleviate such barriers

3. Conduct cost-shared demonstrations and operate experimental facilities where necessary for technical demonstration and economic evaluation

4. Encourage greater participation in the Geothermal Loan Guaranty Program

5. Continue activities to assess resources and confirm reservoirs to expand the resource base and reserves required to support growth of the geothermal industry

6. Maintain a vigorous supporting research and development (R&D) program to provide new and improved technology for finding required resources, reducing energy conversion costs, and controlling potential environmental impacts.

To carry out this approach, the federal geothermal energy program is divided into five activities:

- Hydrothermal Industrialization
- Geothermal Resource Development Fund
- Geopressured Resources

- Geothermal Technology Development
- Program Direction.

The following sections describe these activities and their funding levels in more detail.

HYDROTHERMAL INDUSTRIALIZATION

The major objective of the Hydrothermal Industrialization activity is to accelerate private-sector development and use of hydrothermal resources for electric power production and direct heat applications. The activity consists of research, development, and demonstration (RD&D) projects designed to stimulate geothermal development, including:

- Assessment and confirmation of geothermal reservoirs in cooperation with the U.S. Geological Survey (USGS), state agencies, and industry. This activity will end in FY 1982.

- Field experiments to demonstrate the engineering and economic aspects of using hydrothermal resources for direct heat. The participants are selected through competitive solicitation of cost-shared projects. This activity will also end in FY 1982.

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

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

- Transfer of technology developed under the federal geothermal energy program to the private sector.

Table 1

Funding Levels for Geothermal Energy Activities FY 1980 through FY 1982

Activity	Budget Authority (Dollars in Thousands) Actual FY 1980	Estimate FY 1981	Estimate FY 1982	Increase (Decrease)
Hydrothermal Industrialization	**70,412**	**67,935**	**35,039**	**(32,896)**
Resource Definition	12,634	21,224	0	(21,224)
Non-electric Demonstration	9,778	11,500	0	(11,500)
Planning and Analysis	6,011	6,081	1,500	(4,581)
Private-Sector Development	3,409	2,378	2,175	(203)
Geothermal Facilities	35,363	24,152	31,201	7,049
Environmental Control	2,184	2,600	0[a]	(2,600)
Capital Equipment	1,033	0	163	163
Geothermal Resource Development Fund	**181**	**43,266**	**5,574**	**(37,692)**
Program Direction	181	193	200	7
Guaranty Reserve Fund	0	41,982*	4,300	(37,682)
Loan Evaluation Fund	0	1,091	1,074	(17)
Energy Security Act	0	0	0	0
Geopressured Resources	**34,692**	**35,800**	**26,436**	**(9,364)**
Resource Definition	33,032	32,126	23,800	(8,326)
Supporting Research and Development	1,360	3,474	2,436	(1,038)
Capital Equipment	300	200	200	0
Geothermal Technology Development	**41,178**	**49,910**	**28,100**	**(21,810)**
Component Development	25,058	35,300	15,000	(20,300)
Hot Dry Rock	14,000	13,500	12,600	(900)
Capital Equipment	2,120	1,110	500	(610)
Program Direction	**1,802**	**2,376**	**2,000**	**(376)**
Total Geothermal Energy	**148,265**	**199,287**	**97,149**	**(102,138)**

* Represents reappropriation of unobligated balances in FY 1981.

a Transferred to Geothermal Technology Development.

- Legal and regulatory streamlining and reform.
- Planning activities and interagency coordination of federal programs and policies.

GEOTHERMAL RESOURCE DEVELOPMENT FUND

The Geothermal Energy Resource Development and Demonstration Act of 1974 provided for the establishment of the Geothermal Loan Guaranty Program and of the Geothermal Resource Development Fund to support the federal geothermal energy program. The Energy Security Act (1980) authorizes expenditures from the fund for reservoir confirmation loans and feasibility study loans. The Energy Security Act also provides for a study of the need for a reservoir insurance program. If such a program is enacted, appropriations will also be required prior to the start-up of this program. To date, no appropriation bill has been enacted for any of the Energy Security Act programs.

GEOPRESSURED RESOURCES

The principal responsibility of this activity is in resource definition, which entails defining the magnitude, availability, and producibility of geopressured resources. The ultimate goal of the activity is to foster the industrial development of such resources.

The term "geopressured resources" refers to the energy contained in a geopressure-geothermal aquifer, a geological formation under extremely high pressure. This energy is found in three forms: as chemical energy (in the form of dissolved methane); as thermal energy (in the form of hot brines); and as mechanical energy (in the form of high pressure).

GEOTHERMAL TECHNOLOGY DEVELOPMENT

The Geothermal Technology Development activity seeks technical solutions to the problems of operating in geothermal environments. The component technology efforts focus on: developing techniques, materials, and equipment specifically tailored to geothermal conditions; reducing technology costs; and promoting industry-wide standards for geothermal materials and equipment.

The potential to accelerate geothermal development by reducing risks and costs with new and improved technology is significant. Research into high-temperature drilling technology, reservoir stimulation, wellbore pumping, and binary power plants will have a great impact on geothermal energy costs. Research in exploration technology and reservoir engineering will accelerate discovery of new resources and provide a methodology for evaluating the financial risk of reservoir-related development. In most instances, major technological advances will result in more economic recovery of geothermal resources.

The activity also assesses the potential of HDR resources and supports development of new extraction techniques to demonstrate the commercial feasibility of HDR-derived energy. Although HDR research began in 1972, the present HDR program was formally instituted at the beginning of FY 1979 after successful operation of a 5-MWe thermal loop at the Fenton Hill site in New Mexico in 1978. The general objectives of this effort are: (1) to confirm the potential of HDR resources; (2) to develop a technology base for HDR energy extraction; (3) to verify the acceptability of environmental and social consequences of HDR energy development.

PROGRAM DIRECTION

To coordinate these activities, the U.S. Department of Energy (DOE) has been designated by Congress as the lead agency for federal geothermal energy programs. DOE vests its interests in the Division of Geothermal Energy (DGE) under the direction of an Assistant Secretary for Resource Applications. DOE operations offices, national laboratories, and regional representatives are responsible for project definition, day-to-day project management in the field, and coordination with state and local authorities.

Each of the next five chapters, structured along the lines of the FY 1982 budget, presents a detailed activity description, which consists of a general discussion of relevant technical aspects, a summary of project status and plans, a milestone chart presenting major decision points through FY 1986, and funding levels for FY 1980 through FY 1982. Funding levels for each of the activities described above are presented in Table 1. A final chapter describes the nature and extent of DOE's participation in international geothermal activities.

2 HYDROTHERMAL INDUSTRIALIZATION

Hydrothermal resources consist of hot water and steam trapped in the earth. Different energy conversion systems are used to recover the energy found in hot water or steam hydrothermal resources. Electricity is generated from steam deposits by passing the steam directly through turbines. Liquid-dominated deposits are exploited for electric 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 which in turn is passed through the turbines (binary-cycle system).

Energy derived from hydrothermal resources can also be used for direct thermal applications. These non-electric applications, primarily space conditioning and industrial process heat, are feasible at reservoir 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 are known to contain hydrothermal resources; most western states contain known resources. Substantial electric power and direct use capacity is expected to be realized by 1984. Projections of approximately 2,600 MWe of electric power generating capacity and nearly 300 MWt of thermal power reflect the near-term potential for this resource.

The major objective of the Hydrothermal Industrialization activity is to accelerate private-sector development and use of hydrothermal resources for electric power production and direct heat applications. The activity consists of RD&D projects designed to stimulate geothermal development by the private sector. These projects include:

- Assessment and confirmation of geothermal reservoirs in cooperation with the USGS, state agencies, and industry. This activity will end in FY 1982.

- Field experiments to demonstrate the engineering and economic aspects of using hydrothermal energy resources for direct heat. The participants are selected by competitive solicitation of cost-shared projects. This activity will also end in FY 1982.
- Experimental facilities constructed and operated to perfect new geothermal equipment and process techniques, particularly for electric power production, to reduce the costs of exploiting hydrothermal resources.
- Major demonstration plants to generate commercial quantities (50 MWe) of electric power from moderate- and high-temperature hydrothermal fluids. These plants will provide operating experience needed to establish full, commercial-scale technical and economic viability of the technology. They will be built and operated by industry, which will share the project cost.
- Transfer of technology developed under the federal geothermal energy program to the private sector.
- Legal and regulatory streamlining and reform.
- Planning activities and interagency coordination of federal programs and policies.

The Hydrothermal Industrialization activity is divided into five major subactivities:

- Resource Definition
- Non-Electric Demonstration
- Planning and Analysis
- Private-Sector Development
- Geothermal Facilities.

These subactivities and the tasks comprising them are described in detail in the following sections.

Table 2.a

Funding Levels for Hydrothermal Industrialization Subactivities FY 1980 through FY 1982

Subactivities	Budget Authority (Dollars in Thousands)			
	Actual FY 1980	Estimate FY 1981	Estimate FY 1982	Increase (Decrease)
Resource Definition	12,634	21,224	0	(21,224)
Non-Electric Demonstration	9,778	11,500	0	(11,500)
Planning and Analysis	6,011	6,081	1,500	(4,581)
Private-Sector Development	3,409	2,378	2,175	(203)
Geothermal Facilities	35,363	24,152	31,201	7,049
Environmental Control[a]	2,184	2,600	0[a]	(2,600)
Capital Equipment	1,033	0	163	163
Total	**70,412**	**67,935**	**35,039**	**(32,896)**

a Transferred to Geothermal Technology Development.

RESOURCE DEFINITION

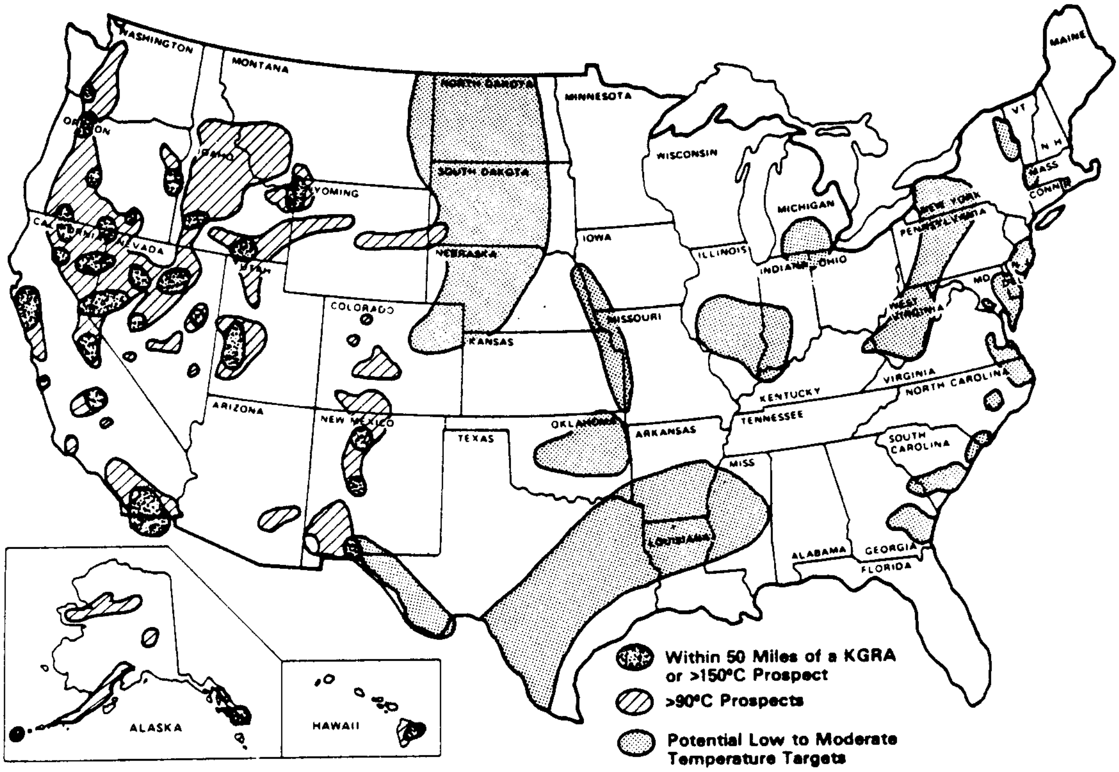
DOE and USGS are collaborating on a federal program to establish the extent of geothermal resources and their locations throughout the United States. The objectives of the assessment program are: (1) to characterize the geological nature of each type of geothermal resource; (2) to estimate the location, distribution, and energy content of geothermal resources in the United States; and (3) to evaluate geothermal energy potential in the United States through inventory of the identified portion and prediction of the undiscovered portion of the nation's resources.

In pursuit of these objectives, DGE works with USGS to conduct regional and national assessments of hydrothermal resources. Additionally, DGE supports drilling to confirm high-temperature reservoirs with near-term commercial potential under projects 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 task has focused on several regions with potential for direct heat applications, but without confirmed hydrothermal reservoirs. This task will terminate in FY 1982.

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

National Resource Assessment

USGS, the lead federal agency for geothermal resource assessment, is responsible for conducting resource inventory and assessment through a program of multidisciplinary research. The USGS Geothermal Research Program (GRP) is aimed at understanding the nature, distribution, and energy potential of the various types of geothermal resources and estimating the location and magnitude of the nation's geothermal resources. In addition, the GRP advances the methods of exploration for geothermal energy sources, develops a systematic knowledge of the characteristics of natural geothermal systems that may affect their development, and investigates certain environmental problems that may be associated with the extraction of geothermal energy.



Known and Potential Hydrothermal Resources

Table 2.b

Funding Levels for Resource Definition Tasks FY 1980 through FY 1982

Task	Budget Authority (Dollars in Thousands)			
	Actual FY 1980	Estimate FY 1981	Estimate FY 1982	Increase (Decrease)
National Resource Assessment	174	185	0	(185)
State-Coupled Program	4,019	5,867	0	(5,867)
Capital Equipment	184	0	0	0
Industry-Coupled Case Studies	1,736	530	0	(530)
User-Coupled Confirmation Drilling Program	800	10,600	0	(10,600)
Exploratory Drilling - - Low and Moderate Temperature	5,905	4,042	0	(4,042)
Total	**12,818**	**21,224**	**0**	**(21,224)**

A major product of the GRP, USGS Circular 790, was published in FY 1979: "Assessment of Geothermal Resources of the United States, 1978." This circular is based on data available July 1978 and is an update and expansion of USGS Circular 726, published in 1975. Circular 726 systematically assessed for the first time moderate- and high-temperature hydrothermal resources and geopressured resources. Based on new data, Circular 790 refines the original estimates and also includes the first tabulation of data on low-temperature (90°C) geothermal fluids at depths of less than 1 kilometer. The assessment of low-temperature reservoirs is being expanded to provide the first quantitative inventory of these hydrothermal resources using data from many new sources, particularly from DOE's State-Coupled Program. Similar updates for other resource types should follow as new data make further refinements in the resource estimates possible.

State-Coupled Program

As a supplement to the resource assessment performed by USGS, DOE has initiated the State-Coupled Program, under which a more detailed definition of low- and moderate-temperature resources is achieved than is performed by USGS in its regional surveys. The State-Coupled Program has resulted in cooperative agreements with agencies in 22 states to carry out assessments in their respective states, as well as contracts with several institutions that provide for geothermal investigations covering several states. For example, the Virginia Polytechnic Institute and State University is undertaking an evaluation of the geothermal potential along the Atlantic Coastal Plain from New Jersey to Georgia. In all, assessment activities are underway, or planned, in 37 states that are known to contain geothermal resources.

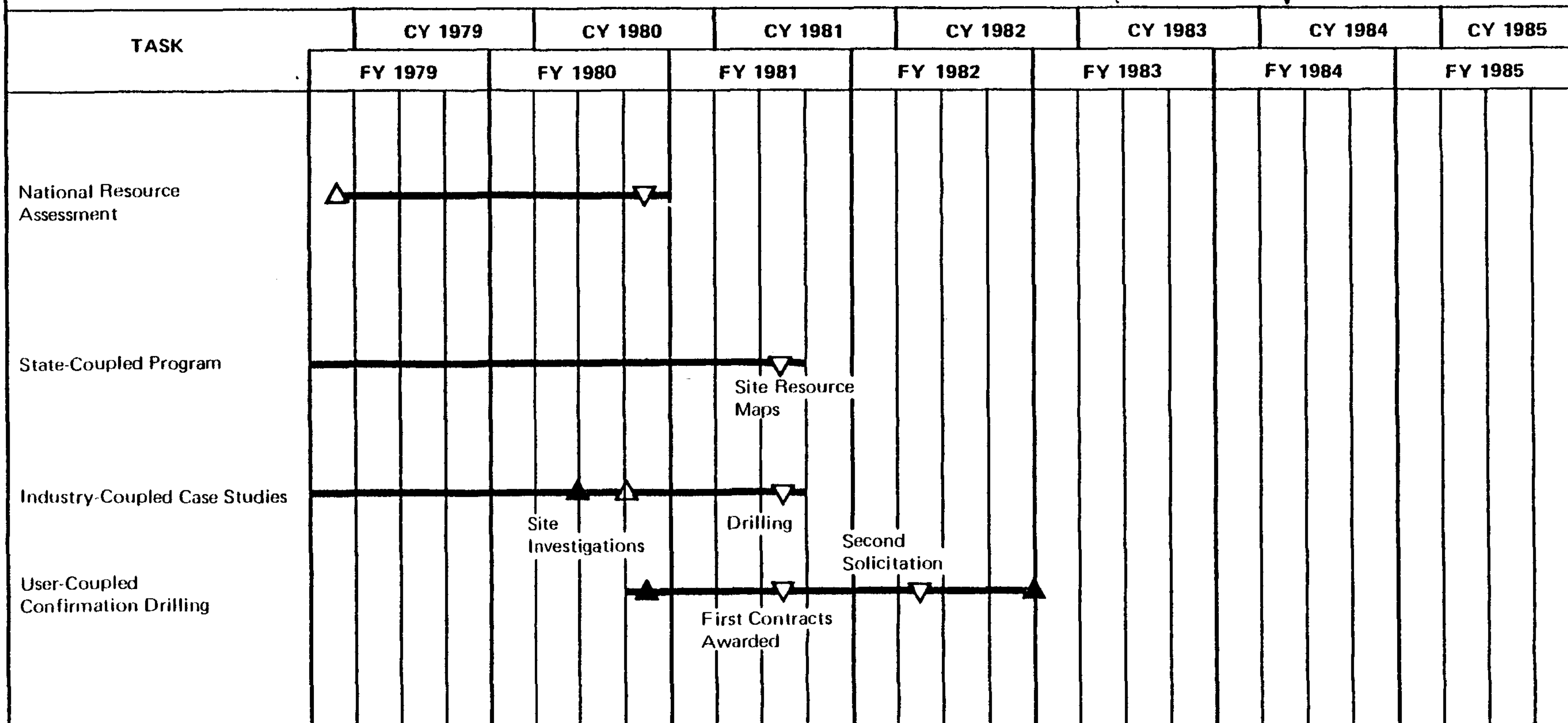
A product of the State-Coupled Program is a resource map of the state showing the location of hot springs, wells with elevated temperatures, and, in general, areas with good potential for geothermal development. To date, resource maps have been published for Arizona, Oregon, Nevada, Colorado, Idaho, New Mexico, Utah, and California.

Exhibit 2.a

ACTIVITY HYDROTHERMAL INDUSTRIALIZATION

SUBACTIVITY RESOURCE DEFINITION

LEGEND
- △ BEGIN MILESTONE
- ▽ END MILESTONE
- ◁ DECISION MILESTONE
- ▲ COMPLETED TASK
- ◆ ORIGINAL MILESTONE



Total Budget Authority (Dollars in Thousands)	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
	26,163	12,818	21,224	0			

Industry-Coupled Case Studies

The Industry-Coupled Case Study task was initiated in FY 1978 to accelerate the development of high-temperature reservoirs with commercial potential for electric power generation. The decision was made in FY 1979 to terminate this program in light of passage of the National Energy Act with its incentives for continued hydrothermal development. The only continuing activity under this program is the completion of drilling operations in northern Nevada supported by the FY 1979 funding for the program. To date, 9 of the 14 exploratory wells have been drilled, with the remaining wells to be drilled during 1981.

User-Coupled Confirmation Drilling Program

To stimulate the development of low- and moderate-temperature hydrothermal resources for direct heat applications, the User-Coupled Confirmation Drilling Program (UCCDP) was established during FY 1980. This program will share the cost of the exploration, well siting, drilling, flow testing, reservoir engineering, and, if necessary, of injection well drilling, to confirm the temperature and flow rate of a hydrothermal reservoir.

To implement the program, a solicitation was issued, requesting proposals that would detail a plan for siting and drilling a confirmation well to provide hot water for direct heat. Response to the solicitation was very encouraging, demonstrating the widespread interest in the use of geothermal energy for several different applications. Projects selected for funding under this program will begin in early 1981. Thus far, eight projects have been selected for contract negotiations from the proposals received.

As a precursor to the UCCDP, several reservoir confirmation drilling projects were initiated in FY 1980. Two wells were drilled on Mt. Hood, Oregon -- one at Old Maid Flat, and one at Timberline Lodge. The 6,000-foot well at Old Maid Flat was drilled to test for a reservoir that could provide hot water for district heating in Portland; the 4,000-foot well at Timberline was drilled to seek a reservoir that could provide heat for the lodge. Both wells encountered zones with sufficient temperatures to meet the user's needs, but neither provided sufficient fluid flow.

Two of the projects initiated in FY 1980 will not begin drilling operations until early 1981. An exploratory well will be drilled in collaboration with the New York State Energy Research and Development Authority at a site near Auburn, New York. Higher than normal thermal gradients have been measured in the area, and there are prospects for tapping a resource that could be used by Clinton Corn Products as part of its industrial process. The second project will be undertaken at Lewes, Delaware, where a cost-shared well will explore for a resource that can be used by Barcroft Corporation for industrial processing, and by the town of Lewes for space heating. This program is scheduled to terminate in FY 1982 as a result of increasing private-sector involvement in geothermal energy.

NON-ELECTRIC DEMONSTRATION

Use of geothermal energy for non-electric purposes by the private sector within the United States has been limited. There is, however, a large potential market for thermal energy in the 50° to 150°C temperature range used in industrial processing (paper mills, sugar refineries, and other chemical and food processing plants); agribusiness (space-, soil-, and water-heating in applications such as greenhouses, fish farming, and animal husbandry); and space/water-heating of commercial downtown business districts (shopping centers, schools, hospitals); and in residential buildings.

Feasibility Studies

DOE has sponsored detailed studies of the specific economics of direct heat applications to help identify prospective non-electric users and match their energy needs to specific, low- to moderate-temperature hydrothermal reservoirs. To date, 42 technical and economic feasibility studies have been supported by DOE/DGE. Thirty-four of these studies have been completed; 11 were completed

Table 2.c

Funding Levels for Non-Electric Demonstration Tasks FY 1980 through FY 1982

Task	Budget Authority (Dollars in Thousands)			
	Actual FY 1980	Estimate FY 1981	Estimate FY 1982	Increase (Decrease)
Feasibility Studies	0	765	0	(765)
Direct Heat Projects	9,778	10,735	0	(10,735)
Total	**9,778**	**11,500**	**0**	**(11,500)**

in FY 1980. A competitive solicitation covering cost-shared industrial applications was issued near the end of FY 1980, which led to the support of the following eight new studies (for which work will begin in FY 1981):

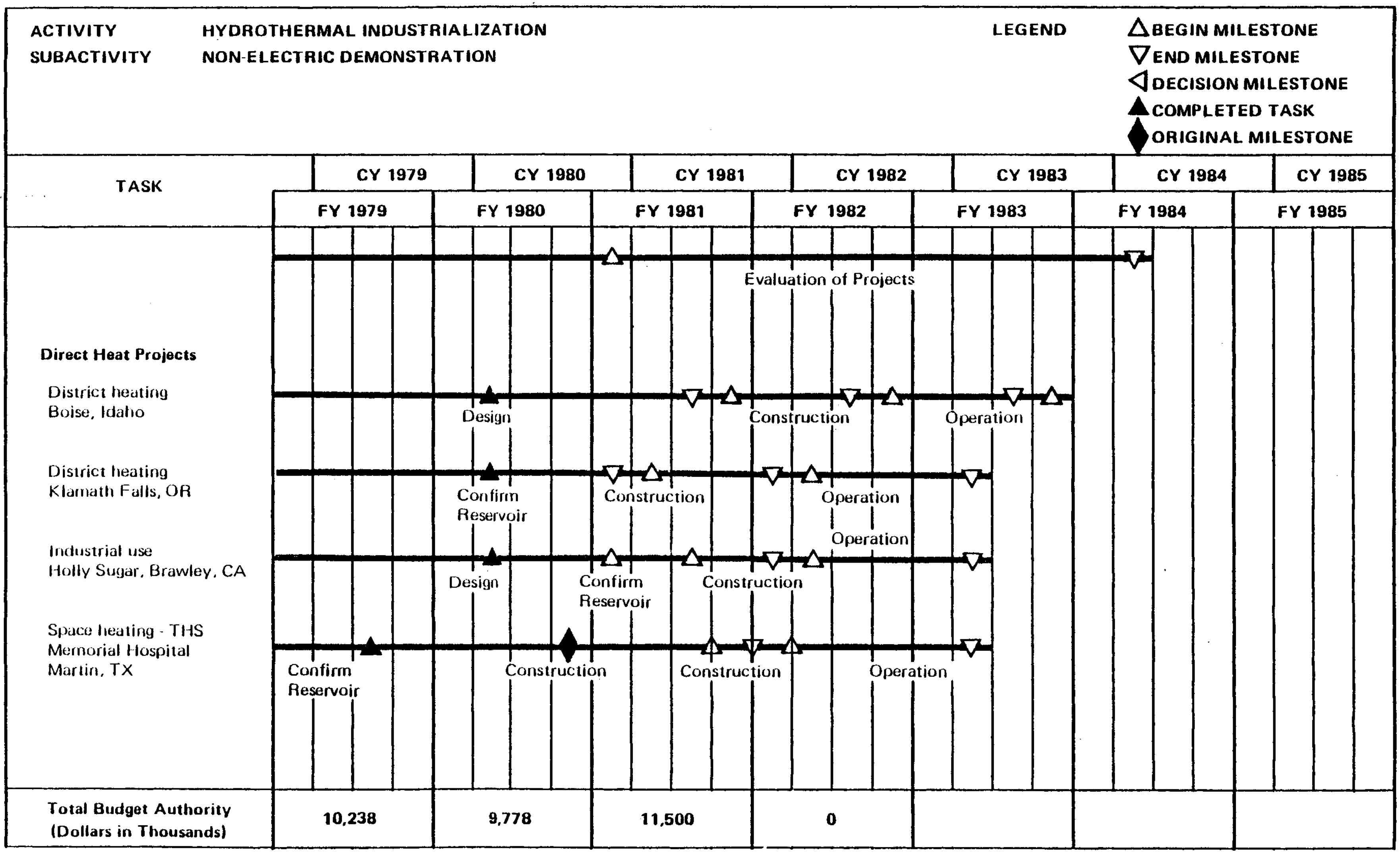
Project	Location
Alcohol Plant	Vale, OR
Ethanol Plant	San Luis Valley, CO
Ethanol Plant	East Mesa, CA
Ethanol Plant, Mushroom-Growing Facility, and Cannery	Fernly, NV
Zinc-Processing Facility	Salida, CO
Barley-Malting Facility	Pocatello, ID
Cottage Cheese-Processing Facility	Friendship, NY
Waste Water-Treatment Facility	San Bernardino, CA

Direct Heat Projects

The lack of experienced personnel and working relationships between non-electric users and energy suppliers as well as the absence of a service industry infrastructure are inhibiting the adoption of geothermal energy by the non-electric industry. Technical uncertainties and associated economic risks can influence users' perceptions of profitability to the point of limiting private investment in geothermal direct heat applications. DOE has sponsored field experiments to: (1) provide visible evidence of the profitability of various direct heat applications in a number of geographical regions and (2) obtain reliable, objective, definitive technical/economic data under field operating conditions that will facilitate decisions on the use of low- to moderate-temperature hydrothermal energy.

Twenty-four cost-shared direct heat demonstration projects are now underway. The majority of these field

Exhibit 2.b


ACTIVITY HYDROTHERMAL INDUSTRIALIZATION
SUBACTIVITY NON-ELECTRIC DEMONSTRATION
LEGEND
BEGIN MILESTONE
END MILESTONE
DECISION MILESTONE
COMPLETED TASK
ORIGINAL MILESTONE
TASK
CY 1979
CY 1980
CY 1981
CY 1982
CY 1983
CY 1984
CY 1985
FY 1979
FY 1980
FY 1981
FY 1982
FY 1983
FY 1984
FY 1985
Evaluation of Projects
Direct Heat Projects
District heating
Boise, Idaho
Design
Construction
Operation
District heating
Klamath Falls, OR
Confirm Reservoir
Construction
Operation
Industrial use
Holly Sugar, Brawley, CA
Design
Confirm Reservoir
Construction
Operation
Space heating - THS
Memorial Hospital
Martin, TX
Confirm Reservoir
Construction
Construction
Operation
Total Budget Authority
(Dollars in Thousands)
10,238
9,778
11,500
0

experiments are for space- and district-heating applications, while 3 are directed toward agribusiness, and 3 involve industrial processing. Each project will go through 5 phases: environmental assessment; reservoir confirmation; system design; construction and installation or retrofit; and operation. Ten of these projects are in the reservoir confirmation phase, and 5 field experiments currently involve construction and installation. The following 6 projects are in operation:

- Truth or Consequences, NM - Space- and water-heating augmentation for a hospital
- Haakon and Philip, SD - space conditioning for five school buildings
- Pierre, SD - space- and water-heating augmentation for a hospital
- Klamath Falls, OR - space conditioning and water-heating for a YMCA
- Midland, SD - agricultural uses on ranch
- Mecca, CA - prawn aquaculture.

Of the remaining projects, 1 is delayed pending the outcome of an environmental review; 2 are being reevaluated based on an apparently inadequate resource; and 1 has been found infeasible. It is anticipated that a total of 7 projects will be operational by the end of FY 1981. An additional 12 projects are expected to become operational during 1982 and 1 more in 1983. The DOE direct heat field experiments initiative is expected to promote industrial involvement and the building of an industry infrastructure based on direct use of geothermal energy, in the western states. Greater emphasis will be placed on locating future demonstration sites in the East as suitable resources are defined.

PLANNING AND ANALYSIS

This activity formulates geothermal development plans, maintains a national progress monitoring system, assesses the market penetration potential for hydrothermal resources, and identifies direct heat markets suitable for

Table 2.d

Funding Levels for Planning and Analysis Tasks FY 1980 through FY 1982

Task	Budget Authority (Dollars in Thousands)			
	Actual FY 1980	Estimate FY 1981	Estimate FY 1982	Increase (Decrease)
State and Local Assistance	3,761	1,598	0	(1,598)
National Progress Monitoring	200	935	515	(420)
Interagency Coordination	246	250	200	(50)
Economic and Barrier Analysis	904	1,723	285	(1,438)
Planning Analysis	900	1,575	500	(1,075)
Total	**6,011**	**6,081**	**1,500**	**(4,581)**

early market penetration. Other activities encompass continuing interagency coordination and policy development.

State and Local Assistance

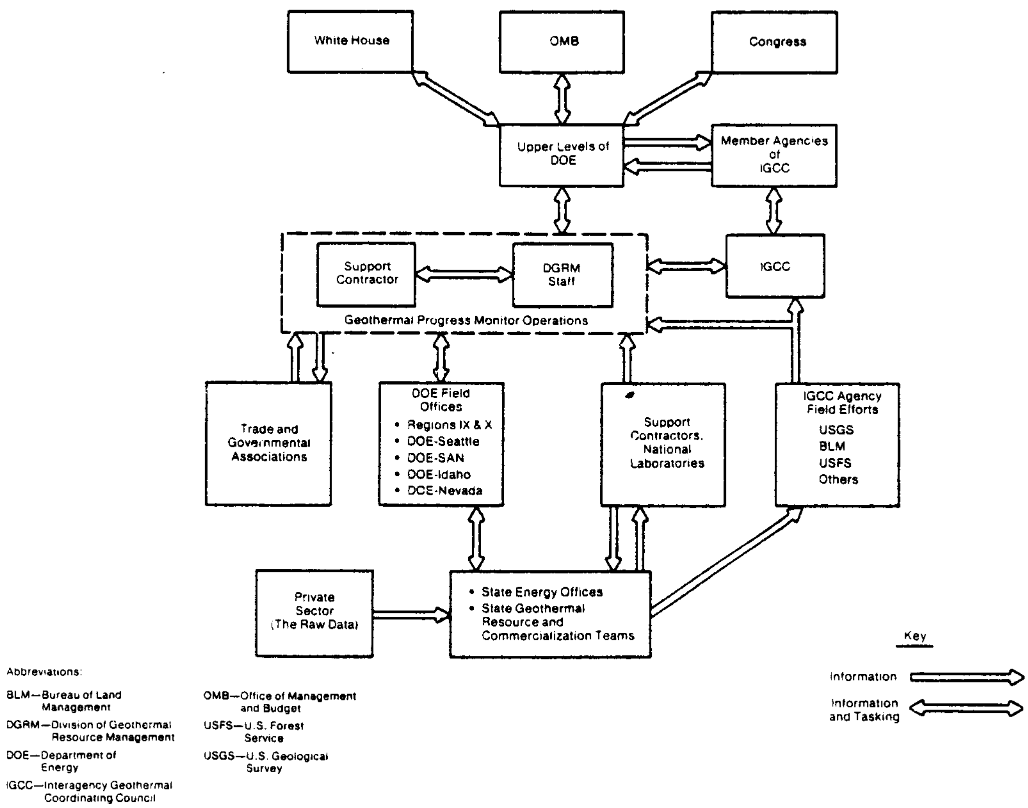
Potential geothermal users commonly are unfamiliar with the existence of geothermal resources nearby, the feasibility of employing them, state laws and regulations affecting geothermal development, financing, and potential environmental effects. Consequently, state industrialization teams have been set up primarily to serve as sources of geothermal information. Each state team first compiles information related to geothermal resources and development in that state, including the factors noted above, and publishes this information in the form of a fact book or handbook. The information is disseminated throughout state executive departments, to county governments, and directly to the industry and the general public through advertising, news media publicity, and speakers for local groups. The state teams also provide important referral services, such as identifying candidates for DGE technical assistance programs, and directing geothermal users to firms that provide geothermal engineering, drilling, construction, legal, environmental, and financial services.

In addition, the state teams serve as focal points for legal and regulatory reform and for efforts to streamline administrative processes (e.g., leasing, permitting) at the state level. They also assist in determining priorities for federal leasing and regulatory activities.

Over the past year, state industrialization teams have been active in 15 western states. A new team was initiated in Delaware in FY 1980 and one more will be formed in Texas in FY 1981. Federal support of these teams, which have been cost-shared cooperative projects, will be discontinued in FY 1982; continuation of the teams will depend entirely on state funding.

National Progress Monitoring

DGE initiated the design and implementation of a national geothermal progress monitoring system. The system is



Geothermal Progress Monitoring Network

designed to assess early indications of success or shortfall in private sector development, thereby allowing for the adjustment of geothermal programs and plans. It also provides periodic reports on status and progress and maintains selected data bases to support progress evaluation. The design of the system was completed in FY 1980; in the same year, the publication of quarterly reports was begun. By monitoring and reporting the pace of geothermal commercialization, the system provides a measure of the impact of the federal geothermal program.

Interagency Coordination

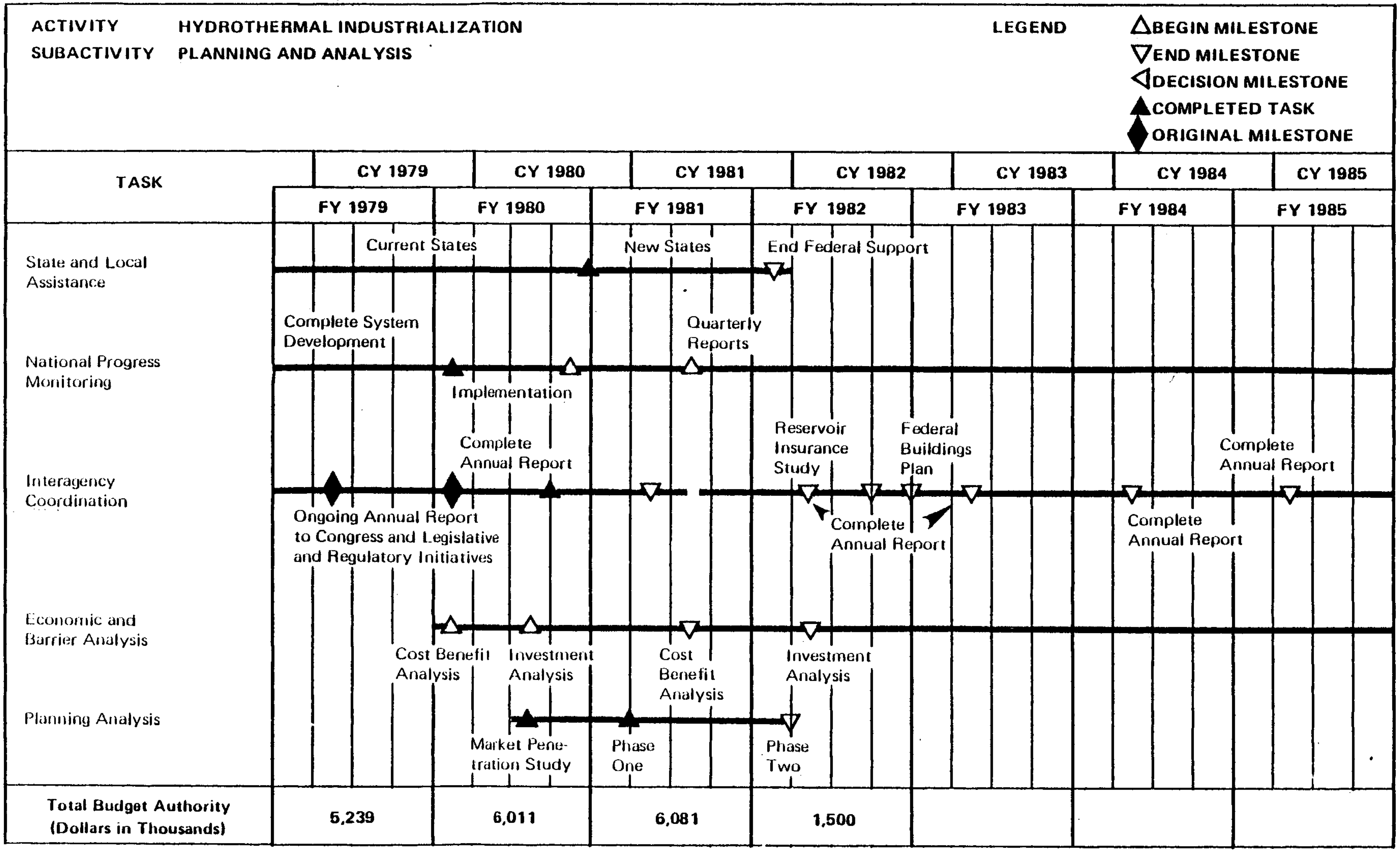
The objective of this task is to support the Interagency Geothermal Coordinating Council (IGCC) and to provide an interagency forum for the review of federal programs, policies, regulation, and legislation related to geothermal matters. This activity also coordinates the IGCC Annual Report to Congress, as required by law. (The fourth IGCC Report to Congress was issued in June 1980).

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 national geothermal goals.

Economic and Barrier Analysis

The purpose of this task is to analyze and reduce institutional barriers to the commercial development of hydrothermal resources. Barriers to hydrothermal electric power development are mainly related to federal, state, and local regulatory and leasing processes, and to financial risk associated with a new technology characterized by high front-end expense. Barriers to hydrothermal direct heat use include a lack of geologic information about specific geothermal areas, a lack of a commercial geothermal infrastructure (architects, geologists, engineers, equipment dealers, lawyers, regulatory experts, construction contractors, financiers), and the reluctance of users in low-risk businesses to make high-risk investments.

Exhibit 2.c


ACTIVITY HYDROTHERMAL INDUSTRIALIZATION
SUBACTIVITY PLANNING AND ANALYSIS
LEGEND
BEGIN MILESTONE
END MILESTONE
DECISION MILESTONE
COMPLETED TASK
ORIGINAL MILESTONE
TASK
CY 1979
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CY 1981
CY 1982
CY 1983
CY 1984
CY 1985
FY 1979
FY 1980
FY 1981
FY 1982
FY 1983
FY 1984
FY 1985
State and Local Assistance
Current States
New States
End Federal Support
National Progress Monitoring
Complete System Development
Quarterly Reports
Implementation
Interagency Coordination
Complete Annual Report
Reservoir Insurance Study
Federal Buildings Plan
Complete Annual Report
Ongoing Annual Report to Congress and Legislative and Regulatory Initiatives
Complete Annual Report
Complete Annual Report
Economic and Barrier Analysis
Cost Benefit Analysis
Investment Analysis
Cost Benefit Analysis
Investment Analysis
Planning Analysis
Market Penetration Study
Phase One
Phase Two
Total Budget Authority (Dollars in Thousands)
5,239
6,011
6,081
1,500

The program continues to assess the environmental, legal, and institutional barriers to industrialization of hydrothermal energy.

Planning Analysis

In order to focus activities related to assistance and information on areas with the greatest potential, this task identifies market strategies and specific markets suitable for early penetration. In addition, it seeks to establish the economic competitiveness of geothermal energy and of alternative fuels on a case-specific basis through removal of barriers, provision of incentives, and reduction of risk.

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

PRIVATE-SECTOR DEVELOPMENT

This program includes activities designed to acquaint potential users with: the availability and competitive cost of hydrothermal energy; the availability of financial assistance through various federal programs; the availability of technical assistance to start projects; and the availability of legal assistance to help states prepare appropriate legislation.

Technical Analysis and Assistance

Major impediments to private-sector development of hydrothermal resources for direct applications are the lack of information and lack of a business infrastructure. A prospective user of geothermal energy typically cannot find local expertise related to the geologic availability of geothermal resources, the technology for exploiting such resources, or assistance in such related matters as economics, financing, and permitting. Few prospective users are equipped to determine whether geothermal heat as an energy source would be feasible and competitive in cost with alternative fuels. By providing such prospects with technical assistance (limited to about 100 man-hours per project), DGE aims to accelerate the process of information dissemination and technology transfer. Successful projects will thus attract local attention and stimulate others to consider geothermal energy as a viable energy source.

To this end, DGE has established four regional Technical Assistance Centers (TACs); another Center will be added in FY 1981. A substantial portion of the work done at each Center is conducted by commercial engineering and resource subcontractors. The use of local subcontractors permits these firms to develop expertise in geothermal projects and is intended to remedy the present lack of knowledgeable and experienced firms in regions with high geothermal potential. As the private sector acquires the needed expertise, federally funded centers will be phased out.

State Law Project

The laws of most states that pertain to underground resources were enacted before there was much knowledge of, or interest in, geothermal resources. Their application to geothermal development is often inappropriate and usually uncertain. In states with identified geothermal promise, the lack of a clear legal status for geothermal resources has discouraged potential developers. DGE has addressed this barrier by funding the National Conference of State Legislatures (NCSL) to provide research support to state legislatures that wish to revise their statutes to accommodate and control geothermal development. NCSL works directly with legislators, legislative staffs, and in some cases, with state executive branch personnel, by developing policy papers and assisting in workshops and hearings. DGE technical assistance contractors work with NCSL on a consulting

Table 2.e

Funding Levels for Private-Sector Development Tasks FY 1980 through FY 1982

Task	Budget Authority (Dollars in Thousands)			
	Actual FY 1980	Estimate FY 1981	Estimate FY 1982	Increase (Decrease)
Technical Analysis and Assistance	820	1,928	1,750	(178)
State Law Project	275	0	425	425
Hydrothermal Applications	2,314	0	0	0
Reservoir Insurance Study	0	450	0	(450)
Total	**3,409**	**2,378**	**2,175**	**(203)**

basis to assure that geothermal expertise is available to the state legislative processes.

The NCSL approach is to analyze relevant existing statutes, provide background information about geothermal energy and the barriers to its development, identify legal issues related to geothermal development, list the legislative options for each issue, and summarize the pros and cons of each option. The results are presented in written reports. At the request of a state, NCSL also assists in drafting legislation embodying the options specified by the legislators.

The NCSL is currently working with 14 states. This work resulted in the publication of 30 reports to states in FY 1980. The FY 1981 level of effort is planned for about the same level, but will involve several new states. States that passed geothermal legislation in FY 1980 include Alaska, Washington, and Delaware (the latter bill was vetoed but will be reworked in 1981). Several more states are expected to pass geothermal legislation in 1981. Because of the long lead time associated with legislative reform, continuation of work with states receiving assistance in 1978-1981 must also be expanded in FY 1982. During FY 1981 and 1982, the project will also focus on the large number of eastern states where potential geothermal resources have been identified.

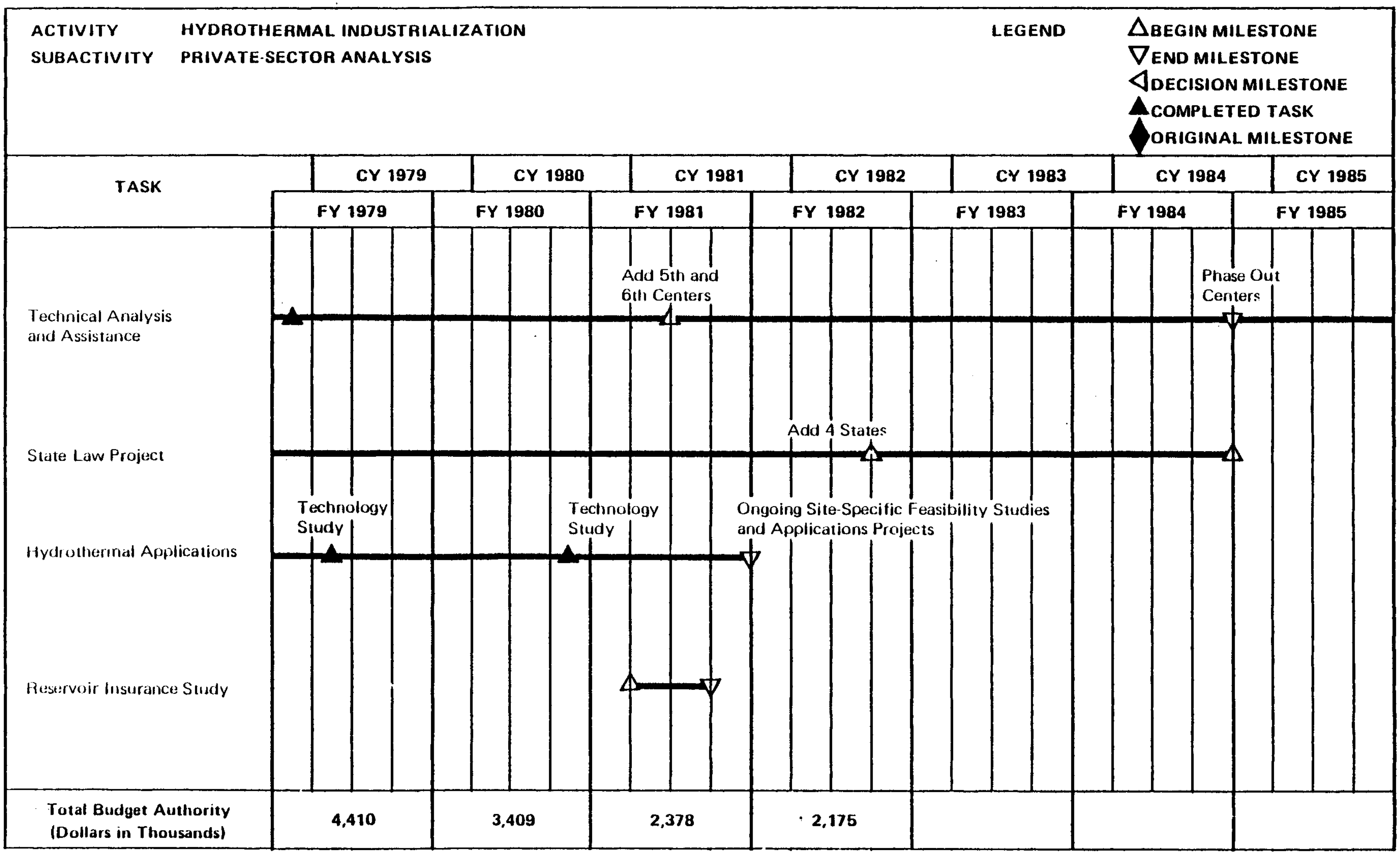
Hydrothermal Applications

This program element orginally focused on the economic feasibility of hydrothermal energy use. The feasibility studies under this element have since been transferred to the non-electric demonstration element, and were previously discussed in this report under that heading.

Reservoir Insurance Study

As required by the Energy Security Act, DOE is conducting a study of the need for a program to provide reservoir insurance and reinsurance. This study will be completed in June 1981.

Exhibit 2.d


ACTIVITY HYDROTHERMAL INDUSTRIALIZATION
SUBACTIVITY PRIVATE-SECTOR ANALYSIS
LEGEND
BEGIN MILESTONE
END MILESTONE
DECISION MILESTONE
COMPLETED TASK
ORIGINAL MILESTONE
TASK
CY 1979
CY 1980
CY 1981
CY 1982
CY 1983
CY 1984
CY 1985
FY 1979
FY 1980
FY 1981
FY 1982
FY 1983
FY 1984
FY 1985
Technical Analysis and Assistance
Add 5th and 6th Centers
Phase Out Centers
State Law Project
Add 4 States
Hydrothermal Applications
Technology Study
Technology Study
Ongoing Site-Specific Feasibility Studies and Applications Projects
Reservoir Insurance Study
Total Budget Authority (Dollars in Thousands)
4,410
3,409
2,378
2,175

GEOTHERMAL FACILITIES (ELECTRIC)

DGE supports the design, construction, and operation of pilot and commercial-scale electric power plants. These facilities generate technical and economic operating data and provide information on the environmental impact of geothermal electric power generation.

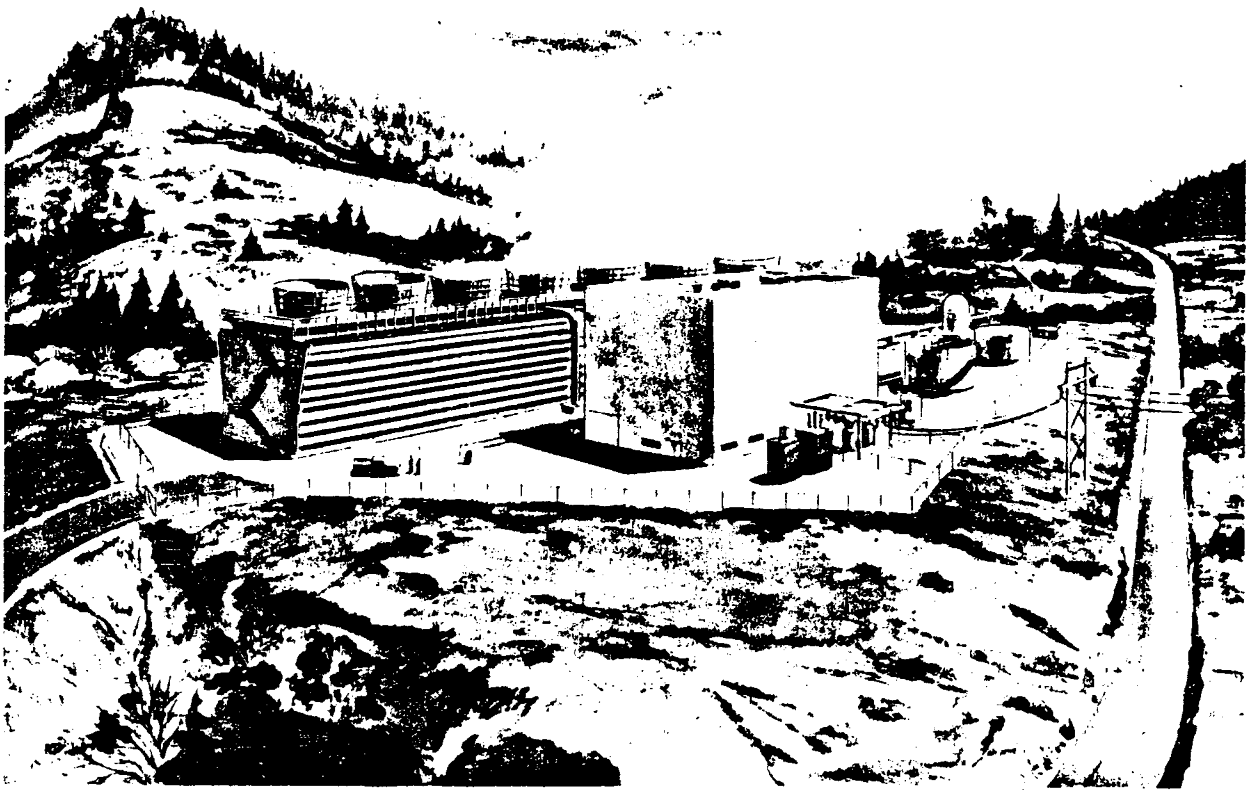
The purpose of these pilot plants and test facilities is to stimulate non-federal development of liquid-dominated hydrothermal resources for generating elecric power by (1) demonstrating technical and economic feasibilty and environmental acceptability of geothermal systems, (2) providing "hands-on" operating experience for industry, and (3) fostering growth of an industrial infrastructure necessary for wide-scale use of geothermal systems.

50-MWe Geothermal Flash-Steam Demonstration Power Plant - Baca

A 50 MWe flash-steam geothermal demonstration power plant project is underway at the Baca Ranch located in Valles Caldera, Sandoval County, NM. A federal environmental impact statement and record of decision (documenting DOE's intention to proceed) were filed in January and May 1980, respectively. Drilling and field construction are proceeding, and two new wells have been completed. Plant-site preparation is complete but plant construction has been delayed until a construction permit is issued by the New Mexico Public Service Commission. Construction is expected to begin in the spring of 1981, and will take approximately one and a half years. The plant is a cooperative effort of DOE, the Public Service Company of New Mexico (PNM), and Union Geothermal Company of New Mexico.

50-MWe Geothermal Binary Demonstration Power Plant - Heber

A cooperative agreement was executed between DOE and the San Diego Gas and Electric Company (SDG&E) on September 26, 1980, for the design, construction, and operation of a 45-MWe-net (65-MWe-gross) binary plant at Heber in the Imperial Valley of California. For this project, SDG&E has acquired the participation of the Imperial Irrigation District, the California Department of Water



50-MW_e Hydrothermal Demonstration Plant

Resources, Southern California Edison, and the contributions of the Electric Power Research Institute and others. The geothermal fluid will be sold to SDG&E under a heat sales agreement by the Heber reservoir lease holders (Chevron Resources, Inc., Union Oil Company of California, and New Albion Resource Company, a subsidiary of SDG&E). Chevron will be the well field unit operator.

Fluor Power Service has initiated plant design. A water assessment by the Water Resource Council and a federal environmental assessment by DOE were completed in FY 1980 with a "Finding of No Significant Impacts." Plant construction is scheduled to begin in the first quarter of FY 1983. Plant check-out and start-up is scheduled to commence in FY 1984.

5-MWe Raft River Pilot Plant

This project is a 5-MWe binary-cycle pilot 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, plant equipment, operations, and economics for future improvements to commercialize moderate-temperature resources.

Plant and well field construction at Raft River, Idaho, was completed by the end of FY 1980. Difficulties in procuring reliable downwell pumps have delayed well field flow tests and plant check-out and start-up. Replacement and backup pumps have been procured. The plant is presently scheduled to be operating by the third quarter of FY 1981.

HPG-A Geothermal Wellhead Generator - Hawaii

The objective of this project is to evaluate the feasibility of using a wellhead generator to produce base-load electrical power. The 3-MWe 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 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

Table 2.f

Funding Levels for Geothermal Facilities Tasks FY 1980 through FY 1982

Task	Budget Authority (Dollars in Thousands)			
	Actual FY 1980	Estimate FY 1981	Estimate FY 1982	Increase (Decrease)
50-MWe Geothermal Flash-Steam Demonstration Power Plant — Baca	20,025	12,050	6,000	(6,050)
50-MWe Geothermal Binary Demonstration Power Plant — Heber	4,000	8,000	21,000	13,000
5-MWe Raft River Pilot Plant	7,046	3,702	3,657	(45)
Capital Equipment	776	0	163	163
HPG-A Geothermal Wellhead Generator — Hawaii	3,642	0	0	0
Geothermal Test Facility (GTF)	600	400	544	144
Capital Equipment	60	0	0	0
Geothermal Loop Experimental Facility (GLEF)	50	0	0	0
Total	**36,199**	**24,152**	**31,364**	**7,212**

areas of the western U.S., Hawaii, and other parts of the world.

The geothermal well located in the Puna District, Hawaii, had to be repaired as a result of cement degradation prior to flow testing. Flow test data were needed to finalize designs for equipment and the plant. Well repair was completed on December 12, 1979, and flow test data were available on January 18, 1980. Final design of the plant was approved on June 17, 1980.

Underground site work, including foundations, ponds and piping are complete. The turbine/generator building has been erected, and interior and electrical work are in progress. The cooling tower, condenser, and H_2S abatement system have been shipped to the site. The turbine/generator unit is scheduled to arrive in January 1981.

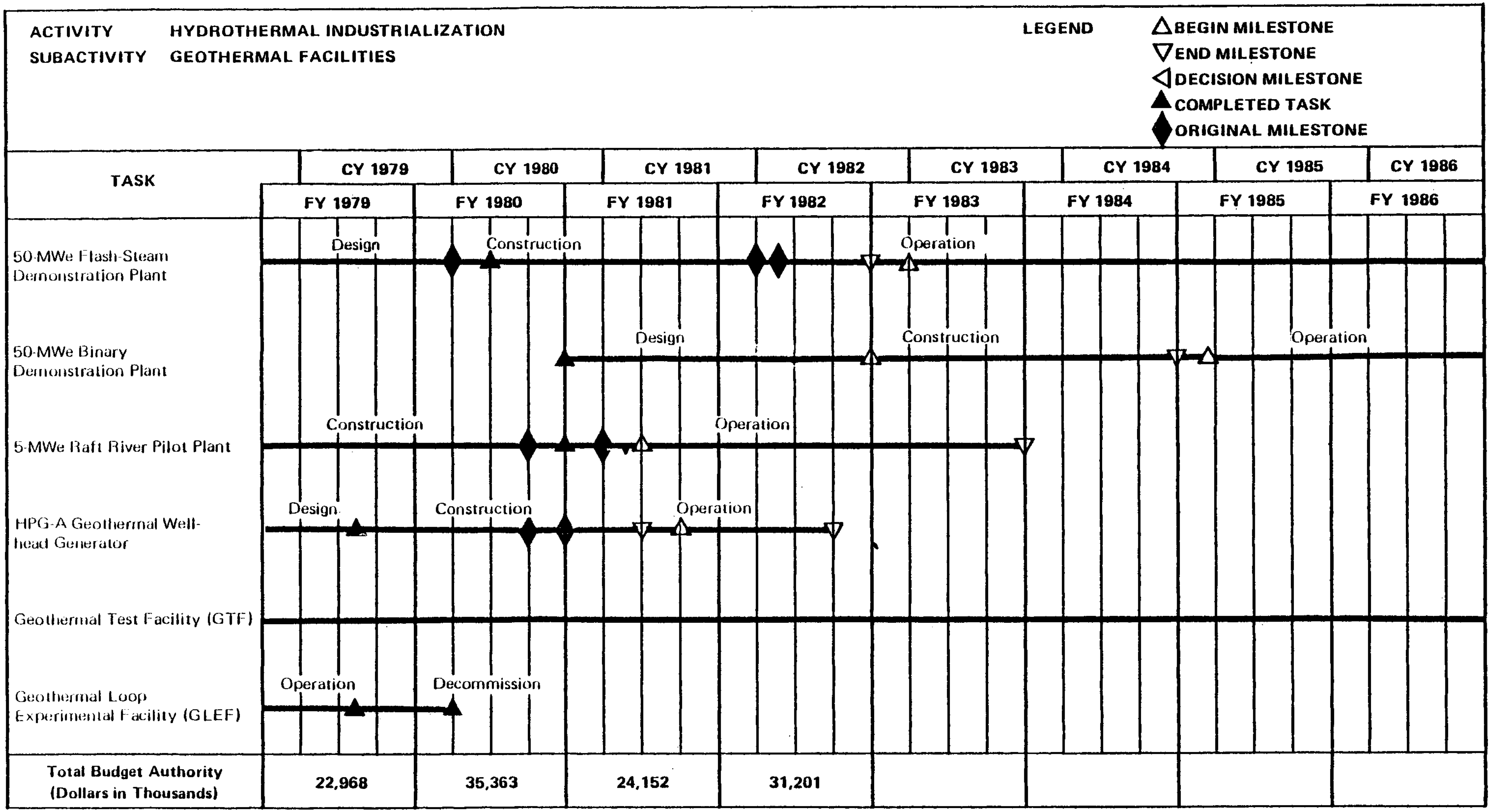
There are delays in delivery of the control room modules, presently scheduled to arrive at the site during the second quarter of FY 1981. Plant check-out and start-up is scheduled for the third quarter of FY 1981.

Geothermal Test Facility

The Geothermal Test Facility (GTF) has been established by DOE to help accelerate commercialization of geothermal energy resources. The facility provides geothermal fluid and support services for tests of heat extraction and of energy conservation equipment and materials. Exchange of reliable information among investigators within the energy community, and with the general public is actively promoted.

The GTF is located in the East Mesa area of California's Imperial Valley. Two geothermal fluid wells have been piped to the test pad to provide experimenters with a range of chemical characteristics for flexibility in testing. Two other wells are used for reinjection. The facility supports numerous experiments, including the 500-kWe direct contact tests and the gravity-head binary system described in Chapter 5 of this report.

Exhibit 2.e



ACTIVITY HYDROTHERMAL INDUSTRIALIZATION
SUBACTIVITY GEOTHERMAL FACILITIES
LEGEND
BEGIN MILESTONE
END MILESTONE
DECISION MILESTONE
COMPLETED TASK
ORIGINAL MILESTONE
TASK
CY 1979
CY 1980
CY 1981
CY 1982
CY 1983
CY 1984
CY 1985
CY 1986
FY 1979
FY 1980
FY 1981
FY 1982
FY 1983
FY 1984
FY 1985
FY 1986
50-MWe Flash-Steam Demonstration Plant
Design
Construction
Operation
50-MWe Binary Demonstration Plant
Design
Construction
Operation
5-MWe Raft River Pilot Plant
Construction
Operation
HPG-A Geothermal Well-head Generator
Design
Construction
Operation
Geothermal Test Facility (GTF)
Geothermal Loop Experimental Facility (GLEF)
Operation
Decommission
Total Budget Authority (Dollars in Thousands)
22,968
35,363
24,152
31,201

Geothermal Loop
Experimental Facility

The Geothermal Loop Experimental Facility (GLEF), 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 was cost-shared on an equal basis with the SDG&E. The facility was decommissioned in FY 1980 and a final report was published documenting the results. Techniques and data from the successful project are being used by developers at the numerous high-temperature/high-salinity resources in California's Imperial Valley.

3 GEOTHERMAL RESOURCE DEVELOPMENT FUND

The Geothermal Energy Research Development and Demonstration Act of 1974 provided for the establishment of the Geothermal Loan Guaranty Program (GLGP) and of the Geothermal Resource Development Fund to support the program. The Energy Security Act (1980) authorized appropriations to the fund for reservoir confirmation loans and feasibility study loans. The Energy Security Act also provides for a study of the need for a reservoir insurance program. If such a program is enacted, appropriations will also be required prior to the start-up of this program. To date there has been no appropriation bill enacted for any of the Energy Security Act programs.

The Geothermal Resource Development Fund activity is divided into four subactivities. These are:

- Program Direction
- Guaranty Reserve Fund
- Loan Evaluation Fund
- Energy Security Act.

These subactivities are discussed below.

PROGRAM DIRECTION

Policy management of the fund is provided by DGE headquarters, while administration of GLGP is handled by DOE's San Francisco Operations Office. All new loan programs will receive final approval from the Assistant Secretary, Resource Applications, DOE. Regulations and implementation plans are currently being developed.

Table 3

Funding Levels for Geothermal Resource Development Fund Subactivities FY 1980 through FY 1982

Subactivity	Budget Authority (Dollars in Thousands) Actual FY 1980	Estimate FY 1981	Estimate FY 1982	Increase (Decrease)
Program Direction	181	193	200	7
Guaranty Reserve Fund	0	41,982*	4,300	(37,682)
Loan Evaluation Fund	0	1,091	1,074	(17)
Energy Security Act	0	0	0	0
Total	**181**	**43,266**	**5,574**	**(37,692)**

* Represents reappropriation of unobligated balances in FY 1981.

GUARANTY RESERVE FUND

The objective of the GLGP is to assist the private sector in accelerating commercial development and use of geothermal energy by minimizing financial risks associated with new technology and reservoir uncertainties. The guarantied loans help reduce a lender's financial risk in making credit available for construction and operation of geothermal facilities, R&D projects, and field exploration. Total value of loan guaranties to an individual borrower is limited so that other borrowers and lenders have access to the guaranty. Guaranties are provided for both electric and non-electric projects. At present, 5 loans have been guarantied; there are 10 applications under active consideration, while 13 other potential applicants are conducting pre-application discussions. The total level of guaranties associated with these projects is $577 million.

The anticipated level of loan guaranty activity is expected to result in a total of 373 MWe of electric power-on-line, 100 MWe of field development for electric power generation, and 3.2 million equivalent barrels of oil per year for non-electric projects by 1984.

The following five loans have been approved under GLGP:

- Republic Geothermal, Inc., obtained a guaranty of $9 million from Bank of America for resource exploration and testing in East Mesa, California. Four reinjection and seven production wells were drilled. Temperatures of 160°C were obtained at the wellhead. It is estimated that 64 MWe can be produced from this project for 25 years. Republic Geothermal plans to submit guaranty applications for follow-on loans for full field development and power plant construction in the near future.

- Westmorland Geothermal Associates was awarded $29.1 million by Bank of America to explore, test, and develop the resource in Westmorland (Imperial County, California). This guaranty was approved June 22; a site for drilling has not yet been chosen. Among the issues to be resolved are whether a viable resource can be found, whether a power plant can be built at acceptable terms, and whether Westmorland can find a customer.

- Geothermal Food Processor, Inc., borrowed $3.5 million from the Georgia State Teachers Retirement System, with Bankers Trust as the trustee under a refinancing of the original $2.8 million note with Nevada National Bank. Geothermal heat is being used in a food-drying project at Brady Hot Springs, Nevada. The plant, now operating at 88-100 percent of capacity, has netted drying contracts sufficient to repay its debt and has successfully completed its second full season of operation. Additional food processing contracts are being sought to enhance plant utilization.
- California-Utah (CUI) borrowed $1.8 million from the Bank of Montreal (California) for resource exploration and testing in Brawley (Imperial County, California). One production well was drilled to 14,000 feet with a wellhead temperature of 232°C and a salinity of over 269,000 ppm. Whether the technology exists to permit use of such a highly saline resource, and whether handling costs will be deemed reasonable, remains to be determined. A follow-on contract of $49.4 million for full field development has also been guarantied.
- Northern California Power Corporation borrowed $45 million from the Bank of Montreal (California) for construction of a 110-MWe power plant at the Geysers, CA.

LOAN EVALUATION FUND

At present, three additional loan quaranty project applications are under evaluation. The cost of these projects would total $85 million, with $64 million being guarantied. Two of the projects involve field development of geothermal reservoirs: one at the Geysers, CA, by Rorabough; and the other at Coso Hot Springs, CA, by California Energy Corporation. The third project involves the use of geothermal energy at the mushroom plant of Oregon Trail Mushroom, Vale, OR. Nine additional loan guaranty applications are being prepared. Estimated total cost of the projects in preparation, which include heat projects, field development, and power plants, is $556 million.

ENERGY SECURITY ACT

The recently enacted Energy Security Act (P.L. 96-294) includes provisions for: loan programs for hydrothermal reservoir confirmation drilling, direct-heat feasibility studies, licensing and construction; a reservoir insurance and reinsurance program; and extension of GLGP to 1990. These initiatives are intended to reduce the economic risks in drilling for and developing hydrothermal reservoirs. Regulations are being developed for these programs, but no funds are requested for FY 1982.

The reservoir confirmation drilling loan program is intended to provide funds for projects that: are designed to explore for, or determine the economic viability of, a geothermal reservoir; and that consist of surface exploration and drilling of one or more exploratory wells.

The program can provide loans of up to $3 million to cover no more than 50 percent of project costs (up to 90 percent if the project will provide process heat or space-heating or cooling for present structures or for those under construction). Interest rates are about 7 percent since the rate is tied to interest under the Water Resources and Development Act of 1974. Loans are repayable out of project revenues, if the project is successful.

Direct heat feasibility study licensing and construction loans are intended to provide up to 90 percent of the costs of studies, on a forgivable basis, to determine the feasibility of geothermal projects for non-electric applications. Costs eligible for loans under the program also include expenses for preparing applications for federal, state, or local licenses or approvals for the project. Loans are also authorized for up to 75 percent of construction costs for non-electric geothermal systems. Interest rates are tied to the Water Resources Development Act of 1974. Although no loan size was specified by the Energy Security Act, $5 million was authorized for the program for FY 1981, with subsequent years' funding to be determined by future legislation.

The Energy Security Act requires the Secretary of Energy to study the need for a reservoir insurance and reinsurance program. If established, the program would provide insurance at reasonable premiums to persons with an investment of not less than $1 million in the development and use of a geothermal reservoir (excluding exploration and testing). The insurance available would be limited to the lesser of either 90 percent or $50 million of the loss of investment subject to risk. The DOE Secretary is required to submit the study of the need for such a program by June 30, 1981. If the study recommends establishment of the program, it must be implemented within 6 months of authorization.

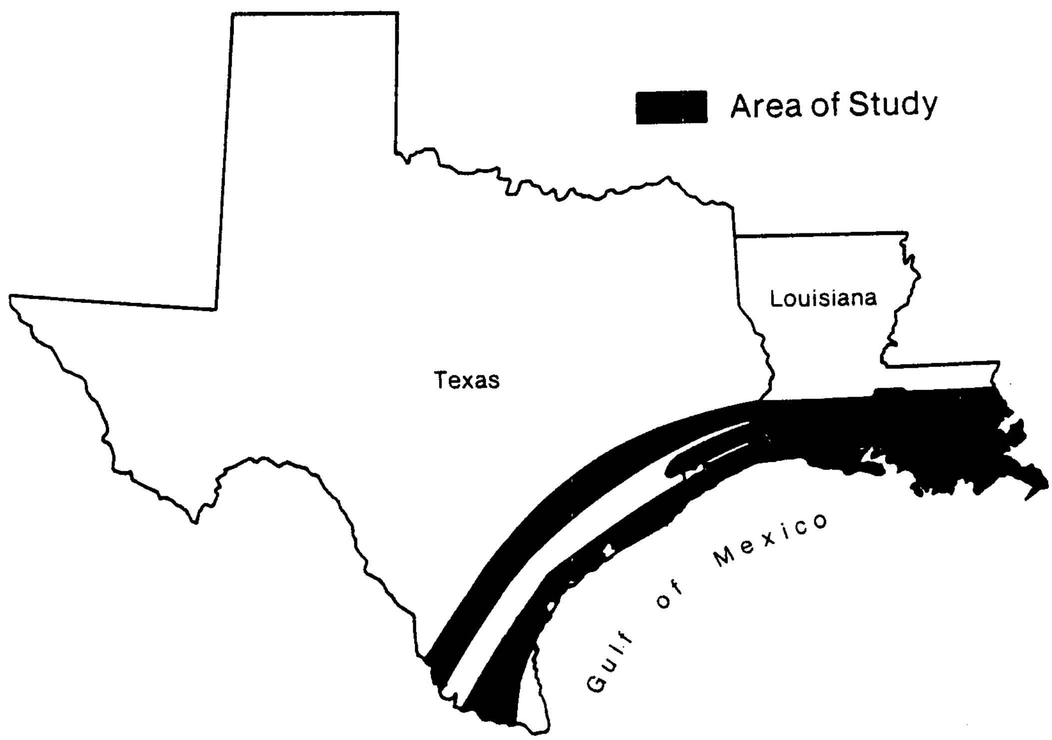
4 GEOPRESSURED RESOURCES

The objective of the Geopressured Resources activity is to determine the magnitude and economic potential of this resource. To accomplish this objective, efforts are underway to define the extent of the resource (principally natural gas potential), demonstrate recovery potential, and identify potential environmental effects of development.

Geopressured aquifers are underground reservoirs of hot, overpressured brine that contains methane in solution. Such geopressure-geothermal aquifers are known to occur in the United States along the Gulf of Mexico Coast, the Pacific Coast, and in Appalachia, as well as in deep sedimentary basins elsewhere in the nation. Extraction of methane, thermal energy, and mechanical energy from these aquifers could make a substantial contribution to U.S. energy supply.

The geopressure-geothermal resource base (energy in the ground) is believed to be substantial. Estimates of the amount of in-place methane range between 1,000 and 50,000 trillion cubic feet (Tcf). This large variation reflects uncertainties about the geographic area, the size of the reservoirs, and the volume of methane dissolved in the geopressurized brines. USGS estimates that 5,700 Tcf of natural gas is contained in the waters of sandstone formations in onshore and offshore areas along the Gulf of Mexico. Recoverability has been estimated at between 50 and 5,000 Tcf. (This is significant in that the United States uses about 20 Tcf of natural gas per year.)

The initial target for DOE's geopressure-geothermal program is the methane in solution found in the onshore coastal areas of Texas and Louisiana. The importance attached to the recovery of methane stems from the larger size of the resource and its high recovery potential relative to that of thermal and mechanical energy. There is also a large data base available from oil and gas exploration in this area.



Gulf Coast Geopressured Zones

The Gulf Coast oil and gas producing industry can be expected to undertake rapid commercial development of geopressured resources. The Geopressured Resources activity is now working to show that the resource base is sufficiently large and that it can be tapped economically without adverse environmental effects. DGE supports activities in resource definition and environmental assessment at the University of Texas at Austin and at the Louisiana State University, Baton Rouge.

The characteristics of geopressured aquifers vary widely, and reservoir performance under production conditions is a complex phenomenon. For these reasons, a substantial number of tests will be required to permit reliable estimates of the potential of the total geopressured resource. The Geopressured Resources activity focuses on production tests of wells completed in geopressured reservoirs that reveal reservoir characteristics and basic drive mechanisms that enable production of geopressured brine. Results of such tests permit estimates of reservoir productivity and longevity.

The Geopressured Resources activity is divided into two major subactivities:

- Resource Definition
- Supporting Research and Development.

These subactivities are discussed below.

RESOURCE DEFINITION

Reservoir and production data now available are insufficient to estimate reliably the technical and economic potential of the geopressured aquifers in the resource base. The purpose of resource definition is to establish the location and size of the aquifers by conducting geologic studies and well tests. This will build a base of engineering and geologic data by the end of FY 1986, and will reduce the uncertainty associated with the size and nature of the recoverable resource. Moreover, it will establish the location of aquifers suitable for commercial development by the private sector.

Table 4.a

Funding Levels for Geopressured Resources Subactivities FY 1980 through FY 1982

Subactivity	Budget Authority (Dollars in Thousands)			
	Actual FY 1980	Estimate FY 1981	Estimate FY 1982	Increase (Decrease)
Resource Definition	33,032	32,126	23,800	(8,326)
Supporting Research and Development	1,360	3,474	2,436	(1,038)
Capital Equipment	300	200	200	0
Total	**34,692**	**35,800**	**26,436**	**(9,364)**

Aquifer data will be gathered as an output of the wells of opportunity and design wells programs. These data will be used to better understand the resource and to verify the methodology used in selecting well sites.

Wells of Opportunity

These are wells that the private-sector petroleum industry has drilled into or through geopressured reservoirs in the search for oil and gas, and that are made available for testing. The advantage of using these wells for short-term tests of geopressured zones is that they allow DOE to obtain valuable information at costs considerably below those of design wells. The disadvantage is that these wells are often drilled on-structure or near structural closure for entrapment of hydrocarbons; accordingly, they may not be in the most favorable locations for testing high-volume delivery of aquifers. The testing provides information on important properties of the reservoir fluids (e.g., salinity, water chemistry, gas chemistry, and gas-to-water ratios) and on the reservoir characteristics around the wellbore.

Plans include tests of three to four wells of opportunity per year for each of the next 4 years. Efforts will be made to select wells from the prime prospect areas of Texas and Louisiana, which include the Wilcox and Frio formations in Texas, and the Tuscaloosa and Tertiary formations in Louisiana.

The first successful test of a geopressured aquifer, conducted in Vermilion Parish, Louisiana, in 1977, produced methane-saturated brine. Additional tests in a well located in St. Mary's Parish were conducted in FY 1979. Through the end of FY 1980, a total of five wells had been sucessfully tested. Two recent tests in low-salinity aquifers proved the existence of high methane content in a variety of formations.

Design Wells

These are wells completed in potentially favorable geopressure-geothermal locations as defined by the best available geological and geophysical data. Large-volume reservoirs are required to enable the high cost design

Table 4.b

Funding Levels for Resource Definition Tasks FY 1980 through FY 1982

Task	Budget Authority (Dollars in Thousands)			
	Actual FY 1980	Estimate FY 1981	Estimate FY 1982	Increase (Decrease)
Wells of Opportunity	9,173	10,000	10,000	0
Design Wells	23,859	22,126	13,800	(8,326)
Total	**33,032**	**32,126**	**23,800**	**(8,326)**

wells to determine crucial issues, such as whether geopressured aquifers can be produced at high-volume flow rates for the period of time required for acceptable economic returns.

One design well is being tested in Brazoria County, Texas. Two more are being drilled in Louisiana, one in Vermilion Parish and one in Cameron Parish. DOE has contracts for seven more design wells through FY 1984.

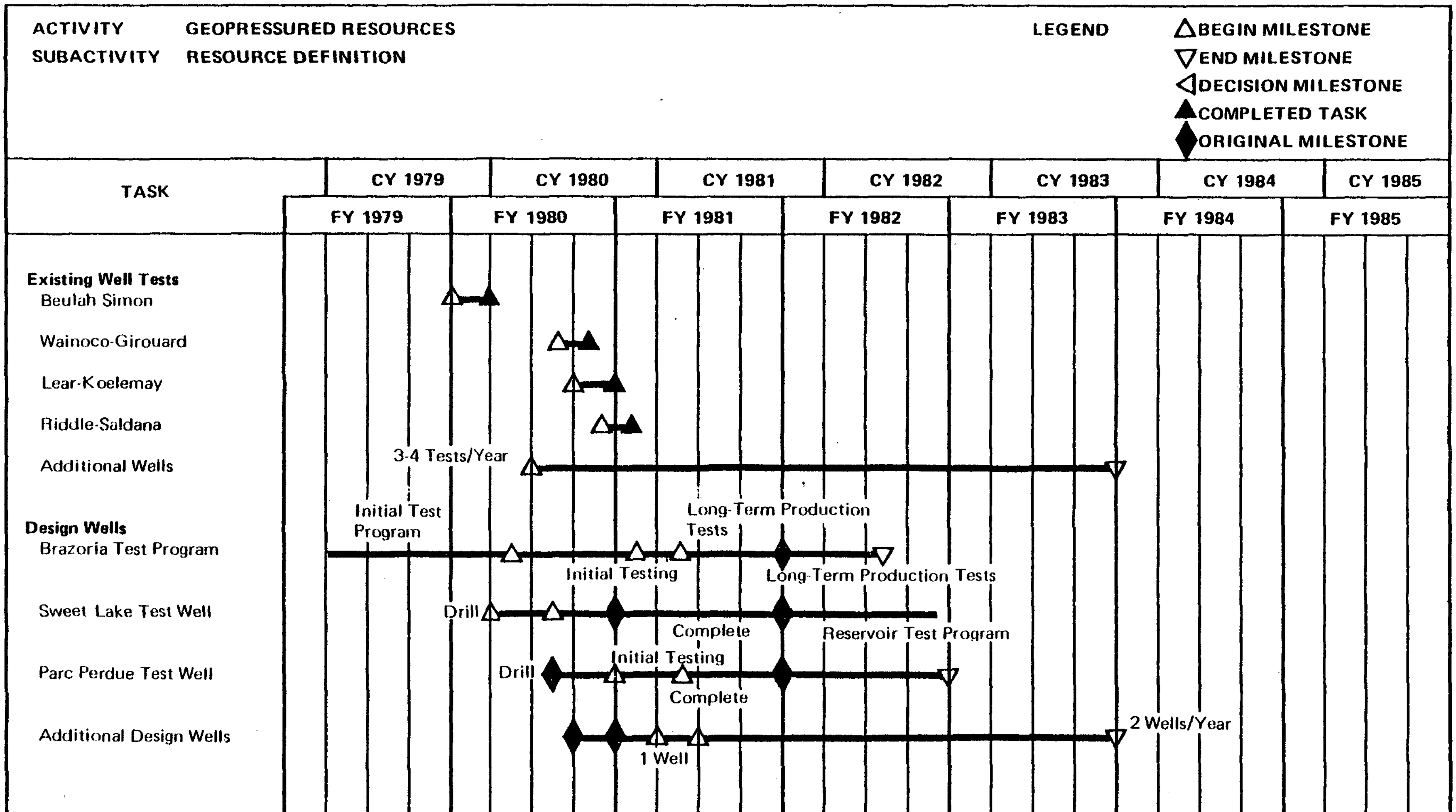
SUPPORTING RESEARCH AND DEVELOPMENT

This subactivity involves such tasks as program coordination, geopressure-environmental control, and engineering applications. The purpose of the program coordination task is to identify the economic, environmental, institutional, and technological considerations that must be met in order to develop geopressured resources. The activity also provides 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. Coordination of regional planning activities is organized through the Louisiana State University and the University of Texas. DGE is also cooperating with the Gas Research Institute to investigate the potential for recovery of methane from geopressured resources.

The geopressure-environmental control task supports continued research on potentially adverse environmental effects of sustained high-volume production of geopressured brines. The high pressure of the fluids produced and the large volume of fluid withdrawal present potentially far more serious environmental problems than does production of conventional resources.

The two main environmental concerns are subsidence and fluid disposal. Subsidence is a particular concern on the Gulf Coast. In many localities, elevations are low and large-scale subsidence could have a serious impact. Current waste treatment technology is probably adequate to prevent contamination of drinking water, but new technology may be needed to remove hazardous substances from geothermal fluids.

Exhibit 4.a



Total Budget Authority (Dollars in Thousands)	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
	24,455	33,032	32,126	23,800			

The Pleasant Bayou Test Well in Brazoria County, Texas, has been instrumented to measure environmental parameters, including subsidence, micro-seismicity, and air and water quality. Data obtained for the monitoring of the well tests will be used to gauge the potential environmental impact of geopressured aquifer development.

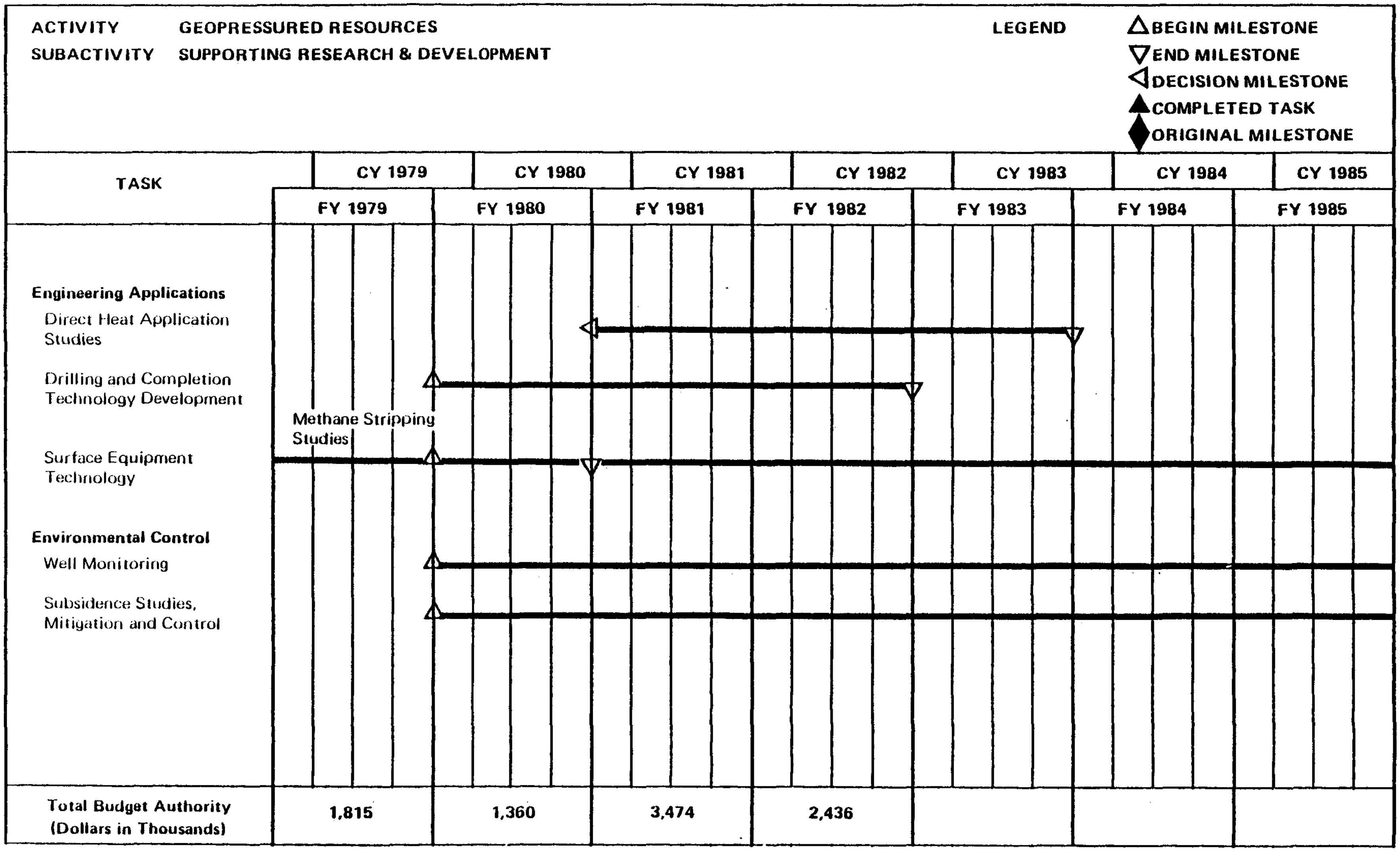
Environmental assessment and monitoring of well sites in Texas and Louisiana will be accelerated to keep pace with drilling. Environmental documentation will be prepared as necessary in connection with well-testing activities conducted under the resource definition subactivity.

The engineering applications task seeks to establish the technical and economic feasibility of recovering energy from geopressured resources. This is essential for industry interest and development. It requires establishing the technical feasibility of high-volume brine production and disposal and the economic recovery of the produced energy, gaining an improved technical and mathematical understanding of the resources, and resolving any legal and institutional constraints that may impede timely development. The program is carried out under two basic categories, (1) surface technology and resource utilization, and (2) well drilling and completion.

Activities in surface technology and resource utilization have been conducted for methane fuel production, direct heat utilization, and power generation. This work includes conceptual design of facilities for electric power generation and for direct heat applications from geopressured resources. Appropriate experiments will be undertaken in FY 1982 and FY 1983. Studies on methane stripping will take place in FY 1981.

The development of well drilling and completion technology 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 geopressured resources will be carried out in 1982.

Exhibit 4.b



ACTIVITY GEOPRESSURED RESOURCES
SUBACTIVITY SUPPORTING RESEARCH & DEVELOPMENT
LEGEND
BEGIN MILESTONE
END MILESTONE
DECISION MILESTONE
COMPLETED TASK
ORIGINAL MILESTONE
TASK
CY 1979
CY 1980
CY 1981
CY 1982
CY 1983
CY 1984
CY 1985
FY 1979
FY 1980
FY 1981
FY 1982
FY 1983
FY 1984
FY 1985
Engineering Applications
Direct Heat Application Studies
Drilling and Completion Technology Development
Methane Stripping Studies
Surface Equipment Technology
Environmental Control
Well Monitoring
Subsidence Studies, Mitigation and Control
Total Budget Authority (Dollars in Thousands)
1,815
1,360
3,474
2,436

5 GEOTHERMAL TECHNOLOGY DEVELOPMENT

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

DGE's geothermal technology development program seeks technical solutions to the problems of operating in geothermal environments. Efforts focus on developing techniques, materials, and equipment specifically tailored to geothermal conditions, reducing technology costs, and encouraging establishment of industry-wide standards for geothermal materials and equipment. DGE is also developing techniques to extract energy from hot dry rock (HDR).

The activity is divided into two major subactivities:

- Component Development
- Hot Dry Rock.

These subactivities are discussed in detail in the following sections.

COMPONENT DEVELOPMENT

Improved technology for drilling and well completion could reduce the cost of geothermal wells 25 percent by 1983 and 50 percent by 1987. These technology improvements would affect the cost of the projected 10,000 wells that must be drilled in order to bring 25,000 MWe of geothermal power on line. This subactivity is organized into several tasks aimed at improving the overall discovery and exploitation of a geothermal resource.

Table 5.a

Funding Levels for Geothermal Technology Development Subactivities FY 1980 through FY 1982

Subactivity	Budget Authority (Dollars in Thousands)			
	Actual FY 1980	Estimate FY 1981	Estimate FY 1982	Increase (Decrease)
Component Development	25,058	35,300	15,000	(20,300)
Hot Dry Rock	14,000	13,500	12,600	(900)
Capital Equipment	2,120	1,110	500	(610)
Total	**41,178**	**49,910**	**28,100**	**(21,810)**

Table 5.b

Funding Levels for Component Development Tasks FY 1980 through FY 1982

Task	Budget Authority (Dollars in Thousands)			
	Actual FY 1980	Estimate FY 1981	Estimate FY 1982	Increase (Decrease)
Drilling and Completion Technology	6,530	9,400	3,500	(5,900)
Energy Conversion Technology	8,311	10,703	3,900	(6,803)
Reservoir Stimulation	1,656	3,200	3,900	(300)
Geochemical Engineering and Materials	3,931	4,700	700	(4,000)
Geoscience Technology	4,630	7,297	3,500	(3,797)
Environmental Control Technology	0	0	500	500
Total	**25,058**	**35,300**	**15,000**	**(20,300)**

The conversion tasks are developing pumps, heat exchangers, and systems for use with moderate-temperature geothermal fluids for economic production of electricity.

The reservoir stimulation task seeks ways to increase production from individual wells, thereby reducing the number of wells required to exploit a reservoir.

The geochemical engineering and materials task 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 geoscience task concentrates on improving the technologies for exploration, reservoir engineering, logging instrumentation, and log interpretation.

Drilling and Completion Technology

Private industry has identified improvements in drilling and well completion technology as a major requirement for reducing costs of geothermal field development. The drilling and completion effort is developing conventional rotary drilling equipment, such as drill bits and downhole motors, and completion equipment for use in geothermal environments.

Bit Development

Field evaluations are planned for 10 advanced drill bits, which were supplied by 4 manufacturers, 3 of whom used cutter placements designed by Sandia Laboratories. Testing will begin at the Geysers fields, California, and at the Baca fields, New Mexico, after evaluation testing at the Drilling Research Lab, Salt Lake City, to establish performance characteristics.

The third generation polycrystalline diamond cutter (PDC) drag bits manufactured by General Electric Co. are ready for field tests. General Electric's participation in this project is now complete and Sandia Laboratories will carry out further development.

Table 5.c

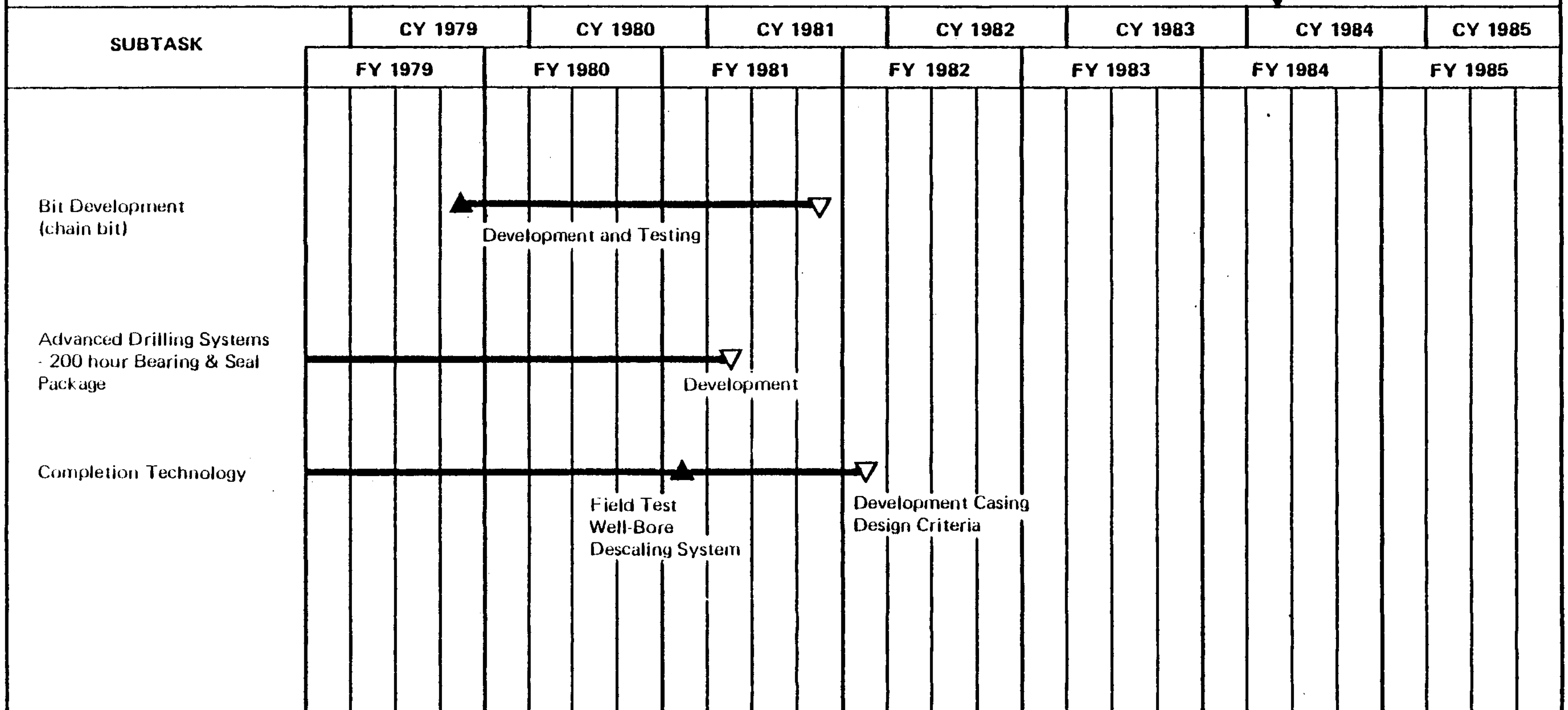
Funding Levels for Drilling and Completion Technology Subtasks FY 1980 through FY 1982

Subtask	Budget Authority (Dollars in Thousands)			
	Actual FY 1980	Estimate FY 1981	Estimate FY 1982	Increase (Decrease)
Bit Development	3,918	5,640	2,100	(3,540)
Advanced Drilling Systems	653	940	0	(940)
Completion Technology	1,959	2,820	1,400	(1,420)
Capital Equipment	100	350	0	(350)
Total	**6,630**	**9,750**	**3,500**	**(6,250)**

Exhibit 5.a

ACTIVITY GEOTHERMAL TECHNOLOGY DEVELOPMENT
SUBACTIVITY COMPONENT DEVELOPMENT
TASK DRILLING AND COMPLETION TECHNOLOGY

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



	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
Total Budget Authority (Dollars in Thousands)	5,432	6,530	9,400	3,500			

Advanced Drilling Systems

With support from Sandia Laboratories and DGE, high-speed downhole motors and bits are being developed to facilitate exploitation of high-temperature, hard rock geothermal reservoirs. The motors are made with special bearings and seals that should permit their operation for up to 200 hours under high-temperature conditions. New materials are also being used in the development of percussion drill bits. The new materials replace plastic parts, which deform and fail at the high temperatures encountered in many geothermal reservoirs.

Completion Technology

In conjunction with the geochemical engineering and materials task, the completion technology subtask is working on the development of polymer concrete and on scale-removal techniques for use in exploitation of geothermal resources. A scale-removal system using cavitation techniques has been designed and tested at East Mesa, California. A final field demonstration model of the system, which removes scale by forming and collapsing bubbles under high pressure, was completed in FY 1981.

Energy Conversion Technology

The objective of the energy conversion technology task is to reduce geothermal electric generating costs by increasing well productivity (pumping), increasing plant efficiency at moderate temperatures, and improving overall system reliability. The task emphasizes technology for moderate-temperature geothermal reservoirs, which constitute a much larger resource base than do high-temperature resources. However, moderate-temperature reservoirs are inherently more expensive to exploit because more geothermal fluid is required per unit of power. Downhole pumps, heat exchangers, and conversion systems for electricity production are being developed under this task. Specific activities are discussed below.

Downhole Pump Development

Wells attaining commercial flow rates (adequate for producing 3 MWe or more per well) become progressively

Table 5.d

Funding Levels for Energy Conversion Technology Subtasks FY 1980 through FY 1982

Subtask	Budget Authority (Dollars in Thousands)			
	Actual FY 1980	**Estimate FY 1981**	**Estimate FY 1982**	**Increase** (Decrease)
Downhole Pump Development	1,000	1,000	200	(800)
Gravity Head Binary	3,911	6,000	2,500	(3,500)
Direct Contact Binary	2,000	2,000	1,200	(800)
Waste Heat Rejection	1,000	1,000	0	(1,000)
Alternate Systems	400	703	0	(703)
Capital Equipment	470	115	0	(115)
Total	**8,781**	**10,818**	**3,900**	**(6,918)**

less common as reservoir temperatures decline below 400°C due to the rapid reduction of water vapor pressure resulting from reduction in temperature. Mechanical pumps, commonly used for oil recovery, can sustain high flow rates while they simultaneously suppress the scale and precipitate that frequently accompany the flashing process in an unpumped well. Unfortunately, the hostile temperature and chemical environment in a geothermal reservoir causes conventional oil-field pump technology to be highly unreliable for geothermal applications (service life seldom exceeds a few weeks). The pump development subtask involves a number of activities ranging from pump modification (redesign and/or new materials) to extensive laboratory component testing and long-duration field testing. The program is targeted to produce, by 1984, pumps with service lives of 12 to 18 months and to provide reliable components for the 50-MWe binary demonstration plant (which is strongly dependent upon pumped, single-phase heat addition for its efficiency).

Gravity Head Binary

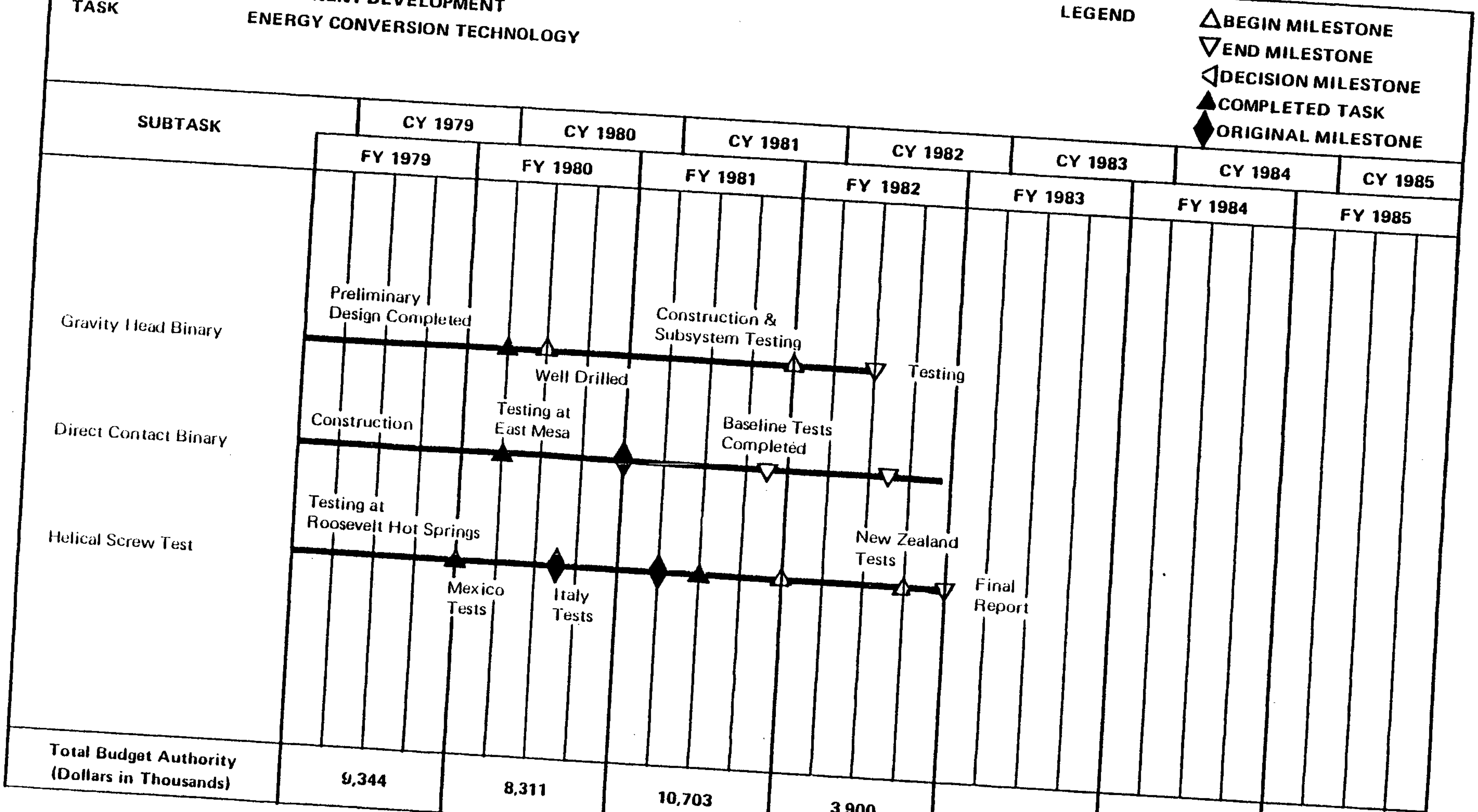
The gravity head binary subtask focuses on an advanced binary process (i.e., two-fluids, geothermal and fluorocarbon) capable of producing 30 percent more power per unit of brine at essentially the same capital cost as conventional binary designs. The system, now in the final design phase, features a downhole heat exchanger and a thermal siphon effect for fluorocarbon circulation. A large (30-inch diameter) well has been successfully drilled and flow-tested at the East Mesa, California, geothermal test facility. Downhole component testing will begin during the second quarter of FY 1981, and start-up of the 4.2-MWe pilot plant is scheduled for approximately 1 year later.

Direct Contact Binary

The direct contact binary design is intended to reduce capital and operating costs while maintaining efficiency comparable to conventional binary designs. This contrasts with the gravity head binary process, which benefits from increased thermal efficiency. The term "direct contact" refers to the heat exchange process in which geothermal brine and isobutane are mixed during counter-current flow in a simple open column. The isobutane is vaporized and exits at the top of the column,

Exhibit 5.b

ACTIVITY GEOTHERMAL TECHNOLOGY DEVELOPMENT
SUBACTIVITY COMPONENT DEVELOPMENT
TASK ENERGY CONVERSION TECHNOLOGY



Total Budget Authority (Dollars in Thousands)	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
	9,344	8,311	10,703	3,900			

where it powers a turbine. The direct contact heat exchanger is approximately 80 percent less expensive than a conventional shell and tube heat exchanger, and it is not subject to fouling or leakage. The concept has been demonstrated in a highly successful 500-MWe pilot plant being tested at the East Mesa geothermal test facility.

Waste Heat Rejection

All power plants require cooling to condense the working fluid, lower turbine back-pressure, and increase efficiency. Geothermal power plants, however, require removal of approximately four times more heat per kWh to condense the working fluid than do either fossil fuel or nuclear plants. As cooling is normally accomplished through water evaporation in a cooling tower, excessive water consumption will result unless advanced technology is employed for geothermal applications. The waste heat rejection subtask, in cooperation with DOE's nuclear program, is investigating technology capable of using low quality water sources, such as brine, for cooling tower systems or for partial dry-cooling systems.

Alternate Systems

Numerous other activities are being carried out under the energy conversion technology task. These activities range from the determination of equations-of-state properties of isobutane to the testing and evaluation of a 1-MWe brine-power helical screw expander. These activities provide support for associated hardware test programs and enlarge the scope of the overall effort.

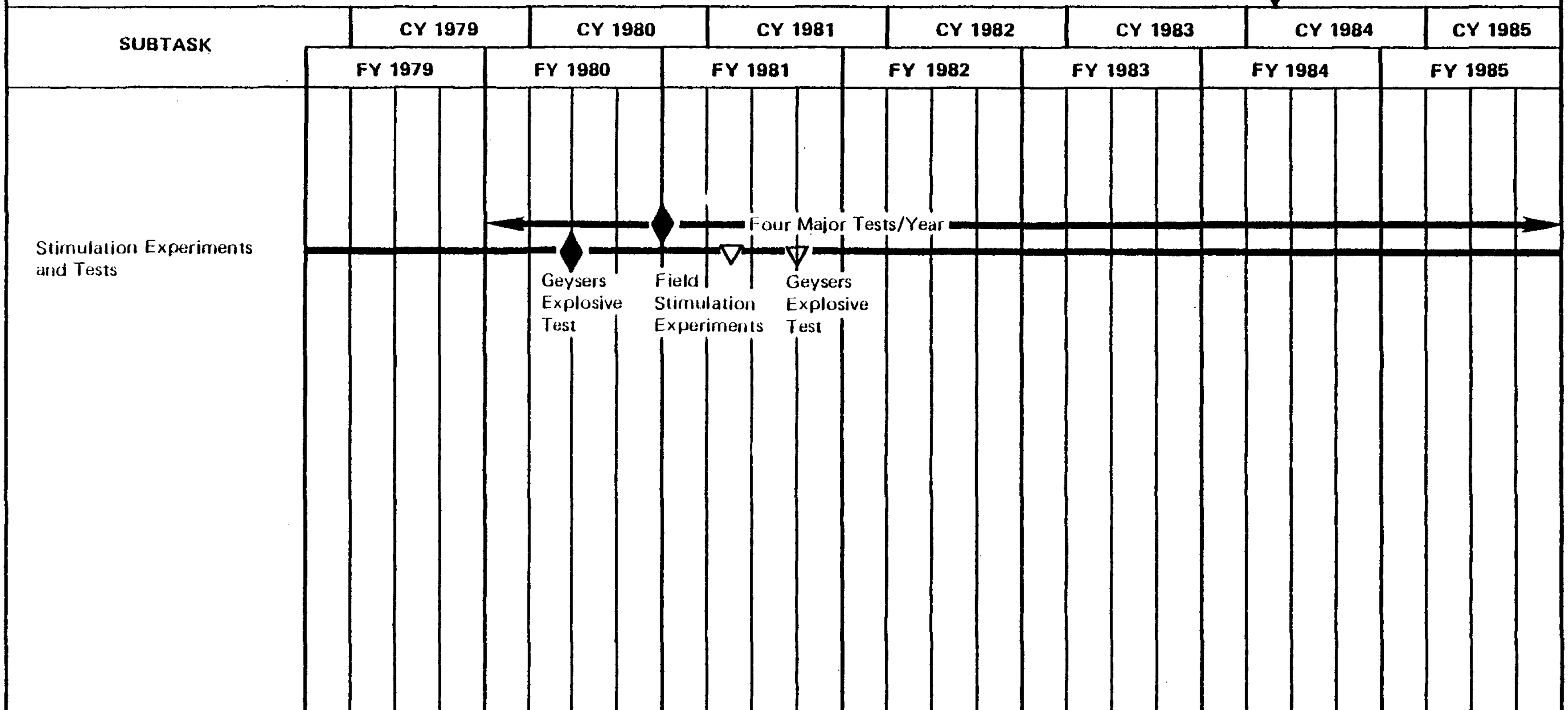
Reservoir Stimulation

The economics of geothermal systems development can be greatly improved by increasing well flow rates through stimulation of the geothermal reservoir. To develop new reservoir stimulation technology, field experiments are conducted first at lower-temperature reservoirs, then at confirmed high-temperature reservoirs as appropriate technology is developed. Techniques under development include chemical treatment and hydraulic and explosive fracturing.

Exhibit 5.c

ACTIVITY: GEOTHERMAL TECHNOLOGY DEVELOPMENT
SUBACTIVITY: COMPONENT DEVELOPMENT
TASK: RESERVOIR STIMULATION

LEGEND
- △ BEGIN MILESTONE
- ▽ END MILESTONE
- ◁ DECISION MILESTONE
- ▲ COMPLETED TASK
- ◆ ORIGINAL MILESTONE



Total Budget Authority (Dollars in Thousands)	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
	4,442	1,656	3,200	2,900			

During 1980, hydraulic fracturing was used to stimulate two moderate-temperature wells at Raft River; productivity of both wells was increased slightly. Tests on higher-temperature wells at the Baca location and at the Geysers are scheduled to be completed in FY 1981. The tests will use high-viscosity fluids and high temperature proppants.

Geochemical Engineering and Materials

The geochemical engineering and materials task focuses on containment and handling of geothermal fluids. Fluid disposal and maintenance procedures for injection wells are being developed to control wastes and to optimize the use of geothermal waste by-products.

Materials activities address the interaction of geothermal fluids with plant and well materials. DGE's program seeks to advance economic construction materials and to develop elastomers, metals, and non-metallic materials for use in geothermal environments. Materials under development include polymer concrete for pipes and pressure vessels, and corrosion-resistant steels for well casing, drill pipes, and energy-conversion equipment. Over the next 5 years, the geochemical engineering and materials effort will complete laboratory development of new corrosionand temperature-resistant materials and will apply this knowledge to construction and field testing of equipment for new components and systems.

Geochemical Engineering

Several engineering handbooks have been issued under this subtask, with others planned for future publication. An analysis handbook was published in FY 1979; a sampling handbook was published in FY 1980; and a geochemical engineering process handbook is scheduled for completion in FY 1982.

Another project under this subtask is a project cost-shared by industry, the development of first-generation plant monitor/control instrumentation. DOE will provide instrumentation and data interpretation at the Magma Power Company binary plant at East Mesa. In return, DOE will gain information on fluid characteristics. Among the new instruments being developed as part of this project are high-temperature meters, specific ion electrodes, conductivity meters, and corrosion-monitoring equipment.

Table 5.e

Funding Levels for Geochemical Engineering and Materials Subtasks FY 1980 through FY 1982

Subtask	Budget Authority (Dollars in Thousands)			
	Actual FY 1980	Estimate FY 1981	Estimate FY 1982	Increase (Decrease)
Geochemical Engineering	1,943	2,548	250	(2,298)
Materials Development	779	1,177	350	(827)
Alternate Materials Development	1,209	975	100	(875)
Capital Equipment	265	95	0	(95)
Total	**4,196**	**4,795**	**700**	**(4,095)**

Materials Development

In order to achieve overall economy in construction, operation, and maintenance of geothermal systems, durable materials resistant to corrosion and catastrophic failure are required. To help develop such materials, DGE has been involved in forming a special committee of the American Society for Testing and Materials on geothermal resources and energy. This committee, which brings together representatives from government, industry, and the academic community, evaluates standards for geothermal materials and procedures.

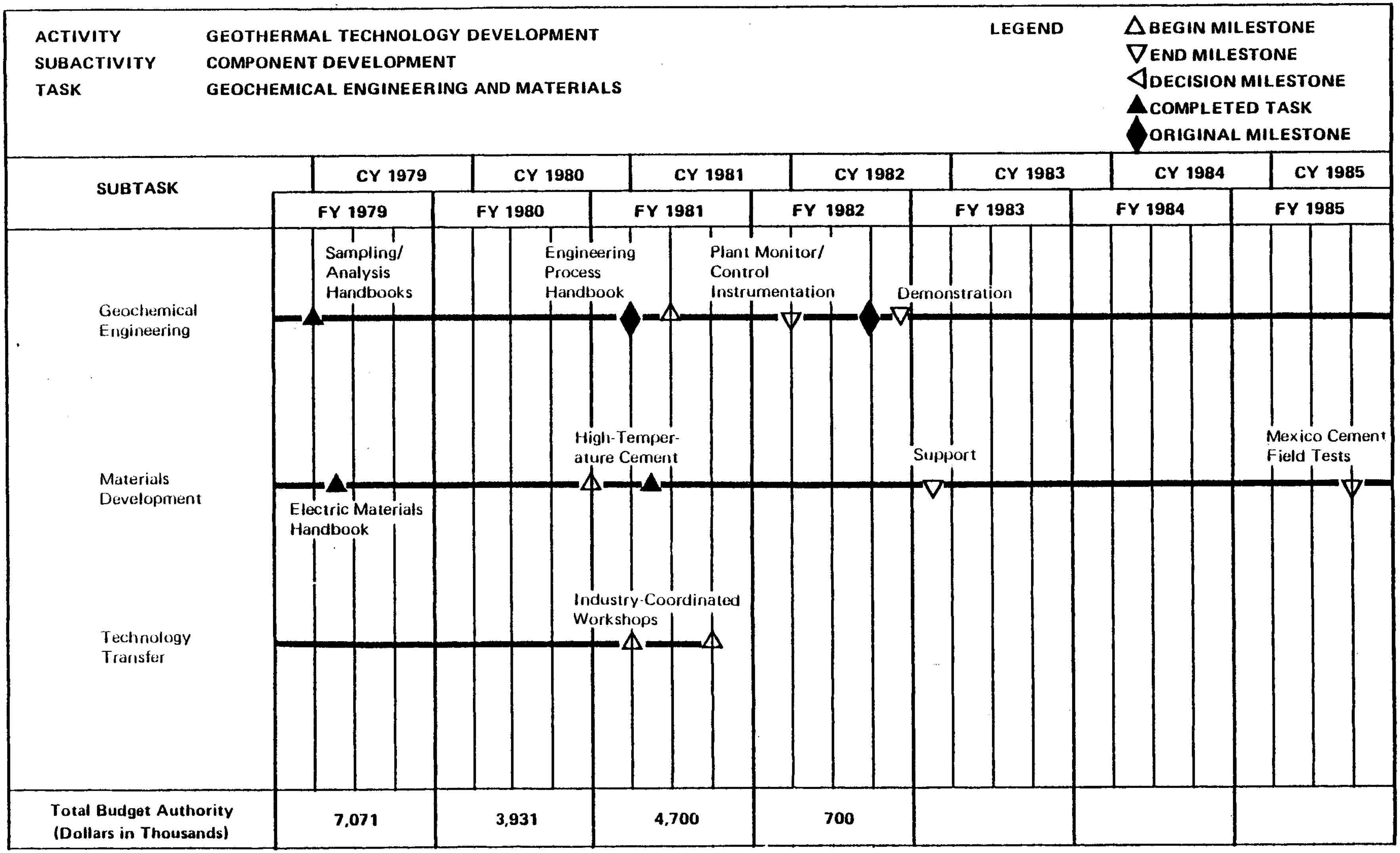
In 1978, DGE published an analysis handbook of materials available for electric applications of geothermal energy. A completely revised edition of the handbook will be published in March 1981. This expanded edition will include information on non-electric applications and extensive international information. DGE also cooperated with the National Academy of Sciences to prepare a review of geothermal materials needs to the year 2000, which is due to be published in the first quarter of 1981. In addition, DGE issues a monthly newsletter, "Geothermal Materials Review," which is sent to 2,200 interested members of industry and the general public.

A series of high-temperature well cements have been developed and tested at the National Bureau of Standards as part of an American Petroleum Institute task group effort to develop geothermal well cement standards. With laboratory development complete, field testing of high-temperature well cements will begin under an arrangement with the Mexican government.

Alternate Materials Development

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 and flash tanks were tested at Niland, California, and at East Mesa. As hoped for, carbonate scale did not adhere to the concrete surface, thereby offering a potential remedy to the scaling problem in a portion of the brine-handling equipment at East Mesa and at other geothermal fields with high carbonate content in the water.

Exhibit 5.d


ACTIVITY GEOTHERMAL TECHNOLOGY DEVELOPMENT
SUBACTIVITY COMPONENT DEVELOPMENT
TASK GEOCHEMICAL ENGINEERING AND MATERIALS
LEGEND
BEGIN MILESTONE
END MILESTONE
DECISION MILESTONE
COMPLETED TASK
ORIGINAL MILESTONE
SUBTASK
CY 1979
CY 1980
CY 1981
CY 1982
CY 1983
CY 1984
CY 1985
FY 1979
FY 1980
FY 1981
FY 1982
FY 1983
FY 1984
FY 1985
Geochemical Engineering
Sampling/ Analysis Handbooks
Engineering Process Handbook
Plant Monitor/ Control Instrumentation
Demonstration
Materials Development
Electric Materials Handbook
High-Temperature Cement
Support
Mexico Cement Field Tests
Technology Transfer
Industry-Coordinated Workshops
Total Budget Authority (Dollars in Thousands)
7,071
3,931
4,700
700

The manufacture of commercial, prototype polymer concrete pipes and of a high-temperature logging cable and the technology transfer of new high-temperature elastomers were initiated during 1978 and 1979. A non-destructive evaluation technique to predict drill pipe failure will be field tested in FY 1981.

Work on geothermal materials in FY 1981 will emphasize development and testing of elastomers, metals, and cements 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.

Geoscience Technology

Improvements in technology related to exploration for geothermal resources and assessment of reservoirs are essential to maintain the rate of discovery and development necessary to reach national goals. The geoscience technology task consists of four subtasks:

- Exploration technology
- Reservoir engineering
- Logging instrumentation
- Log interpretation.

Exploration technology emphasizes improvements in surface exploration equipment and techniques. Reservoir engineering addresses improvements in the areas of well testing, assessment of rock and fluid properties, reservoir performance analysis and prediction, and economics. Activities in logging instrumentation are aimed at upgrading tool capabilities from the present rating of 180°C to typical geothermal temperatures of up to 275°C. Log interpretation involves analyzing the data interpretation problems encountered in the use of available well logging devices.

Exploration Technology

The objective of this subtask is to develop an effective strategy, based on demonstrated methods, that

Table 5.f

Funding Levels for Geoscience Technology Subtasks FY 1980 through FY 1982

Subtask	Budget Authority (Dollars in Thousands)			
	Actual FY 1980	Estimate FY 1981	Estimate FY 1982	Increase (Decrease)
Exploration Technology	1,138	2,938	900	(2,038)
Reservoir Engineering	2,110	2,320	1,800	(520)
Logging Instrumentation	956	1,699	800	(899)
Log Interpretation	426	340	0	(340)
Capital Equipment	285	50	0	(50)
Total	**4,915**	**7,347**	**3,500**	**(3,847)**

will accurately locate hydrothermal resources in a number of varying geological settings. In order to do this, a series of exploration case studies have been accumulated, particularly under the industry-coupled task. These case studies are used to evaluate the effectiveness of different geological, geochemical, and geophysical techniques in providing pertinent information on the location and extent of the resource. Where case histories were incomplete under the industry-coupled task, additional surveys were funded under exploration technology so that a complete set of survey techniques could be evaluated for their effectiveness in delineating reservoirs confirmed by drilling.

For the first time, two- and three-dimensional models have been developed for use in interpreting data from magnetotelluric and resistivity surveys. Factors such as topographic variations, layering, and other structural features can be introduced into the models, thereby affording a more meaningful interpretation of results.

Reservoir Engineering

The major emphasis to date in reservoir engineering has been on the analysis and simulation modeling of high-temperature reservoirs because of the initial association of geothermal energy with electric power generation. However, as interest increases in the development of low- and moderate-temperature resources for direct heat applications, the capability to model reservoir behavior of these resources will be extended.

Cooperative agreements with countries having geothermal reservoirs with long production histories have permitted development of valid reservoir simulation models. These models are continually refined as additional data become available and as understanding of reservoir behavior improves.

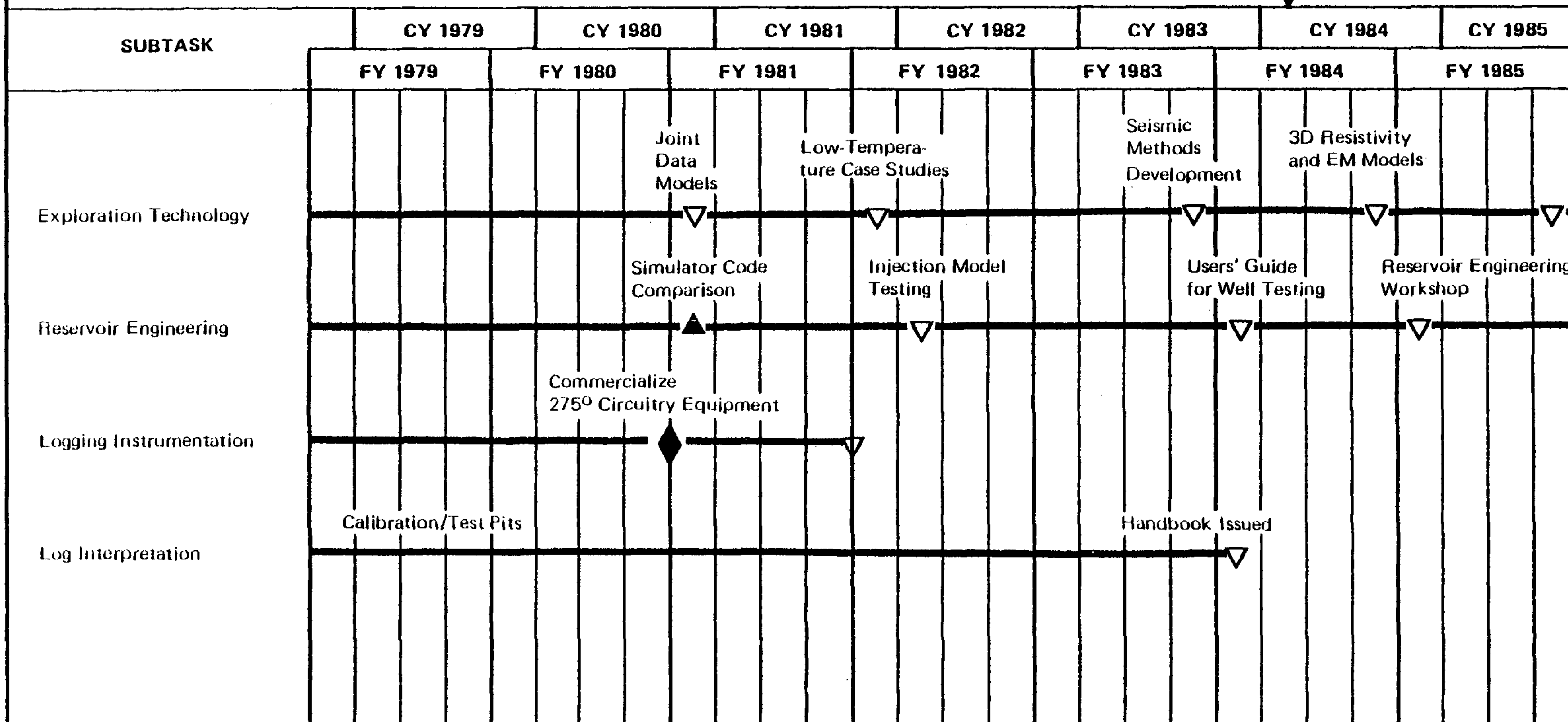
Logging Instrumentation

The well-logging services presently available are often unsuitable for the hostile environments of geothermal wells, and essential data for reservoir engineering are difficult to acquire. Logging instrumentation activities are therefore aimed at upgrading tool capabilities

Exhibit 5.e

ACTIVITY GEOTHERMAL TECHNOLOGY DEVELOPMENT
SUBACTIVITY COMPONENT DEVELOPMENT
TASK GEOSCIENCES TECHNOLOGY

LEGEND
- △ BEGIN MILESTONE
- ▽ END MILESTONE
- ◁ DECISION MILESTONE
- ▲ COMPLETED TASK
- ◆ ORIGINAL MILESTONE



Total Budget Authority (Dollars in Thousands)	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
	8,477	4,630	7,297	3,600			

from the present rating of 180°C to typical geothermal temperatures of up to 275°C.

Development of high-temperature (275°C) components for logging tools is continuing. Prototype tools that use high-temperature circuits have been made commercially available. Sandia Laboratories and Union Oil Co. have successfully tested hand-wired prototype temperature, pressure, and flow tools. Other prototype tools that use commercially made circuits are being evaluated.

Log Interpretation

To improve techniques of log interpretation, DOE is participating in the construction of a calibration/test facility at the Denver Federal Center. Two large, heated tanks containing samples of rock representative of those found in geothermal reservoirs have been completed, with one more in progress. Saw cuts in the rock simulate fractures that control production of geothermal reservoirs. When completed, the facility will be available for use by geothermal developers, logging companies, and others as a standard for calibrating tools. The facility should be completed by January 1981. In addition, two wells, one at East Mesa, and the other at Roosevelt Hot Springs, Utah, are available to the public at no charge. The East Mesa well was used six times and the Roosevelt well, four times.

Environmental Control Technology

Environmental control technology (ECT) issues and priorities were established in the "Status of Environmental Controls for Geothermal Energy Development - April 1980" prepared by the Environmental Control Panel of the Interagency Geothermal Coordinating Council. Although it is generally accepted that the use of geothermal heat causes fewer environmental problems than do other competitive energy sources, research is needed to improve the state-of-the-art of geothermal ECT to comply with federal, state, and local environmental regulations. To accomplish this, DOE and the U.S. Environmental Protection Agency (EPA) are pursuing a research program to control hydrogen sulfide and other air emissions, injection of geothermal fluids as they may affect underground sources of drinking water, solid waste resulting from geothermal operations, induced subsidence, and induced seismicity.

Table 5.g

Funding Levels for Environmental Control Technology Subtasks FY 1980 through FY 1982

Subtask	Budget Authority (Dollars in Thousands)			
	Actual FY 1980	Estimate FY 1981	Estimate FY 1982	Increase (Decrease)
H_2S Technology	247	1,500	200	(1,300)
Capital Equipment	13	0	0	0
Fluid Waste	0	300	200	(100)
Solid Waste	37	200	0	(200)
Subsidence	1,840	300	0	(300)
Induced Seismicity	60	300	100	(200)
Total	**2,197**	**2,600**	**500**	**(2,100)**

H_2S Technology

Hydrogen sulfide (H_2S), ammonia, boron, carbon dioxide, methane, arsenic, radon and mercury vapor have been found associated with geothermal fluids. H_2S, which is found in high concentrations in certain geothermal fluids, has required particular control. Stringent state air quality standards have been established to reduce H_2S odor and protect public health.

DOE and EPA have jointly initiated a project to develop a process that removes H_2S and at the same time produces a usable by-product (sulfur) rather than solid waste. This process will be field tested during FY 1981-1982. Laboratory and field testing of other H_2S removal systems is planned for 1981-1982.

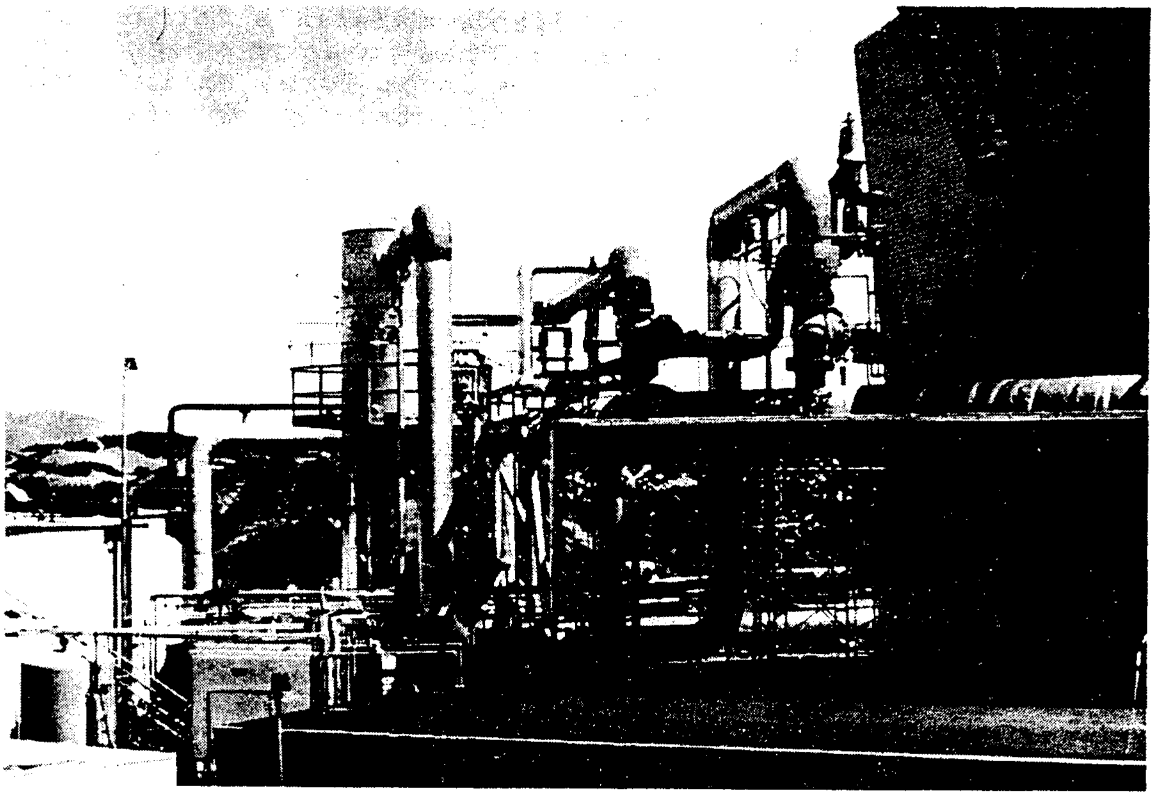
A demonstration of an EIC Corporation prototype process to scrub 100,000 pounds of raw steam per hour, was tested at the Geysers field in California. Supported by DOE, EPA, and Pacific Gas & Electric Co. (PG&E), this process removes H_2S during stream stacking (when the plant is shut down). Following the pilot-scale field test of the process, PG&E contracted with EIC Corporation for a full-scale plant. Installation should be complete by 1984.

DGE is continuing work on theoretical H_2S research and on improving the economics and applicability of existing systems. Also planned for 1981-1983 is a cooperative agreement with industry on H_2S removal systems.

To date, other air emissions have not been identified as causing significant environmental impacts. EPA, however, plans a characterization study to better understand air emission rates from geothermal operations.

Fluid Waste

Both surface and subsurface injection of geothermal fluids, which may contain hazardous substances, could adversely affect the use of surface water and of underground sources of drinking water. Current waste treatment technology is probably adequate to prevent contamination of drinking water, but new technology may be needed to remove hazardous substances from geothermal fluids.



Hydrogen Sulfide Removal System at The
Geysers Geothermal Field

Of particular concern is the lack of a reliable technique to monitor the migration of injected fluids in hydrologic regimes containing ground water fit for drinking. DOE plans a project in conjunction with Lawrence Livermore Laboratory to develop remote sensing instrumentation to track fluid migration from injection wells. The project is scheduled to begin in FY 1981 and run through FY 1983.

Solid Waste

Quantities of solid waste are generated by geothermal operations. Water treatment and air abatement as well as drilling operations contribute to the load. When hazardous materials are found, waste storage, transport and disposal controls are required.

Subsidence

DOE continued its subsidence research, establishing the geothermal subsidence research effort to characterize, measure, predict, and mitigate subsidence. This year DOE completed an assessment of the environmental and economic effects of subsidence and prepared a manual of guidelines for monitoring surface displacements. Projects continued to assess mathematical subsidence models, study the compressibility of reservoir cores, and study the compaction properties of reservoir materials. Case histories of subsidence were prepared for Long Beach, California, and Wairakei, New Zealand. Analytical models were developed for comparison with observed data. Near-future projects will include a detailed case history for Chocolate Bayou, Texas, a subsurface risk assessment, and an assessment of potential indirect measurement techniques.

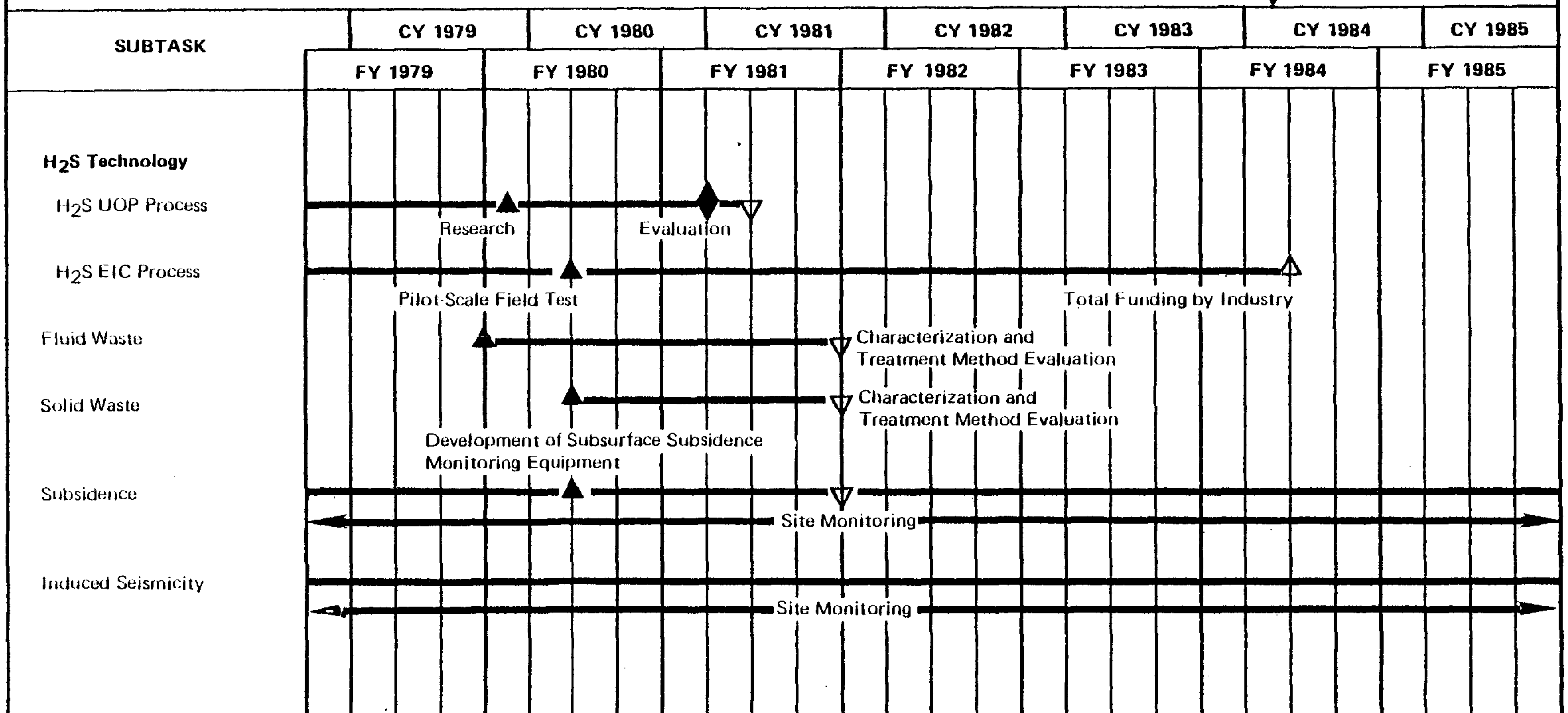
Induced Seismicity

A major effort to understand, predict, and mitigate induced seismic activity from geothermal development is in progress by USGS and DOE. A study to evaluate the effectiveness of current seismic control techniques was begun and was scheduled for completion in FY 1980. Monitoring nets were emplaced in northern Nevada, at Roosevelt Hot Springs, Utah, and at the Geysers field in California to detect and measure induced seismicity.

Exhibit 5.f

ACTIVITY — GEOTHERMAL TECHNOLOGY DEVELOPMENT
SUBACTIVITY — COMPONENT DEVELOPMENT
TASK — ENVIRONMENTAL CONTROL TECHNOLOGY

LEGEND
- △ BEGIN MILESTONE
- ▽ END MILESTONE
- ◁ DECISION MILESTONE
- ▲ COMPLETED TASK
- ◆ ORIGINAL MILESTONE



Total Budget Authority (Dollars in Thousands)	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983	FY 1984	FY 1985
	1,859	4,630	7,297	3,500			

HOT DRY ROCK

The HDR geothermal resource is defined as the heat stored in rocks that contain little or no water. Energy is extracted from HDR 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 reduction in drilling and fracturing technology.

The HDR development subactivity assesses the potential of the 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 5-MWe thermal loop at the Fenton Hill site in New Mexico in 1978. General program objectives are (1) to confirm the potential of the HDR resource, (2) to develop a technology base for HDR energy extraction, and (3) to verify that the environmental and social consequences of HDR development are acceptable.

Technology Development

This task centers on two HDR demonstration sites. At Site 1, Fenton Hill, New Mexico, a 5-MWe loop has been operated successfully, with the first electricity from HDR generated on May 13, 1980. Emphasis at Fenton Hill will now shift from research to engineering development. A second loop (20-50 MWe) is under construction at the site and will serve as the prototype for Site 2. The design of the engineering system for the second loop at Fenton Hill will allow for a possible follow-on commercial electric pilot plant. The project is intended to show that the HDR concept demonstrated at Site 1 can be successfully and economically applied to other sites. The project will simulate, as closely as possible, a commercial venture, and research work at the site will be kept to a minimum. The building of a pilot plant is outside the scope of DGE's program, but an electric cooperative has expressed interest in acquiring the site once tests of the engineering system are completed.

The location of the Site 2 project has not yet been determined. The location will depend on a number of factors, particularly the presence of a shallow hot rock

Table 5.h

Funding Levels for Hot Dry Rock Tasks FY 1980 through FY 1982

Task	Budget Authority (Dollars in Thousands)			
	Actual FY 1980	Estimate FY 1981	Estimate FY 1982	Increase (Decrease)
Technology Development	11,272	12,375	11,975	(400)
Resource Evaluation	2,728	1,125	625	(500)
Capital Equipment	1,000	500	500	0
Total	**15,000**	**14,000**	**13,100**	**(900)**

mass. Other factors will include water and land availability, environmental and institutional constraints, market proximity, and public awareness. Project plans are still tentative, pending site selection and further results of the Fenton Hill projects.

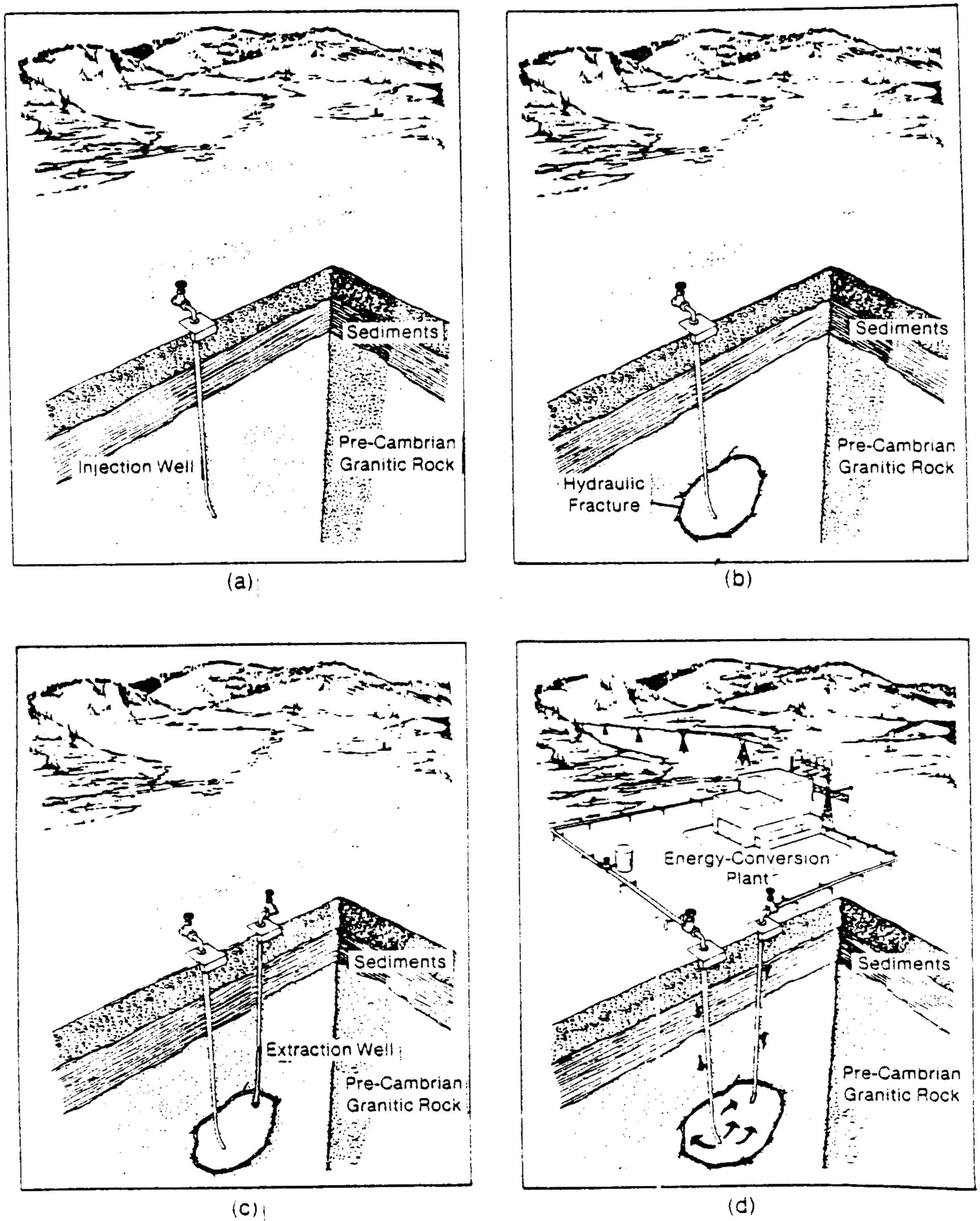
There are a number of quasi-technical and non-technical issues that will affect the suitability of HDR as an alternative energy source. For convenience, they are categorized as institutional issues and include: (1) legal aspects of HDR development, (2) regulatory issues, (3) environmental effects of intensive development, (4) water availability and (5) public awareness. The program will examine the extent to which these issues may impact HDR development.

Environmental studies will be directed at obtaining more definitive information about the effects of commercial-scale HDR development. Much experience from hydrothermal projects is directly applicable to these studies because the effects are similar to those expected from HDR; other environmental aspects of HDR are unique to its application. The investigations will not try to resolve outstanding issues. Rather, environmental monitoring will be done in conjunction with the demonstration projects. This operation experience will clarify the environmental issues and help to place them in perspective for the regulatory authorities.

Studies of laws and regulations at both the federal and state levels will identify potential barriers to HDR development. Where possible, ways to avoid or eliminate barriers will be suggested.

The interested public, including the geothermal industry, financial community, and regulatory agencies will be kept informed of task progress and findings. Information will be disseminated through discussions and presentations, press releases, newsletters, educational materials, brochures, technical reports, and annual conferences. Regular free mailings of publications will provide information about HDR development to decision makers and the general public.

If energy from HDR is not competitively priced, the concept, although technically feasible, will not be commercialized. Commercial feasibility can best be proved by



Hot Dry Rock Site Development

demonstration combined with appropriate economic analyses; both are deemed essential to reaching the activity's goal. Demonstration is inherent to technology development. Economic analysis, on the other hand, involves a synthesis of all critical factors affecting the cost of HDR systems.

Initially, an economic systems study will be conducted, focusing on the modeling of reservoir establishment and management strategies. The overall study will examine drilling and conversion costs, among other topics. Sensitivity analyses will identify cost-sensitive factors, and, through a feedback mechanism, technology improvements that reduce costs will be pursued. The study will include institutional and other factors that influence development costs. As more field data become available, the study will be updated.

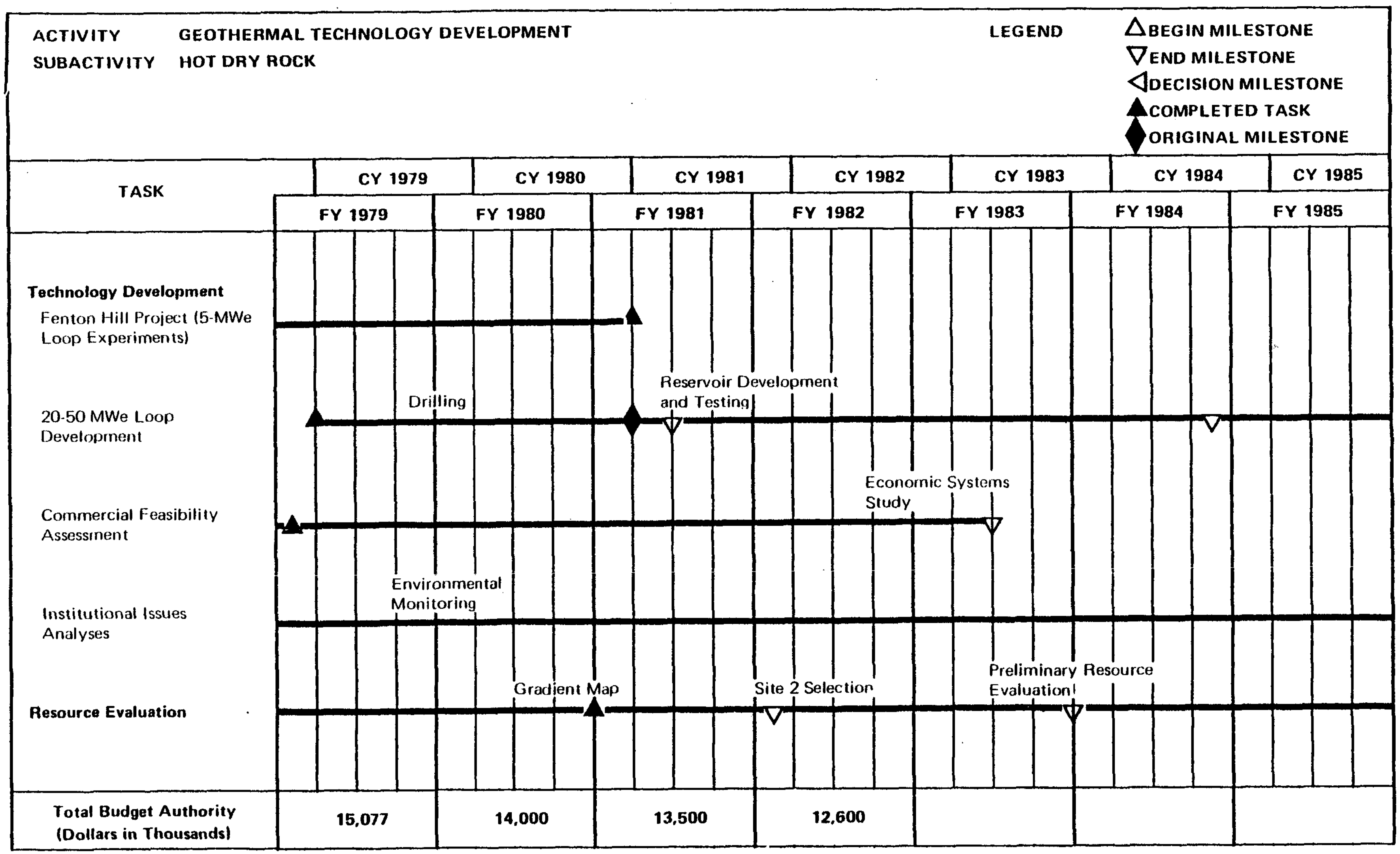
The ultimate question to be answered is: can energy produced through HDR technology compete with that from other energy-production technologies in the private marketplace? The answer will come from a final commercial feasibility analysis that accounts not only for technology costs and benefits, but for the availability of resources, market needs, and regulatory requirements.

Resource Evaluation

DOE is continuing regional and national activities to assess the HDR resource. In FY 1979, DOE cooperated with USGS to determine HDR resource potential; it also 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 geothermal gradient map of the United States has been published by the Los Alamos National Scientific Laboratory.

Over the next several years, the resource evaluation task will consist of two activities: (1) the gathering and analysis of existing data on a national scale, supplemented by acquisition of new, selected data when necessary; and (2) the characterization of candidate HDR sites. The first activity will allow for an assessment of resource potential; the second activity will establish a group of the most promising sites for HDR development.

Exhibit 5.g


ACTIVITY GEOTHERMAL TECHNOLOGY DEVELOPMENT
SUBACTIVITY HOT DRY ROCK
LEGEND
BEGIN MILESTONE
END MILESTONE
DECISION MILESTONE
COMPLETED TASK
ORIGINAL MILESTONE
TASK
CY 1979
CY 1980
CY 1981
CY 1982
CY 1983
CY 1984
CY 1985
FY 1979
FY 1980
FY 1981
FY 1982
FY 1983
FY 1984
FY 1985
Technology Development
Fenton Hill Project (5-MWe Loop Experiments)
20-50 MWe Loop Development
Drilling
Reservoir Development and Testing
Commercial Feasibility Assessment
Economic Systems Study
Institutional Issues Analyses
Environmental Monitoring
Resource Evaluation
Gradient Map
Site 2 Selection
Preliminary Resource Evaluation
Total Budget Authority (Dollars in Thousands)
15,077
14,000
13,500
12,600

6 PROGRAM DIRECTION

The geothermal energy programs described in this report will require federal funding of about $92 million in FY 1982. Several hundred active DOE contracts, involving projects being carried out throughout the United States and abroad, are supported by these funds. In addition, DOE has significant intragovernmental coordination responsibilities for geothermal energy.

DOE is designated by Congress as the lead agency for federal geothermal energy programs, while several other federal agencies also have substantial responsibilities related to geothermal energy. The U.S. 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 commercial geothermal development. Leasing must be coordinated with DOE programs in reservoir definition and technology development in order to meet federal goals for commercial geothermal development.

Management of such a complex program requires an organization that is geographically extensive and employs a wide range of professional skills. DOE's management approach is to concentrate policy, planning, overall budget definition, and program defense activities at its Washington, D.C. headquarters. DOE field organizations (i.e., operations offices, national laboratories, and regional representatives) are responsible for project definiton, day-to-day project management in the field, and coordination with state and local authorities.

HEADQUARTERS ORGANIZATION

DOE vests its interests in geothermal energy in the Division of Geothermal Energy (DGE) under the direction of the Assistant Secretary for Resource Applications.

Exceptions are some basic research conducted by DOE's Office of Energy Research, and environmental research conducted by the Assistant Secretary for Environment.

DGE headquarters staff is organized into five branches. Overall program coordination is provided by the Program Coordination Branch. Technical and scientific considerations are the responsibility of the other four branches: Advanced Energy Systems, Geothermal Industrialization, Geosciences, and Hydrothermal Technology. The structure and interrelationships of this organization are shown below.

The geothermal program staff is responsible for: initiating the geothermal portions of DOE's annual congressional budget request; defending that request and the program within DOE, the administration, and 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.

Intragovernmental coordination is provided through the Interagency Geothermal Coordinating Council (IGCC). IGCC serves a board of directors for federal geothermal programs. This council, chartered by Congress (P.L. 93-410), is chaired by the Assistant Secretary for Resource Applications. About 8 federal agencies are represented on the council at the Assistant Secretary level, and about 25 agencies are represented in working groups, panels, and committees.

The IGCC, which meets collectively 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 they constitute a coherent federal geothermal plan. The council also submits a combined federal geothermal budget request to the President's Office of Management and Budget and recommends appropriate changes in national policy and legislation.

Field Organization

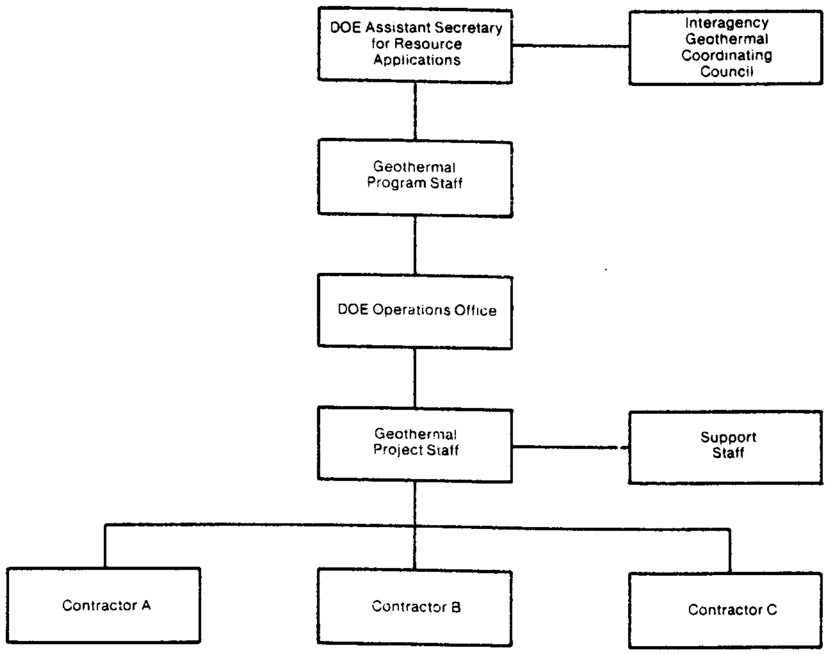
DOE field offices and some DOE national laboratories have been assigned major responsibility for coordination and management of substantial parts of the DOE geothermal program. The Los Alamos National Scientific Laboratory, for example, has been given a lead role in the HDR subactivity. DOE's San Francisco Operations Office conducts the Geothermal Loan Guaranty Program, and the Nevada Operations Office conducts drilling activities under the geopressured resource definition subactivity. In general, the relationship between each of these offices and the headquarters organization is documented in a formal written management agreement.

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:

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

The organizational relationships between headquarters, a typical field office, and project contractors are depicted in the figure below.



Program Management Organization

7 INTERNATIONAL GEOTHERMAL ENERGY ACTIVITIES

Geothermal energy resource potential has been identified in over 20 countries. Existing worldwide installed electric capacity is 2,475 MWe, with planned additional capacity through 1985 of 2,400 MWe. There are 12 countries that make significant direct use of geothermal energy, which is used in space conditioning and water heating, and for agriculture and industrial applications.

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 R&D efforts. Information exchange facilitates expansion of the geothermal data base and helps ensure that related experience gained elsewhere is available to U.S. developers.

In September 1979, the United States and the Federal Republic of Germany signed an International Energy Agency (IEA) implementing agreement providing for participation of German scientists in the Los Alamos National 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 4 years. In addition, a cooperative agreement under the IEA was signed for overseas testing of a U.S.-manufactured wellhead generator unit, the helical screw expander. The test, conducted in Mexico, was completed successfully in 1980. Further tests are planned to take place in Italy in 1981, and later in New Zealand. Under another arrangement with the IEA, the study of manmade geothermal energy systems (MAGES) for exploiting HDR resources has been completed.

The U.S. also has bilateral agreements with Italy and Mexico, and is negotiating agreements with Japan and New Zealand. Activities carried out under these agreements are summarized below:

- Italy and the United States have exchanged information of drilling techniques and materials. Exchange of reservoir data has led to initial selection of wells for application of stimulation techniques. Reservoir assessment activities have included validation of a computer model of the geothermal field at Lardarello, Italy. In addition, the United States has provided environmental monitoring equipment and has cooperated in seismic studies.

- Cooperative investigations between Mexico and the United States on the geophysical and hydrological characteristics of the Cerro Prieto field continued in 1980. The first symposium on the results of these investigations was held in San Diego, California, and bilingual proceedings have been published. The second symposium was held in October, 1979, in Mexicali, Baja, California. Discussions are underway to extend cooperation under the bilateral agreement to other geothermal fields.

- The first meeting of an executive coordinating committee for Japan-U.S. cooperation was held in May 1979. Cooperative projects related to binary conversion systems and the LASL HDR program were discussed. Negotiations have since begun for Japan to join the existing IEA agreement on HDR research by contributing to the HDR project at Fenton Hill, New Mexico.

- A "memorandum of understanding" between the United States and New Zealand is under negotiation. Areas of cooperative study will include drilling and completion, logging instrumentation, chemistry and materials, reservoir stimulation, reservoir engineering, two-phase flow evaluation, and brine disposal.

Future international activities will include the following:

- Observation by Italian scientists of well stimulation activities at the Geysers field, California

- Expansion of activities in brine technology and materials testing by Italy and the United States
- Continued activities in reservoir assessment and engineering by Italy, Mexico and the United States
- Continued exchange of drilling and environmental information between Italy and the United States
- Negotiations between the United States and Japan for Japan to join the IEA HDR implementing agreement.