REGIONAL OPERATIONS RESEARCH PROGRAM
FOR DEVELOPMENT OF GEOTHERMAL ENERGY
IN THE SOUTHWEST UNITED STATES

Project Director:
J. M. Marlin
New Mexico Energy Institute
New Mexico State University

Second Quarterly Report

by

Regional Project Staff
New Mexico Energy Institute
New Mexico State University

January 1978

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This project was conducted under the auspices of the NEW MEXICO ENERGY INSTITUTE at New Mexico State University. The research project was supported by the United States Department of Energy as Contract No. EG-77-S043992, by the Four Corners Regional Commission as Contract No. 672-066-075, and by the New Mexico Energy and Minerals Department as Project No. ERB 76-262.

NMEI 10-2Q

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ABSTRACT

This report describes the work accomplished in the second quarter of the Regional Operations Research Program for Development of Geothermal Energy in the Southwest United States.

The scope of work is as described in New Mexico State University technical proposal entitled, "Regional Operations Research for the Development of Geothermal Energy, Southwest United States," dated April 1971.

The report describes continuation of efforts by the Core and State Teams in data acquisition, electric and non-electric economic studies, and development of computer support functions and operations.

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1. INTRODUCTION

This report describes the work accomplished in the second quarter of the Regional Operations Research Program for Development of Geothermal Energy in the Southwest United States.

The work is being performed by a core team at New Mexico State University/ New Mexico Energy Institute, with subcontracts to state teams from Arizona, Colorado, Nevada, New Mexico, and Utah.

The objectives of the program are:

- 1) To develop realistic but aggressive scenarios with certainty factors for the development of each identified geothermal resource area in Arizona, Colorado, Nevada, New Mexico, and Utah.
- 2) To delineate the public actions, together with their schedules required, for the scenarios to materialize.
- 3) To develop a computer-base data storage and retrieval system of a regional program progress monitor at the level of a preliminary working model which is capable of displaying program approach, but not loaded with all available data.

2. WORK ACCOMPLISHED TO DATE

A. Core Team Economic Modeling

During the second quarter, economic modeling was considered for both electric and non-electric applications of geothermal energy. The effort made in each individual area is described below:

GIRORA - Electric Model

At the end of the second quarter, the simulation model for electricity production was fully operative and sensitivity analysis had begun. A complete description of the Geothermal Internal Rate of Return (GIRORA) - electric model was attached in the first quarterly report. The refinements of the model given earlier are:

- i) The brine temperature decline with time is considered. Empirical relationships are established using the data from Bechtel and Chevron.¹
- ii) Year by year cash flow is considered (revenues and expenses), which is more realistic.

The sensitivity analysis output is shown in Figures 1 and 2. The sensitivity analysis first analyzes an estimated rate of return against increases in downhole temperature. The temperature range was selected to represent that found in excess of 90% of potential electric sites in the five relevant states.

The base case is analyzed for three sizes of power plants, 50Mw, 100Mw, and 150Mw (Figure 1). An optimal power level curve is found which traces the 50Mw curve at the lower temperature range and the 100Mw curve at higher temperatures. Other parameters of the base case are listed on a separate sheet.

Utilizing the optimal-power curve for further sensitivity analysis, the impact of changes in selected variables on the Internal Rate of Return (I.R.R.) is illustrated (Figure 2). The important point to recognize is the usefulness of the model as a tool to test the sensitivity of geothermal electric power as a business venture to changes in policy.

Additionally, the GIRORA simulation package lets us take into consideration, simultaneously, a variety of factors which may differ from site to site and enables us to rank them ordinally as business ventures. This is an important first step in preparing our aggregated, time phased scenarios effort for the third quarter.

¹Advanced Design and Economic Considerations for Commercial Geothermal Power Plants at Heber and Niland, California. Final Report, Prepared for the Energy Research and Development Administration Contract E (04-3)-1124, Prepared by Bechtel Corporation, San Francisco, California: June 1977.

GI R O R A
S E N S I T I V I T Y A N A L Y S I S

Figure 1

GIRORA SENSITIVITY ANALYSIS

Figure 2

GIRORA - Non-Electric Model

Much work effort has been allocated to the low temperature potential of geothermal resources in the Southwest during the second quarter. Much progress has been made in the development of an analytical framework within which the commercial feasibility of low temperature applications of hydrothermal geothermal resources may be considered.

The entire work effort for the second and third quarter pertaining to low temperature uses is summarized as a three-step work program (Figure 3). At each of these steps, the extent of current progress is indicated as well as the work effort to be undertaken.

The first step consists of an iterative technological partitionment stage. This consists of a partitioning process at which all identified low temperature sites are to be grouped into two subgroups. The first subgrouping will consist of sites which are considered currently usable given the existing state of production technology in the industry. Those sites which fall in the second subgroup will be resources which, for one reason or another, are not now usable given the present state of "know-how". As production techniques advance, however, these resources may become of substantive importance.

There are three criteria which shall be employed to partition the resource. The first is the temperature of the resource. Thus, for example, as sites have temperatures above or below 50°C, they shall be considered appropriate or inappropriate for current consideration. The second criterion is distance from the site to the nearest market. Thus, for example, if 75 miles is considered the maximum distance over which to transport a low temperature resource, sites will be judged appropriate or inappropriate, based upon the spatial proximity of potential market. The final criterion for partitioning low temperature resources is the size of the potential market. Some minimum feasible size of population center will be designated; if within the necessary distance, there is or is not a market of acceptable size, the sites will be considered usable or not currently usable.

The partitioning process described above has been designed to group geothermal sites on the basis of objective (rather than subjective) benchmarks. Insofar as these criteria (temperature, distance and demand) accurately differentiate between the currently feasible and infeasible, then some rough measure of the technological supply potential of low temperature resources is known. In addition, the impacts of future technological innovations may be easily considered. The initial partitioning process will be reiterated for various temperatures, distances and demand measures. Each successive iteration will thus provide a new estimate of technological supply potential given a different state of production "know-how".

CORE TEAM WORK PLAN

ANALYSIS OF DEVELOPMENTAL PROSPECTS OF LOW TEMPERATURE GEOTHERMAL RESOURCES

STEP I - ITERATIVE TECHNOLOGICAL PARTITIONMENT (ITP)

- CRITERIA
1. TEMPERATURE ($\geq 65^{\circ}$ C)
 2. DISTANCE (≤ 50 MILES)
 3. DEMAND (≥ 650 PERSONS)

STEP II - COMMERCIAL FEASIBILITY ANALYSIS

GIRORA - NON ELECTRIC

STEP III - DEVELOPMENT OF SITE SCENARIOS - TIME-PHASED CHARACTERIZATIONS OF PROSPECTIVE DEVELOPMENT

AGGREGATE BY STATE AND REGION

Figure 3

The iterative technological partitioning stage is currently underway; site specific data are being incorporated as they are received from state teams. Thus, Stage I is an ongoing effort that will continue as long as site data are received.

In each of the sites deemed technologically usable at the present time, a commercial feasibility analysis will be undertaken. For this second stage of effort, an internal rate of return model for space heating application of geothermal resources has been developed. This model is labeled GIRORA - NON-ELECTRIC. As with GIRORA - ELECTRIC, this simulation model generates a measure of expected economic profitability for each site. A copy of the model is given in Appendix A. After each technologically feasible site has been considered by GIRORA - NON ELECTRIC model, an ordinal ranking of sites on the basis of economic desirability, i.e., internal rate of return, will be developed. Insofar as low temperature geothermal resources are concerned, this ordinal ranking will provide a best guess listing of which sites (Stage I) will be developed and in which order (Stage II) in the southwestern states.

As the initial version of GIRORA - NON ELECTRIC has been completed, the model is being tested and debugged at the present time. Specific improvements will undoubtedly be made from time to time.

The final stage is the development of site-specific scenarios. These are time phased characterizations of prospective development on a site by site basis. All of the legal demands, institutional requirements, social and political obstacles, etc., that must be addressed to bring each site on line will be identified. For each of these factors, an estimate of the time necessary for successful compliance will be estimated, and taken together, a temporal mapping of the total time span necessary to bring each site on line will be proposed. An example of such a scenario is presented in Figure 4 (adapted from some earlier work by the MITRE Corporation). When completed for all sites, the scenarios will provide time phased composite schema of geothermal energy development in the Southwest.

Most of the effort required in Stage III will be provided in the third quarter.

SITE DEVELOPMENT SCHEDULE (FOR FIRST 50 MWE PLANT)

OPERATING ENTITIES	ACTIVITY	RECIPIENTS	1977	1978	1979	1980	1981	1982	1983
STATE, OWNER	ISSUE PERMITS -- PROSPECTING, EXPLORATION, LAND USE, DRILLING	DEVELOPER	}	ASSUMED COMPLETED					
OWNER, STATE	LEASE LAND	DEVELOPER							
	PROCESS ENVIRONMENTAL REPORTS	STATE DEQ							
DEVELOPER & UTILITY	FEASIBILITY STUDY								
UTILITY	PREPARE ENVIRONMENTAL DATA STATEMENT	STATE, COUNTY							
DOE-DGE	FEDERAL RD & D PROGRAMS								
STATE	CERTIFY PLANT & SITE, ISSUE PERMITS	PRODUCER & UTILITY							
UTILITY	PLANT CONSTRUCTION								
UTILITY	INITIAL POWER LINE (16KM)								

Figure 4

B. Progress in Identifying Institutional Barriers
and Opportunities to Geothermal Resource Development

The information contained in the First Quarterly Reports submitted by each state team in other documents was used to generate flow diagrams which describe the issues and procedures relevant to the leasing of land and the subsequent development of geothermal resources. Examination of these flow diagrams permitted the Core Team to identify some general and some very specific questions which need to be answered, or at least recognized by the respective state teams. We will prepare and send to each state team a copy of these flow diagrams and a list of the issues and questions we have identified. The state teams will be receiving their copies of these materials in about thirty days.

Our intention is to launch an iterative process in which the Core Team and the respective state teams will continually interact until--by the end of the third quarter--the legal, institutional and political barriers to geothermal development are described in a manner that is as accurate as possible. The ultimate outgrowth of these procedures--in addition to firm knowledge as to what these barriers are--will be twofold: (A) a set of recommendations for minimizing the adverse effects of these barriers and (B) a model (probably quite qualitative at this stage of our investigation) which will permit one to examine the consequences of changes in the institutional framework of the state and federal systems.

For example, Mary Beth Ball, one of the graduate students working on the project, is exploring the possibility of using response time data (e.g., the times required to obtain a lease or a drilling permit) as a basis for determining the costs incurred as a result of institutional barriers. If she is successful, we will be able to incorporate at least one measure of the institutional aspects of this project into the econometric models.

As an example of the approach we are taking and the types of results we are obtaining, a few illustrations derived from our examination of the information available for the State of New Mexico are enclosed herewith. These illustrations are concerned with the activities of a developer and the appropriate state agents from the point at which a potential developer decides that he wishes to lease land for the purpose of geothermal exploration and development. Note, we have not at this time examined any activities which might precede the leasing procedures--activities like establishing financial support, prelease exploration, etc.

1) Three major types of land: Federal, State and Private..

- i) Distinction between formal and unofficial routes for obtaining a lease on Indian land. Formally, the lease is between the **federal government** and the developer, with the tribe consenting to the lease and receiving royalty benefits. In actual practice, lease is

obtained by direct negotiation between the developer and the applicable Indian tribe. We assume there are similar distinctions between formal and unofficial procedures with regard to forest service, reclamation, and other types of land.

- ii) More information is needed concerning the issue of mineral rights owned by the state while surface rights belong to a second party.
- iii) More information is needed concerning the role of the Commissioner of Public Lands in leasing public lands over which he has no direct control.
- iv) The State of New Mexico has no statutes or regulations regarding the leasing of private land for geothermal development. Is this a barrier or an opportunity?

NOTE: The Commissioner of Public Lands (CPL) has broad authority over issues relevant to geothermal development. This is an elective office. This is illustrated in Figure 5.

2) The determination of KGRF (Known Geothermal Resource Field) status is made by CPL.

v & vi) Issues concerning the formal and the informal criteria used by the CPL to determine whether to accept or reject a lease application. Also the issue of what one does if an "unfavorable" decision is made. That is, is there an avenue for appealing or protesting a decision of the CPL?

NOTE: Since March 26, 1974, by CPL Order No. 1-1974, all applications for geothermal leases are rejected and leases will only be obtainable through competitive bidding at public auction. This is illustrated in Figure 6.

3) Procedures for conducting a public auction. Two issues to be resolved:

- vii) Very little is known concerning the distinction between sealed and oral bidding, the basis for the distinction, etc.
- viii) Related to Issues v and vii. What are the criteria used for rejecting all bids and is there a recognized avenue for appealing an unfavorable decision?

NOTE: This is one of the areas within which (maximum) response time data are available. The CPL must post information relevant to the public sale at least ten days prior to the sale. The sale itself must occur on the third Thursday of the month etc. This is illustrated in Figure 7.

LEASING PROCEDURES — NEW MEXICO

Figure 5

LEASING PROCEDURES — NEW MEXICO

Figure 6

LEASING PROCEDURES — NEW MEXICO

Figure 7

- 4) Agencies which have jurisdiction over geothermal development. Note, an executive reorganization of state agencies is scheduled to occur on July 1, 1978. The information presented is based on the current organization of state agencies and then, details are given only for the Office of the State Engineer.

A permit for water appropriation is required if water will be appropriated for use in geothermal development or if drilling will lead to the withdrawal of water (gas or liquid) from declared underground basins. The State Engineer issues license to well-driller and regulates the construction, repair, and plugging of wells.

Central Issue, ix: What happens when a protest is received by the State Engineer? Apparently anyone may register a protest, but then the applicant may reply and a public hearing may be held.???

NOTE: In New Mexico neither the Environmental Improvement Board nor the Water Quality Control Commission have specifically addressed the issue of geothermal development. Similar agencies in Colorado have, and have prepared guidelines for handling the issue. This is illustrated in Figure 8.

REGULATORY AGENCIES - NEW MEXICO

Figure 8

C. SECOND QUARTERLY REGIONAL ADVISORY GROUP MEETING

The Second Quarterly Regional Advisory Group meeting was held in Phoenix on December 7.

Progress to date by the Core and State teams was presented.

Discussion items included:

- lease time for development;
- geothermal/clean air;
- water availabilities;
- comparison with alternate fuels;
- base case data.

The most detailed discussion centered on rate of return modeling for electric application. The advisors suggested that the utilities would perceive a two-stage process where the hot water & steam delivery is a high risk venture, and the electric generation is a controlled profit enterprise. The Core Team researchers will modify the model to incorporate their ideas. The MITRE model which considers busbar cost will be used as a supplement and as a check on the Core model.

See Appendix B for the list of attendees.

D. RPPM EFFORT

An APL-hosted data base system has been installed at the New Mexico State University Computer Center. A work space has been assigned, from which all Data Base Administrator activities are being conducted. The data base system supports design in Relational, Hierarchical, and Network structures. Consideration is being given to the Relational Data Model, as it provides an efficiency in design, update and maintenance not found in the Hierarchical and Network Data Models.

The Relational Data Model is based on mathematical theory of relations. A Relational Data Base is composed of a number of user-defined relations, each of which may be viewed as a file. These relations are manipulated according to relational theory to retrieve the desired data.

Data compilation efforts have been concentrated in two areas: those data regarding Geothermal Resource Areas needed to support the Geothermal Internal Rate of Return Algorithm (GIRORA), and demographic data required for market assessment. Resource Area data are being compiled from collection forms submitted by the state teams. The demographic data which have been collected are organized by city and include the following data for each: city name, county, state, population and geographic coordinates.

The population data were gathered from the U.S. Bureau of the Census Report for 1970. Each incorporated place with a population of at least 500, and each unincorporated place with a population of at least 1,000 has been included for the five states in the southwest region (475 places). The same data have been included for an area extending 50 miles from the border of the southwest region into each neighboring state (an additional 300 places). This coverage of neighboring states will be expanded as needed.

The Demographic Analysis Program (DAP) is a conversational APL program which selectively retrieves and processes demographic data according to user-supplied criteria. Presently, the program is being used to determine the approximate population within a designated radius surrounding each geothermal resource area. The program uses as input the geographic coordinates of these resource areas, a distance representing the radius of each area's potential market for non-electric applications, and the file of demographic data described above. The program produces a list of those cities within the potential market area, the straight line distance from the resource area to each city, and the area population. (See Figure 9.)

ENTER RADIOS

0:

50

PROJECT ID NO

SITE NAME

VALLES CALDERA

LOCATION

35 53 106 32

AREA POPULATION

66928

CITY	POPULATION	DISTANCE
BERNALILLO	2016	41
ESPAÑOLA	4528	27
JEMEZ PUEBLO	1197	22
LOS ALAMOS	11310	13
SAN FELIPE PUEBLO	1187	32
SANTA FE	41167	36
SANTO DOMINGO PUEBLO	1662	21
WHITE ROCK	3861	17

PROJECT ID NO

SITE NAME

LIGHTNING DOCK

LOCATION

32 08 108 50

AREA POPULATION

3429

CITY	POPULATION	DISTANCE
LORDSBURG	3429	18

PROJECT ID NO

SITE NAME

LWR SAN FRANCISCO HS

LOCATION

33 15 108 53

AREA POPULATION

7751

CITY	POPULATION	DISTANCE
SILVER CITY	7751	49

Figure 9

E. STATE TEAM REPORTS

See State reports Appendices C, D, E, F and G.

The updated status of geothermal development is extracted here:

Colorado

Leasing, Drilling Status

Revised lists of active geothermal leases in Colorado indicated by comparison with the previous list, contained in the First Quarterly Report, about 31,487 acres of **state** leases and 8000 acres of **federal** leases have been dropped since August, 1977.

Nevada

1) Leasing

Approximately 86 percent of the lands in Nevada are administered by the federal government, while state lands are a negligible amount. Currently there are approximately 646,613 acres of federal land under geothermal lease, with a large, but presently unknown amount of private land leased.

The most significant development to date has been centered in the northern half of the state in six areas, namely:

- a. Desert Peak, Churchill County, where Phillips has two very promising deep tests, one of which is currently on a long-term flow test.
- b. Brady's Hot Spring, Churchill County, where Magma Power Company has drilled a number of deep exploratory holes which appear to be commercial. Other companies hold leases in this area as well.
- c. Soda Lake, Churchill County, is the site of the first unit authorized for geothermal development in Nevada. Here Chevron, Union, and Phillips have a multiple drilling program planned in this most favorable portion of the Carson Sink.
- d. Steamboat Springs, in Washoe County, is largely fee lands held by a number of companies and individuals, with the more promising federal acreage held and being actively explored by Phillips and Gulf.

- e. Leach Hot Springs, Pershing County, was one of three very promising hot spring areas in adjacent valleys which were the object of intensive geological, geochemical, geophysical, and drilling exploration research by Lawrence Berkeley Laboratory, under contract to ERDA. Results of two years of investigation and study narrowed over 80,000 prospective acres to approximately 7,000 acres--essentially all at Leach. There has been no deep exploratory drilling.
- f. Beowawe Geysers, Eureka County, is the site of a very promising geothermal resource tested by numerous deep exploratory tests by Magma Power, Chevron and others over the past two decades. Each of these prospective sites is in part represented by areas designated by the Conservation Division of USGS, as KGRAs. A tabulation of the thirty KGRAs in Nevada, and their size in acres, is shown in the KGRA table (Exhibit O).

Lease sales have been held on twenty-two of the thirty KGRAs. A brief summary of the sale dates and the resulting range of bids, in dollars per acre are included in KGRA sales data (Exhibit P).

2) Exploration

The Bureau of Land Management has received Notices Intent to do exploration in the Elko, Winnemucca, Carson City, Ely, Las Vegas, and Battle Mountain Districts. A total of 166 Notices have been filed. Companies on record are: Chevron Oil, Union Oil, Phillips Petroleum, Southern Union Production, Dow Chemical, Al-Aquitaine, Sun Oil, Hunt Oil, Earth Power, United Geophysical, Ensco, Republic Geothermal, Hydro-Search, Electrodyne Survey Service, Geotronics, Westinghouse, Geonomics, Geothermal Services, Photo Gravity, Amax Exploration, Anadarko, and Lanton Survey Company. Extensive federal government and academic exploration work has been undertaken as well.

The exploratory surveys undertaken include: resistivity, magnetotelluric, electromagnetic-gravity, and other types or variations of geophysical surveys. Numerous single and multiple hole temperature gradient surveys have been undertaken as well. The surveys and field studies encompass a large portion of northern and western Nevada--perhaps over 75 different valleys in all.

3) Drilling Activity and Production

Although several thousands of temperature gradient holes have been drilled in Nevada within the past few years, there has been no deep exploratory well drilled on federal land.

The temperature gradient holes have been drilled by Chevron Oil, Union Oil, Phillips Petroleum, U.S.G.S., Colorado School of Mines, Sun Oil, Southern Union Production, Earth Power, Republic Geothermal, Dow Chemical, Al-Aquitaine, and Amax.

Over sixty exploratory tests for geothermal resources have been drilled to date. Since leasing on federal acreage began in 1974, seventeen wells have been drilled by Union Oil, Phillips Petroleum, Magma Energy, Chevron-Phillips, Magma Power, Chevron-American Thermal Resources, and Chevron U.S.A. The drilling took place in the Brady Hot Springs, Desert Peak, Soda Lakes-Upsal Hogback, and Stillwater areas of Churchill County; the Hot Springs (Tipton) Ranch area of Humboldt County; Beowawe Geysers area of Lander and Eureka Counties, the Hot Springs area of Eureka County, the Hazen area of Lyon County, and the San Emidio Desert area of Washoe County.

New Mexico

1) Leasing and Drilling Status

The Bureau of Land Management in New Mexico opened sealed bids on September 20 for geothermal leasing of twelve units of land totaling 17,967.86 acres.

The land located within the Radium Springs, San Ysidro and Baca Location No. 1 of the Known Geothermal Resources areas in Doña Ana, Sandoval and Rio Arriba Counties, New Mexico, brought a total of \$233,618.45 for eight of the leasing units. No bids were received on four of the units offered.

The highest bid per acre was \$37.51 for Units 10 and 11. Successful bidder on those units was Aminoil USA, Inc. of Santa Rosa, California. Unit 10 has 1,168.50 acres and Unit 11 has 1,719.60 acres. Aminoil was also the successful bidder on Unit 4, 1,235.45 acres at \$8.29 per acre and on Unit 7, 2,177.14 acres at \$18.53 per acre.

Chevron USA, Inc. of Denver, Colorado had successful bids on two units, Number 1, 1,003.41 acres and Unit 3, 224.19 acres with a bid of \$30.50 per acre for each unit.

Unit 2, 1,158.90 acres was awarded to Texaco, Inc., of Midland, Texas for their bid of \$6.30 per acre. Amax Exploration, Inc. of Denver, Colorado was the successful bidder for Unit 12, 1,993.26 acres with a bid of \$5.31 per acre.

The second BLM lease sale was held on November 29 and this covered the Socorro Peak and Lightning Dock Known Geothermal Resource Areas. A total of 16,978 acres were leased at Socorro Peak with the most successful bidder being Aminoil U.S.A., Inc. Sunoco Energy Development Company and Hoover H. Wright picked up the remaining parcels. The only unit leased for Lightning Dock was picked up by Amax Exploration, Inc. for 1,840 acres.

The active drilling is being conducted as of this date; however, the following is a rundown of the current status of exploration by area:

Lightning Dock Area (Animas)

Amax - has been active in the area since 1974, when it acquired the right to lease. Their preliminary exploration has been completed; area looks promising, but before proceeding certain lease work must be completed. (See first part of report.)

Phillips - has a high risk prospect that is being shelved for the time being.

Aminoil, USA - has done temperature gradient surveys, but has not drilled. Trying to decide where to locate - which side of fault, etc. No money allocated for New Mexico next year.

Chevron - has moved out of their area south of Lordsburg, after drilling a geophysical anomaly that was found to be cold.

Radium Springs

Chevron - has done initial exploration by drilling some holes to 500 feet. Looks encouraging but not in a good land position.

Hunt - has explored but is now waiting for BLM to release leases pending results of an environmental study.

Kilbourne Hole

Phillips - has drilled 5 or 6 exploratory holes, taken temperature gradients which have been disappointing. Have about 3,500 acres in area.

Hunt - area looks "interesting". Contractor exploration data will be in before Christmas. Will send us copies of well logs. About 40 holes drilled in an 8-township area.

Anadasko - holding about 18,000 acres in the area, has done some geophysical work (gravity), is preparing to drill about 30-500 foot holes and 4-2,000 foot holes. They are considering a test hole in the future.

2) Update of Reservoir Information and Potential

A "hot spot" known as the Las Alturas Anomaly lies close enough to the New Mexico State University campus to have triggered serious consideration about using geothermal energy to heat some university buildings on an experimental basis. Surface temperature at this hot spot is 45°C and the geochemistry indicates the subsurface heat potential of 200°C.

San Diego Mountains have been studied for heatflow measurements and geochemistry temperature. Indications are that a small low temperature reservoir may exist there.

3) Related Activities

This project has stimulated much interest and planning in many sectors of the state. Some state agencies such as the Energy Resources Board have initiated effort to create legal institutional and economic inducements in state energy policies and plans for geothermal development. Some consideration has been made on a state-level geothermal depletion allowance. The number of state geothermal R & D programs have increased noticeably during the past six months.

In Valles Caldera development, Union Oil Company and Public Service Company have arranged for the cooperative development of the identified resource and submitted a joint proposal to the Department of Energy for funding consideration.

Los Alamos Scientific Laboratories have a number of R & D projects underway in addition to the hot-dry rock program.

Contact has been made with various Indian tribes, and the Santa Ana Indian tribe has indicated that there is a good possibility that geothermal resources are present on their land and are interested in developing a geothermal steam power plant.

Utah

1) Leasing

Leasing activity for state and federal land is summarized in the attached section. A total of 78 entities have filed for geothermal leases on nearly 657,000 acres of state and federal lands. Approximately 12% (about 75,000 acres) of these lands are KGRA lands as defined by competitive bidding for federal lands. This figure may be modified according to different definitions of KGRA lands.

2) Drilling

As of November 1, 1977, applications for about 223 geothermal wells had been filed with the State Engineer's Office. Most of these (about 162) were temperature gradient wells. In some cases it is not clear whether the wells have been drilled yet. Also, some wells have been drilled without approval of the Division. For these reasons and others, these figures are only preliminary results.

Three exploratory wells are being drilled at this time. Republic Geothermal is drilling in the Thermo area, Thermal Power is drilling in the Roosevelt area, and Union Oil is drilling the Cove Fort-Sulphurdale area.

Geothermal gradient wells are planned for the Monroe area and the Crystal Hot Springs area in the southern part of Salt Lake Valley, as well as in the Roosevelt, Cove Fort-Sulphurdale, and Thermo areas.

3) Electric Development

The areas where electrical development appears to be most likely are the Roosevelt Hot Springs area, the Cove Fort-Sulphurdale area, and the Thermo area. Extensive exploration has been conducted in all these areas, and they will probably be developed in that order. Other areas are not in the stages of preliminary investigation.

4) Non-Electric Development

The City of Monroe has submitted a proposal to the U.S. Department of Energy to take part in a cost-sharing program to utilize geothermal resources (at Monroe Hot Springs) for space heating and industrial purposes. Development would include heating for greenhouses, the South Sevier School District High School, and houses and buildings in the community.

The following is extracted from the Colorado Preliminary Scenario Report by Barbara A. Coe and Richard H. Pearl for the Phoenix Quarterly Meeting.

INTRODUCTION

The purpose of this report is to present some identification of the development of geothermal resources that could occur in Colorado, based upon the resource potential. Scenarios have been prepared for geothermal resource areas in Colorado, describing the steps and the minimum time that would be required for utilization of the resources, were development to begin immediately. U.S. Geological Survey Circular 726, Assessment of Geothermal Resources of the United States, lists 14 geothermal resource areas in Colorado. Estimates of heat content shown in Circular 726 total about 11.5 quads or 3 billion megawatts.

The 14 areas listed below, and the estimates of the resource potential made by the U.S. Geological Survey have been used for this assessment. Until such time as much more detailed information has been accumulated through either geological field exploration or test drilling, any assessment of geothermal resource potential or conjectures about future development should be taken lightly.

Routt Hot Springs	Cottonwood Springs	Cebolla Hot Springs
Steamboat Springs	Mt. Princeton Springs	Orvis Hot Springs
Idaho Springs	Poncha Hot Springs	Wagon Wheel Gap
Glenwood Springs	Mineral Hot Springs	Pagosa Hot Springs
Avalanche Springs	Waunita Hot Springs	

The Colorado Geological Survey has completed an inventory of all geothermal resources in Colorado (Barrett and Pearl, in prep.). This publication lists 56 geothermal resource areas, so the total available energy could be enormous, indeed. As part of the above inventory, various geothermometer analyses were done for each area, resulting in a final "most probable" estimated subsurface temperature range. As the "Resource Characteristics" sections of the scenarios indicate, most of the areas seem to be in a temperature range more suitable for space heating than for power generation. Since the feasibility is, however, based upon existing economic and technological conditions, these resources could become much more valuable in the future for power generation. For instance economic variations which would allow for either the use of lower temperature resources or drilling of deeper wells than currently considered economically feasible could change the picture considerably.

It is even more important to stress that very little exploration for geothermal resources has as yet been done in Colorado. Although indications are that Colorado's geothermal temperatures are lower than those of other states of the southwest region, it has been conjectured that topographic peculiarities such as high elevations may distort the geochemical analyses. Therefore, it is unwise to put limits on the resources. But the surface indicators have kept Colorado a lower priority for exploration than other areas, so a vicious cycle effect occurs.

It cannot be overemphasized that the development scenarios are based upon the information available now. Further, they assume that results of exploration tests will provide satisfactory results, and that all parts of the system, from leasing to obtaining funds and equipment, will operate smoothly. Most significantly, they assume that motivation for development will be intense. Should any of these conditions not be met, events will undoubtedly differ greatly from the scenarios.

METHODOLOGY

Data Collection

To provide the basis for the scenarios, information was gathered from several sources. Colorado Geolo. Survey Bull. 39 (Barrett and Pearl, in preparation) provides information about the locations, temperatures, total dissolved solids and geology of the geothermal resource areas in Colorado. Leasing status on public lands was investigated in records of various federal and state agencies. The land ownership data were obtained from Bureau of Land Management maps. Reservoir dimensions, where indicated, were estimated by Colorado Geological Survey staff, based upon available geological and geophysical information. Footnote notations are used repetitively rather than consecutively to show where various sources of information were obtained.

For those areas where it is anticipated that the resource will be used to generate electricity, the estimated energy potential shown was based upon industry estimates, expressed in megawatts (Mw). For those areas where the resource will most likely be used for non-electrical purposes, the estimates of energy content in Circular 726 were used. To determine how much of this energy could be utilized effectively, the total calculated calories were multiplied by .06 to suggest the amount of beneficial heat available (.25 for recoverable heat then times .24 for efficiency of utilization), as described in U.S.G.S. Circular 726. Calories were then converted to quads, (1 Quad = 1×10^{15} Btu's.)

The energy potential may then readily be compared with the mean Colorado household natural gas consumption to derive estimates of the number of households that could be heated with the geothermal resource. As reported by the Colorado Energy Conservation Office, the average Colorado household uses about 180,000 cubic feet of natural gas per year. The Btu content per cubic foot of natural gas was estimated to be about 850 Btu's. Therefore the "average" household will use a total of 153×10^6 Btu's of heat per year. The assumption was made, for the purpose of this assessment, that the resource was not renewable and would be depleted in equal increments over a 30 year period following installation of the system.

Information of the "Development Status and Activity" sections was derived from field investigations and from meetings with government and industry representatives and citizens. For the sections entitled "Severe Development Problems," data were obtained from the developers themselves, from agency officials, or inferred from descriptions of the conditions of the area.

Scenario Development

For development scenarios where there are active leases on public lands, the lessees provided information regarding possible development schedules and resource potential. For two areas, Pagosa Springs and Glenwood Springs, citizen advisory committees provided information regarding community activities, visions and goals for geothermal development. In the remaining areas, scenarios were developed from site characteristics such as land ownership and population distribution. As indicated, only the 14 areas listed in U.S. Geological Survey Circular 726 were developed in scenario form for this report.

Future Scenario Development

Two related projects being done by the Colorado Geological Survey should provide within the next few months more reliable data on the geothermal resource base in Colorado. One of these projects is an extensive project to assess the geothermal resources in Pagosa Springs and Glenwood Springs. This is a Department of Energy funded study, scheduled for completion in 1979. The other project is a more cursory assessment of the potential of the other resource areas in the state. While this assessment will employ some of the methods used by the U.S. Geological Survey in Circular 726, the estimated reservoir dimensions will be made by Colorado Geological Survey staff geologists with a more intimate knowledge of the geology of the areas. This assessment will include all 56 of the resource areas. As such, it is a refinement and expansion of Circular 726. When that information is available, these scenarios will be revised and scenarios prepared for the remaining resource areas.

SCENARIOS

Scenarios are organized into two groups. Those which describe power generation constitute the first group and those showing space heating potential are the second group. A third grouping consists of "Resource Characteristics" sheets only, for the remaining 42 areas.

As the individual scenarios indicate, very little development of the geothermal resources has occurred, relative to their potential. This is largely explained by the previous lack of demand for the resources. While oil and gas supplies were readily available and cheap, partly because of government incentives to encourage exploration and development by private industry, geothermal resources were neglected. Were the same kinds of incentives to be provided for geothermal development, more activity would undoubtedly occur.

A second condition which has slowed exploration and development of geothermal resources in Colorado to a snail's pace is the length of time that has elapsed since applications were made for federal leases. Court determination of the ownership of geothermal resources has delayed some lease applications; environmental concerns have delayed others.

A third major constraint to geothermal development is mainly applicable to low temperature uses. This constraint is the lack of an infrastructure - a service delivery system - to deliver the resource to the potential users in a cost-effective manner. So far, no profit-oriented developer in Colorado has attempted to develop a geothermal space heating district. Nor have any local governments in the state yet established district heating using geothermal resources.

When the interest in and awareness of these resources has grown, and other resources seem too costly or environmentally damaging, a geothermal development infrastructure might develop "naturally" in response to market demand. But without government assistance, whether in the form of federal leases, tax shelters or direct subsidies, whether or not geothermal resources will be developed is uncertain. Their development would undoubtedly be enhanced by government incentives or grants, either to private industry or to public agencies.

POWER GENERATION

30.0 Chalk Creek - Mt. Princeton #21A

30.2 Resource Characteristics

Surface Fluid Temperature: 44-56⁰ C,

Subsurface Fluid Temperature: 205-236⁰C, estimated

Total Dissolved Solids: 250 mg/l

Estimated Energy Potential: 100 Mw_e

Type of Overlying Rock: Valley fill over quartz monzonite

Estimated Depth From Top of Reservoir:

Estimated Size of Reservoir:

Site Location: T. 15 S., R. 78 W., Sec. 19

Latitude: 38⁰ 43' 58"

Longitude: 106⁰ 09' 40"

County: Chaffee

Land Ownership:

Land Use:

Description of KGRA: None

Leasing Status: Federal acres leased: 1,286

State acres leased: 7,617.

30.3 Development Status and Activity

In October, 1977, Amax Petroleum drilled a 2,000 foot thermal gradient hole in the area. They will probably drill 2 more such holes in the next few months.

30.4 Severe Development Problems

Although we are aware of no technological constraints, institutional constraints have held development nearly to a standstill. Amax Exploration, Inc. and Petro-Lewis Corporation, who hold state and fee leases in the area are waiting on issuance of federal leases before proceeding with drilling of a deep well. Lease applications, which were made in 1974, are still pending. Part of these applications are for federal mineral leases where the surface is under fee ownership. Determination of the legal question of whether geothermal rights belong with the surface or with the mineral ownership is pending in the U.S. Supreme Court. The remainder of the applications, for leases on national forest lands, are still under review by the U.S. Forest Service Supervisor.

30.5 Development Scenario

If the leases are issued as expected, the schedule for development of the area could be as shown on Figure 10. As the schedule shows, there could be 50 Mw of power on-line by 1985, with a total of 100 Mw on-line by 1988. The exploratory work would probably involve drilling 2 more gradient holes before drilling a deeper wildcat well.

SITE: CHALK CREEK, MT. PRINCETON (STATE, FEDERAL, PRIVATE LAND)

No. 21A SITE DEVELOPMENT SCHEDULE

Figure 9

Composite Scenario
of
Geothermal Resource Development
in
Colorado
Power Generation

Figure 10

Composite Scenario
of
Geothermal Resource Development
in
Colorado
Space Heating
Per Year

Figure 11

Appendix A

SUMMARY OF GEOTHERMAL ALGORITHM - NON ELECTRIC

The model which follows posits the very simple economic idea that an investment should be made if the present value of all net income streams is equal to the investment required to generate them when discounted at an interest rate appropriately high. If the amount of an investment is known, and the net income streams are known, the rate of return can be calculated. This model attempts to calculate the internal rate of return for a geothermal field to be harnessed for space heating applications. This model can be easily modified to fit any type of energy production from a geothermal field.

The equation describing the simple form of discounting cash flows is:

$$\sum_{t=0}^T \text{Investment} = \sum_{t=1}^T (\text{net income}) e^{-rt}$$

where

Net Income = Total Revenues - Total Operating Cost - Taxes,

Total Revenues = (Price) (Quantity Output),

Total Operating Cost = A percentage of investment.

All investment, revenue and cost flows are modeled for each year of the life of the project. The program solves the resulting polynomial in T roots for the only single valued root, which is the value of r.

GIRORA -NON ELECTRIC FLOW DIAGRAM

GEOTHERMAL INTERNAL RATE OF RETURN ALGORITHM FOR NON-ELECTRIC APPLICATION

The following material describes a simple model to be used principally for sensitivity and policy analysis in evaluating the effect of changes in selected parameters on the profitability of a geothermal resource. The applications are for non-electrical uses, specifically fulfilling space heating needs. The geothermal resource is assumed to be liquid-dominated (hot water or brine).

The end product of the model is a solution for r , the internal rate of return from the following equation:

$$(1) \sum_{t=0}^T INV_t = \left[\sum_{t=1}^T REV_t e^{-rt} \right] - \left[\sum_{t=1}^T (TC_t) e^{-rt} \right] - \left[\sum_{t=1}^T (TX_t) e^{-rt} \right]$$

where

$$REV_t = (AHD) (8760) (LF) (P) (1+i)^t (1-\lambda),$$

[Input]	POP:	Population of the community
["]	DEGD:	Heating degree days of the community
["]	LF:	Load Factor, decimal
["]	P:	Base price of natural gas, assumed; \$ per million Btu equivalent
["]	i:	Rate of growth of natural gas price
["]	λ :	Royalty rate
["]	T:	Years of project life
["]	INV_t :	Total investment in year t ; \$
[Calc.]	REV_t :	Gross revenue during year t , \$
["]	AHD:	Average heat demand of the population center, in million Btu/hr
["]	TC_t :	Operating costs in year t ; \$
["]	TX_t :	Income taxes in year t ; \$
		$t = 1, 2, \dots, T.$

The term on the left hand side of (1) represents the sum of all capital investments that will be required throughout the active life of the resource. The term on the right hand side is a summation of expected net revenues to be earned throughout the life of the resource. Net revenue is defined as the difference between total revenue (the first bracketed term) and operating expenses and taxes (the second and third bracketed terms).

Assuming that P , the price of natural gas, is given, then differences among internal rates of return in a five-state region will be cost determined. Because capital investment charges are so dominant in such undertakings and because operating costs and taxes are heavily dependent upon the extent of capital investment, the role of capital investment in determining rates of return is of paramount importance. In the following pages, GIRORA (non-electric) will be explained in detail with primary focus on the capital investment model.

GIRORA: NON-ELECTRIC

To employ the GIRORA model to estimate the internal rate of return for low temperature geothermal resources, three factors must be calculated: investment costs, operating costs and taxes. In this model, operating expenses are assumed to be a constant proportion of capital investment, and tax liabilities are assumed to be a joint function of estimated revenue and capital investment. Thus, the capital investment portion of the model is central to GIRORA. The approach to the estimation of capital investment costs is discussed below.

For each geothermal site which has been deemed technologically harnessable on the first round iteration, potential demand for space heating will be estimated. Then, based upon the subsurface temperatures and reservoir volumes, the number of wells necessary to fulfill estimated demand will be calculated.

$$(2) \text{ AHD} = 1.5 [(0.75) (2.01) + (0.25) (0.914)] * (\text{POP}/4) *$$

$$\text{DEGD} * 10^{-6},$$

$$(3a) \text{ INV}_t = \text{DNV}_t + \text{LNV}_t + \text{IDC}_t, t \neq \text{EXP} + \text{DVP} + 1,$$

$$(3b) \text{ INV}_t = \text{DNV}_t + \text{LNV}_t + \text{IDC}_t + \text{PLV}, t = \text{EXP} + \text{DVP} + 1,$$

[Calc.] DNV_t : Total drilling investment costs in year t , \$

[Calc.] LNV_t : Leasing investment cost in year t , \$

[Calc.] PLV : Plant investment cost in \$ (transmission and distribution system)

[Input] EXP : Exploration period in years

[Input] DVP : Development period in years.

Each of the four components of capital investment are estimated individually.

$$(4) \text{ DNV}_t = \left[\left(\frac{\text{NPW}_t}{\text{PSS}} \right) (\text{ADDP}) (\text{CPFP}) \right] + \left[\left(\frac{\text{NIW}_t}{\text{ISS}} \right) (\text{ADDI}) (\text{CPFI}) \right],$$

[Input] PSS: Power well success ratio
 ["] ADDP: Average depth of production well in feet
 ["] CPFP: \$ per foot of production well of given diameter
 ["] ISS: Injection well success ratio, usually 1.0
 ["] ADDI: Average depth of injection well in feet
 ["] CPFI: \$ per foot of injection well of given diameter
 [Calc.] DNV_t : Total drilling investment cost in year t
 ["] NPW_t : New production wells drilled in year t
 ["] NIW_t : New injection wells drilled in year t.

$$(5) \text{ NPW}_t = \text{RPW}_t,$$

[Input] RPW_t : Required producing wells in year t.

$$(6) \text{ NIW}_t = \text{RIW}_t,$$

[Calc.] RIW_t : Required injection wells in year t.

$$(7) \text{ RIW}_t = \text{RPW}_t (\text{PIR})^{-1},$$

[Input] PIR: Necessary PW/IW.

$$(8) \text{ LNV}_t = [(\text{DPAC}) (\text{ACPW}) (\text{NPW}_t)] + [(\text{DPAC}) (\text{ACIW}) (\text{NIW}_t)],$$

[Input] DPAC: Leasing cost, \$ per acre
 ["] ACPW: Required acreage per production well
 ["] ACIW: Required acreage per injection well.

The third segment of the investment outlay is the plant investment expense. Plant investment consists of several parts. The first one is transmission investment, consisting of costs incurred in transporting geothermal hot water from supply site to demand site; the second one is the distribution investment, consisting of costs incurred in distributing the geothermal hot water to individual demand units.

$$(9) \text{ PLV} = \text{TRNV} + \text{DINV},$$

[Calc.] TRNV: Transmission line cost, \$ (Sum of the costs of scheduled 10 international pipe, fittings & valves, 2.5" insulation, tin shield, labor & trenching, modified expansion loop and miscellaneous costs)

[Calc.] DINV: Distribution investment, \$.

$$(10) \text{ TRNV} = [7.2474 + 2.699 * \text{TPD}] * 5280 * \text{DIST},$$

[Input] DIST: Distance from geothermal resource to the population center, miles

[Calc.] TPD: Transmission line pipe diameter, inches.

$$(11) \text{ TPD} = 6.6 + 4.04 * \text{HWLBH} * 10^{-6},$$

The transmission line pipe diameter is adjusted to the next highest of 6, 8, . . . , 30 inches.

[Calc.] HWLBH: Hot water quantity, lbs/hr.

$$(12) \text{ HWLBH} = \text{PHD}/\text{TD},$$

[Calc.] PHD: Peak heat demand, Btu/hr

[Calc.] TD: Temperature drop.

$$(13) \text{ PHD} = 1.5 [53,000 (0.75) + 24,000 (0.25)] * [\text{POP}/4].$$

$$(14) TD = -75.41 + 0.7142 * (TEMP - DIST),$$

[Input] TEMP: Downhole temperature of hot water at source, °F.

$$(15) DINV = [333 + 103.24 \{ (PHD * 0.292 * 10^{-6}) - 1.5 \}] * 10^3,$$

[Calc.] PPY: Preproduction time, years.

$$(16) PPY = EXP + DVP + CON,$$

[Input] CON: Construction period of transmission and distribution system, years.

The final component of investment cost is the interest expense incurred during construction.

$$(17a) IDC_t = [BR] \left[\sum_{j=1}^t DNV_t + LNV_t \right] + PLV,$$

for $t \leq PPY$.

$$(17b) IDC_t = 0, \text{ for } t > PPY.$$

In order to compute the net revenues (right hand side of Equation 1), operating costs and taxes must be computed.

$$(18a) TC_t = [OCE_t] \left[\sum_{j=1}^t INV_j \right], \text{ for } t = 1, 2, \dots, EXP + DVP.$$

$$(18b) TC_t = [OCP_t] \left[\sum_{j=1}^t INV_j \right], \text{ for } t = EXP + DVP + 1, EXP + DVP + 2, \dots, T,$$

[Calc.] OCE_t : Percent of drilling costs, etc., decimal

[Calc.] OCP_t : Percent of drilling and plant costs, etc., decimal.

$$(19) OCE_t = C (1 + \dot{C})^t, \text{ } t = 1, 2, \dots, T.$$

$$(20) OCP_t = PC (1 + \dot{PC})^t, \text{ } t = 1, 2, \dots, T,$$

[Input] C: Base year percentage, decimal
 ["] Ċ: Real rate of increase over time, decimal
 ["] PC: Base year percentage, decimal
 ["] PĊ: Real rate of increase over time, decimal.

$$(21) TX_t = \{TXRT\} \{[REV_t (1-Z)]$$

$$- [TC_t] - [(Y) * DEPRD_t \sum_{j=1}^t (LNV_j + DNVD_j) + DEPRN_t \cdot PLV]\}$$

$$- \{[CRRT] [(1-Y) \{ \sum_{j=1}^t (LNV_j + DNV_j) + PLV \}]\}.$$

$$(22) DEPRD_t = (D + 1 - t) / \sum_{j=1}^D j.$$

$$(22a) DEPRN_t = 0, \text{ if } t \leq PPY.$$

$$(22b) DPRN_t = (N + PPY + 1 - t) / \sum_{j=1}^N j, \text{ if } t > PPY,$$

[Input] D: Period of depreciation for DNV, LNV
 [Input] N: Period of depreciation for PLV
 [Calc.] DNVD_t: A \$ figure for depreciation of drilling investment in year t.

$$(23) DNVD_t = \sum_{j=1}^t DNV_j \cdot DEPRD_{t-j+1},$$

[Input] TXRT: Profit tax rate, decimal
 ["] Y: Percent tangible investment, decimal
 ["] CRRT: Investment tax credit
 [Calc.] DEPRD_t: Percent allowance of depreciation for drilling subleasing investment for time t
 ["] DEPRN_t: Percent allowance of depreciation for power plant investment for time t.

Now, all the terms in equation (1) are known, except the rate of return r . This equation is a polynomial of degree T in r and is solved numerically to get the value of r .

INPUT DATA LIST

Number of Producing Wells:

TEMP: Downhole well temperature

POP: Population of the community under consideration for geothermal space heating

DEGD: Heating degree days of the community

LF: Load factor

Drilling Costs:

RPW: Production wells required in year t

PSS: Production well success ratio

ADDP: Average depth of production well in feet

CDFP: \$ per ft of production well

PIR: Ratio of PW/IW

ISS: Injection well success ratio

ADDI: Average depth of injection well in feet

CPFI: \$/ft of injection well

Leasing Costs:

DPAC: \$ per acre

ACPW: Acres per producing well

ACIW: Acres per injection well

Transmission and Distribution Costs:

DIST: Distance from geothermal resource to the population center

Interest During Construction:

BR: Bond rate
EXP: Exploration period in years
DVP: Development period in years
CON: Construction period in years

Total Operating Costs:

Need to calculate

- i) OCE - % of drilling cost
- ii) OCP - % of drilling and plant cost

To calculate OCE:

C: Base OCE
 $\dot{C}$: Annual increase in OCE

To calculate OCP:

PC: Base OCP
 $\dot{P}\dot{C}$: Annual increase in OCP

Calculate Receipts:

P: Base price of natural gas
 λ : Royalty rate
i: Rate of growth of natural gas price

Taxes:

Z: Depletion allowance
CRRT: Investment tax credit
Y: % tangible investment

Depreciation:

D: Period of depreciation for DNV, LNV

N: Period of depreciation for PLV

General:

T: Total project life in years

Appendix B

SECOND QUARTERLY REGIONAL ADVISORY GROUP MEETING
Phoenix, Arizona
December 7, 1977

ATTENDEES

John W. Arlidge	Nevada Power Company	Las Vegas, NV
Dave Atkinson	Hydro Search, Inc.	Reno, NV
C. W. Berge	Phillips Petroleum Co.	Del Mar, CA
Bill Dolan	AMAX	Denver, CO
Keith Dotson	Four Corners Regional Commission	Albuquerque, NM
Perry T. Larsen	Weber State College	Utah
Joel Robinson	Union Oil Company	California
John H. Woods	Bank of Montreal	California
Robert E. Oliver	DOE - DGE	Washington, DC
B. B. Barnes	DOE - DGE	Washington, DC
Steven Goldstein	Mitre Corp. (National O.R. Contractor)	McLean, VA (Washington, DC area)
A. W. Laughlin	LASL	Los Alamos, NM
Mike O'Donnell	Geothermal Kinetics Inc.	Phoenix
A. K. Doss	Arizona State Land Dept. (Arizona Team)	Phoenix
F. P. Mancini	Arizona Team	Phoenix (ASERC)
Don H. White	Arizona Team	Tucson
David Wolf	Arizona Team	Tucson
Mike Cease	Arizona Team	Tucson
J. F. Warnock	Arizona Team	Phoenix (ASERC)
A. H. Tellier	Arizona Water Commission	Phoenix
Claudia Stone	Arizona Bureau of Geology	Tucson

W. R. Hahman, Sr.	Arizona Bureau of Geology	Tucson
Harold Bell	Arizona Public Service Company	Phoenix
W. E. Allen	Oil & Gas Commission	Phoenix
Richard H. Pearl	Colorado Geological Survey	Denver, CO
Barbara A. Coe	Colorado Geological Survey	Denver, CO
Martin Booth	Nevada DOE	Reno, NV
Tom Ortiz	N.M. Energy Resources Board	Albuquerque, NM
Dennis Fedor	N.M. Energy Resources Board	Albuquerque, NM
L. Ward Wagstaff	Utah Division of Water Rights	Salt Lake City, Utah
Richard T. Meyer	Western Energy Planners Ltd.	Denver, CO
J. M. Marlin	NMSU/NMEI	Las Cruces, NM
C. R. Rao	NMSU/NMEI	Las Cruces, NM
Paul McDevitt	NMSU	Las Cruces, NM
Ken Nowotny	NMSU	Las Cruces, NM