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

**Final Technical Report
June 1977 to August 1978**

January 1979

**NEW
MEXICO
ENERGY
INSTITUTE**

at New Mexico State University

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EXECUTIVE SUMMARY

This report describes the work accomplished in the first fourteen months 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 of the level of a preliminary working model which is capable of displaying program approach, but not loaded with all available data.

The major accomplishments of this project during this contract year have been:

- . Establishment of core team, state teams, and regional and state advisory groups.
- . Identification of locations and geophysical conditions of potential geothermal sites.
- . Modeling of geothermal energy development activities including technological, economic, and institutional factors.
- . Review and analysis of legal and institutional factors in geothermal energy development.
- . Design and creation of computer data base system and software to support economic analyses, scenario design, and progress monitoring.
- . Development of local, state, and regional power-on-line time phased scenarios for geothermal energy in the Southwest.

At the outset, it is useful to review and compare what was known about potential geothermal sites at the beginning of the contract year as compared with the assessments at the close of the contract year. The following table displays by state the large growth in the number of potential geothermal sites in the region. As indicated, the number of potential electric sites increased from twenty-nine to eighty, and the number of potential nonelectric

sites increased from fifty-three to five hundred. As is indicated, the potential number of sites increased more than seven-fold due to the active state team and Core Team review of available literature and parallel low temperature assessment programs that were ongoing during the contract year.

TABLE I

	Temperature greater than 150°C		Temperature Less than 150°C	
	USGS 726	Current Report	USGS 726	Current Report
Arizona	2	13	6	40
Colorado	1	13	13	46
Nevada	20	32	25	329
New Mexico	3	13	3	41
Utah	3	9	6	44
TOTALS	29	80	53	500

Geothermal resources with temperatures in excess of 150° C are considered candidates for generating electricity. Since the production technology is established, the future potential of geothermally produced electricity hinges upon its market competitiveness with alternative fuel sources. Accordingly, a simulation model was developed in order to estimate an internal rate of return on investment in geothermal energy development. The internal rate of return on investment is a general indicator of profitability which provides a measure of the financial attractiveness of geothermal energy.

The examination of the electricity producing potential of geothermal energy consists of an analysis of each of the known high temperature geothermal resources in the Southwest. Primary data were gathered by personnel within each of the states, and on this basis the internal rate of return on producer's equity is calculated for each source site. Several sets of plausible circumstances were proposed, and a unique rate of return was calculated for each. Based upon the estimated profitability of each geothermal resource, an ordinal ranking of resource sites was prepared. Those sites with the highest rate of expected return on investment are expected to come "on line" first, while the least profitable are expected to come "on line" last if at all. In this manner, a time-phased growth path of high temperature geothermal resources was created.

The analysis indicates (1) that the principal impediments to growth in the use of geothermal energy for producing electricity are geophysical or engineering in nature (e.g., subsurface temperatures and flowrates), or at least, are not subjected to policy manipulation; (2) that, of the available policy options, the investment tax credit rate and the bond rates are the most potent alternatives for stimulating development. Traditional

policy tools, such as depletion allowances or royalty rates, seem to be of much less value.

With current levels of economic policy variables, a minimum of 4,000 and a maximum of 20,000 MW of electricity could be brought on line by year 2020. Adequate incentives in the form of bond rate subsidies and investment tax credits could raise the lower estimate to 8,000 MW by 2020, while the maximum estimate cannot be affected by financial incentives.

In addition to the high temperature geothermal resources, the Southwest has also been generously endowed with low temperature ($T < 150^{\circ}\text{C}$) resources as well. These resources can be employed for space heating and cooling, water heating, and cooling, and numerous agricultural, aquacultural, and industrial applications. To date, only district space heating applications have been considered.

Because of the large number of low temperature resources, the market potential of geothermal space heating applications was examined in 2 stages. First, the total population of resource sites was considered for its technological acceptability. These resources that are usable given current production techniques were separated from those which are not usable, and the latter were eliminated from further consideration.

In the second stage, the economic potential of the remaining resources was indicated on the basis of an estimated internal rate of return on investment. Those resources which are not expected to generate a minimum acceptable return were then eliminated from further consideration. The remaining resources constitute the estimated regional supply aggregate of low temperature geothermal resources.

The "in ground" potential of low temperature geothermal resources in the Southwest is estimated to be 39,000 MBtuh. Most of these resources are remote from population centers, and because of the inherent cost factors in transmitting geothermal fluid over large distance, these sites do not prove to be economically feasible. In fact, of the approximately 39,000 MBtuh of geo-heat potential available in these sites, based on estimated internal rate of return, only 27 of the sites or approximately 1800 MBtuh offer realistic potential for district space heating purposes under currently forecast conditions. However, this low figure represents a conservative level. As site exploration and development continue, and as population growth rates and trends are incorporated in the model, it can be expected that an increase in geothermal usage will result.

Based on the state teams power-on-line time phased scenarios, a regional power-on-line scenario was aggregated. Appendices 5 through 10 contain details of the state teams scenarios as well as the regional aggregation.

Concerning the progress toward attaining DOE goals for geothermal development, the following table compares DOE goals for the ten state Rocky Mountain Range and Basin with the estimated geothermal potential sites in the Southwest Region. For the Southwest Region, the optimistic electrical development assumes implicitly that technology will be developed to make feasible the generation of electricity from sites with temperatures in the

range of 150° to 300° C. The pessimistic scenario assumes that only sites with a temperature greater than 190° C will be developed. As indicated previously, the nonelectric potential that is displayed in this table is for district space heating only. It is estimated that a significant increase in industrial process heat applications, agriculture, aquaculture, and other uses of low and moderate geothermal potential will be developed during the next 40 years. However, at this time, techniques have not yet been refined to develop and analyze this latter potential. As is indicated by the table, the Southwest Region alone under the optimistic scenarios can be expected to attain approximately 60% of the ten state region electric capacity in the optimistic case. District space heating, although apparently attractive, is constrained by the limited population of the Southwest Region. As the model is refined to incorporate population growth rate trends and other factors, the nonelectric potential can be expected to increase.

TABLE II
DOE GOALS FOR RMB&R REGION FOR 2020
VS
CALCULATIONS FOR SOUTHWEST REGION

	Rocky Mountain Range Basin	Southwest Region ²	
	<u>DGE Goals¹</u>	<u>Optimistic</u>	<u>Pessimistic</u>
Electric Capacity (MWe)	35,000	20,000	3,000
MEGW Equiv. (Direct Thermal)	60,000		600 ³
Electrical Quads/yr	2.91	1.66	0.32
Direct Thermal Quad/yr	<u>1.80</u>	<u>--</u>	<u>0.02</u>
Total	4.71	1.66	0.34
Barrels of Oil (Equivalent)	793x10 ⁶ /yr	300x10 ⁶ /yr	60x10 ⁶ /yr
Cost Avoidance Oil Import	\$11 Billion	\$4.2 Billion	\$0.8 Billion

¹Data Extracted from "Regional Hydrothermal Commercialization Plan," DOE/DGE, July 14, 1978

²Data for five Southwestern State based on calculations using GIRORA Models.

³This is economically feasible, district space heating only, assuming no population growth, for low temperature sites only.

CHAPTER I

INTRODUCTION

During the past several years, the United States has been relying increasingly on imported oil to meet its energy needs. This trend will continue unless greater use is made of all available domestic energy resources. To achieve this objective the Department of Energy (DOE), through its Division of Geothermal Energy, has established as one of its goals: to stimulate commercial development of geothermal energy as a reliable, operationally safe, and an environmentally acceptable energy resource⁽¹⁾. To provide early momentum to this effort, DOE has initiated several research, development and demonstration type projects and administrative and policy initiatives to stimulate rapid exploration of "liquid dominated hydrothermal" resources. This class of geothermal resources, in comparison with the various other types of geothermal resources (e.g., vapor dominated, geopressured, hot dry rock, etc), is considered most likely to make a significant contribution to the nation's energy supplies in the near future.

According to the estimates presented in USGS 726⁽²⁾, geothermal energy has the potential of contributing thousands of quads to the nation's energy resources. However, there are significant environmental, technological and socio-economic problems which considerably impede the rapid development of the geothermal resources. These problems must be identified and mitigated to realize the geothermal potential that exists. Many of these problems are beyond the capability of U. S. industry to solve, and will require the assistance of action by the public sector. At the national level, this has been recognized by the congress and the administration, who in 1970 passed the Geothermal Steam Act (PL 91-581) to open up federally owned lands for leasing for geothermal development and in 1974 passed the Geothermal Research, Development and Demonstration Act (PL 93-410) to stimulate the environmentally acceptable development of geothermal energy.

As geothermal energy is a regional resource by its nature, its development will require approaches which recognize its regional character. At the same time, there will be many problems common to all regions. In recognition of this factor, DOE (ERDA) has established a regional planning activity, to identify

the specific problems associated with geothermal development in each region of the country, and has established a national planning activity to coordinate the activities of the regional planners and recommend actions and policy initiatives for DOE (ERDA) activities on the basis of maximum national benefit.

One of the regions so established by DOE (ERDA) is the Southwest Region, which consists of the states, Arizona, Colorado, Nevada, New Mexico, and Utah. This region contains a relatively large number of high temperature hydrothermal convective resources. To exploit the possibilities, DOE (ERDA) has contracted with the New Mexico Energy Institute at New Mexico State University for assistance in the development of a plan for stimulating the development of Southwest Region's geothermal resources. In addition, the New Mexico Energy and Minerals Department and the Four Corners Regional Commission have jointly financed the efforts by the New Mexico Energy Institute.

The USGS, in its circular 726, estimates that the recoverable energy content of identified hot water resources show 150°C in the Southwest Region could produce 1312 megawatt - centuries of electrical power, equivalent to an installed capacity of 4374 megawatts for 30 years using current conversion technology. In addition, 3.57×10^{17} calories (equivalent to 1560 MW for 30 years) is available as usable heat for direct thermal applications, such as space heating, agriculture, aquaculture and process heating.

The USGS further estimates that as much as five times this amount of energy may be recoverable from as yet unidentified hydro-thermal resources, and perhaps even more from hot dry rock. If it is assumed that the utilization of geothermal energy can be made economically competitive with other energy resources and that it is in the public interest to utilize the available domestic resource to help meet the growing energy demands in the region/nation and reduce dependence on imported energy sources, then the questions to be addressed are:

- 1) How rapidly can geothermal energy resources be developed in an environmentally acceptable manner; given the present level of knowledge of the resource, present technology, development status, present environmental knowledge and concerns, and present socio-economic conditions;
- 2) What action alternatives are available to the public sector to stimulate the rapid development of geothermal resources; and
- 3) What set of these alternatives will most effectively supply the needed stimulation while protecting all legitimate interests of the public.

An attempt is made to answer these questions during the first year effort of the operations research study for the Southwest Region. This report covers the findings of the study on the state by state and aggregated region basis.

THE UNITED STATES OF AMERICA
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

CHAPTER II

PROJECT DISCUSSION: FORECASTING AND OPERATIONS

The project undertaken by the New Mexico Energy Institute at New Mexico State University is a multi-faceted, multi-discipline regional operations research in the development of geothermal energy resources for the Division of Geothermal Energy (DGE) of the Department of Energy, the Four Corners Regional Commission and the New Mexico Energy and Minerals Department.

In the five states of the study area, it has been broadly estimated that there are geothermal energy resources in excess of 1,800,000 megawatt-years. Over 800,000 acres of land lie in known geothermal resource areas (KGRA's) in the states, and over 25,000,000 acres have been established as prospectively valuable. However, there are a large number of barriers to the exploitation of the energy resources. Available technology does not exist to develop all of these resources. Public utilities are uncertain about the quality and quantity of this resource. This uncertainty, together with the national economic situation, means that available capital for the development of the resource is limited. Institutional barriers, in the form of federal, state and local government laws and regulations, such as environmental controls, tax laws, and land use policies, may inhibit the aggressive exploration and exploitation of the resource. A major task of the contract is to identify these factors and to quantify the relative importance of these factors in terms of their effect on the rate of deployment of this energy resource in the Southwest Region.

The broad method chosen to identify the above barriers and to achieve the DGE's mission, namely, to accelerate the actual commercial utilization of geothermal energy, is the development of a series of scenarios, the outputs of which are a prediction of the amount of commercial power (electric and non-electric) brought on line versus time. Hence a scenario will constitute the mission for the DGE mission-oriented approach to geothermal energy resource development. Since most forms of geothermal energy represent local resources

and since many of the problems associated with commercial geothermal development are local or regional in nature, the local and regional problems are addressed in developing the scenarios. In considering the local problems within each of the five states, the key energy officials in the states were consulted. Each state team leader was responsible for data collection and gathering information from local governments and industries.

The preliminary development scenarios, based on inputs from the regional and local interest groups together with supplemental data concerning the extent and quality of the geothermal resources will show the locally preferred time phasing of power on line. State teams were tasked to supply this kind of information.

The economics of harnessing the geothermal resource (either for electricity production or for direct application) play a major role in the future development of geothermal energy resources. In this free market society, geothermal energy must compete with other sources of energy. The economic analysis must show a distinct advantage for geothermal energy if utilities are to be induced to make extensive financial commitments to the development of this relatively new technology. Associated with the scenario for geothermal energy development are projections of costs of power from alternate resources. Analyses of these projections are very useful in the planning process. For instance, the projections may show that geothermal energy in a particular region will not be economically viable for some years in the future. In order to accelerate geothermal energy development in that case, the gap between the geothermal costs and the lowest cost alternatives must be closed. Economic analyses are required to determine the impacts of several possible alternative actions on the cost of geothermal power such as, technology improvements, tax incentives, government subsidies, and loan guarantees.

One obvious way to decrease the cost of geothermal power is to improve the efficiency of the energy conversion process through research and technology development programs. This is a very desirable approach in that it contributes towards energy resource conservation by providing more energy per unit of resource. However, there are limits to increases in efficiency which can be achieved through research and development. Thermal cycle efficiency is limited to carnot cycle efficiency for a given reservoir, and heat sink temperatures and mechanical efficiency must be less than unity. Further, as the quality of resources decreases (which is an uncertain element) the cost of power tends to increase due to the intrinsic decrease in cycle efficiency associated with

lower temperatures and the need for more expensive equipment (such as heat exchangers and pumps). The increase in the cost of geothermal power tends to delay the commercial use of lower quality resources until technology improves or other policy initiatives which are economically supportive are adopted. If the analyses show that the amount of technology improvement cannot close the gap between the costs of geothermal and alternate energy sources, then it is desirable to consider policy initiatives which temporarily close the gap. Modifications to tax regulations, government guaranteed loans, or even government subsidies are possible techniques for artificially altering the economics of geothermal energy development.

2.1 Resource Knowledge and Scenario Assumptions

The Southwest Region is rich in geothermal resources. They include the familiar hydrothermal systems typified by those under development at Valles Caldera, New Mexico, and Roosevelt Hot Springs, Utah. In addition, they have hot igneous (hot dry rock) and conduction dominated systems which may ultimately prove to be much more extensive and valuable than the hydrothermal systems. A summary of the number of hydrothermal systems present in the five state region is given in Table 2.1. These estimates are obtained from United States Geological Survey (USGS), local researchers at New Mexico State University, and the appropriate state teams. The high temperature hydrothermal systems (i.e., temperatures over 150°C) are especially important because of their potential for near term commercial development for electric power generation. In addition, they can support industrial processes which demand high temperatures, such as paper pulp digestion, timber drying and aluminum extraction. Medium temperature geothermal systems (temperatures between 65 and 150°C) can be used for direct applications such as domestic space heating, greenhouse heating and other industrial uses which do not demand very high temperatures. Finally, low temperature systems, commonly known as warm springs can be utilized for mushroom growing, balneological baths, and other agriculture and aquaculture applications. The subject of the report basically constitutes the scenarios for electric power generation utilizing high temperature resources and district space heating using the medium temperature resources.

There are large uncertainties in the resource estimates. The assessment of geothermal potential presented in this report is based on limited data available. As USGS has indicated, no single estimate of geothermal energy from

Table 2.1

Hydrothermal Resources Present in the Five State Region

State	Number of Hydrothermal Resources			
	Temperature Over 150°C	Temperature Between 65° & 150°C	Temperature Less Than 65°C	Total
Arizona	13	15	25	53
Colorado	14	24	21	59
Nevada	32	52	276	360
New Mexico	13	20	26	59
Utah	8	13	32	53
TOTAL	80	124	380	584

a particular area included in the assessment should be relied upon as an established fact. For some areas, the information was relatively good, but for other areas it was very poor at the time the estimates were made.

It is expected that further research and exploration will show a significant number of additional geothermal fields in the region besides those listed in Table 2.1. Further exploration could also considerably modify the estimates for the sites identified. Further discoveries, according to USGS, could be possibly five times the volume and heat content of the high temperature systems ($>150^{\circ}\text{C}$) already identified. The discoveries could result from:

- 1) New knowledge of the extent of an already identified system that appreciably increases its estimated volume.
- 2) The temperature of an identified system being higher than first estimated (possibly enough to raise some of the medium temperature resources into the higher temperature category).
- 3) The discovery of previously unknown systems.

In addition to the geological and geophysical data, more analyses need to be done to develop the scenarios. Most important of these are the identification of the institutional factors present and the economical analysis for the feasibility of electricity production and domestic space heating. They are considered in detail in this report.

2.2 Legal and Institutional Factors

One of the major impediments for the rapid development of geothermal energy is the existence of nontechnical barriers. The nontechnical factors which inhibit the activities of geothermal industry are legal and institutional factors. Many geothermal developers believe that institutional factors are the major cause of the large time delays and high costs associated with the development of geothermal energy. The time involved in getting permits for leasing, drilling, environmental assessments and other legal factors all contribute to time delays. The impact of permitting delays can be very serious, which may affect the economic exploration of the resource. In the Southwest Region, the permitting process and time delays involved vary from state to state. The details of the permitting process and their impact is described in Chapter III.

2.3 Electricity Production from Geothermal Energy

Experimental production of electricity from geothermal energy began in Lardarello fields in 1904⁽³⁾. By 1931, sufficient quantities of electricity were being generated to begin selling electricity to the Italian Railway System. After being destroyed in World War II, the generating facilities were rebuilt and expanded. The Lardarello fields currently generate enough electricity to supply a city of 600,000 at U. S. consumption rates. Commercial generation of electricity from geothermal energy in the U. S. began in 1960 at The Geysers, California. By 1973, the U. S. was the largest producer of electricity from geothermal steam⁽³⁾. Currently 1000 MW of electricity are generated from geothermal steam worldwide, half of which is produced at The Geysers.

Although worldwide production of electricity from geothermal resources continues to increase yearly, it is doubtful that the overall contribution of this production will be large in the near future. Assuming the production in the world continues to increase at the present rate, 3000 MW will be produced by 1980. This projected production still would constitute less than one percent of the current energy demands.

There are several inherent technological problems in producing electricity from geothermal energy. One major problem is locating a geothermal source with the necessary heat content to produce electricity. Generating electricity from geothermal water at temperatures 150°C or less is generally not economical due to the low efficiencies (less than 7 percent) and large flow rates required⁽⁴⁾. However, it is quite likely that the competitive economics of electrical generation using lower temperature geothermal resources will improve as the technology in the field advances and conventional energy costs continue to rise.

Another problem associated with using geothermal energy is that geothermal water tends to have a higher mineral content than ground water. This high mineral content produces scaling problems in equipment and inhibits production capabilities. Calcium carbonate deposits also cause scaling problems in wet steam utilization. These problems can be eliminated by using binary cycle for energy conversion in contrast to the more traditional flash cycle. In a binary cycle, heat from the geothermal fluid is transferred to a secondary fluid, usually having a low boiling point (e.g., iso-butane) through heat exchangers. The advantages are two-fold: one, the corrosion and scaling problems are reduced and the other, the amount of usable heat

(enthalpy) is greater in the binary fluid. Even the moderately high temperature resources (temperatures between 150° and 200°C) can be more efficiently exploited with the binary cycle technology. Of course, the cost of heat exchangers and the other necessary equipment adds to the capital cost of the power plant.

The details of the economic analysis and sensitivity analysis and their impact on scenario generation for geothermal electricity production are discussed in Chapter IV of this report.

2.4 Non-Electric Utilization of Geothermal Energy

The production of a significant amount of electricity from geothermal energy is years in the future. In comparison, the utilization of geothermal energy for non-electrical purposes holds great possibilities in the near future. The advantages of non-electric utilization of geothermal energy are⁽⁵⁾:

- 1) Approximately one-third of the fossil fuel consumption is used for residential purposes, the majority of which could potentially be supplied from low temperature geothermal sources.
- 2) Low temperature resources are more numerous and generally less polluting than high temperature sources, which are required for electrical production.
- 3) The efficiency of non-electrical utilization is greater than for electrical production.
- 4) Technology is sufficiently advanced to allow immediate development where the resources exist.

Space heating accounts for 18 percent of U.S. yearly energy consumption⁽⁴⁾. Since known geothermal sites are seldom close to large population center, geothermal energy cannot be presently used to supply the bulk of space heating demands. However, as exploration techniques improve and as new geothermal sites are discovered, an increase in the application of geothermal energy to space heating can be expected. In addition to the space heating applications there are several industrial uses of low temperature geothermal energy. The use of this energy for industrial applications basically depends on the heat requirements of the particular industry, quality of the geothermal resource and the proximity of the industry to the resource.

In this report, the economics of space heating is considered. Applications to industrial processes need extensive data and individual economic analyses, and are not considered in this report. The economic model developed

for space heating, sensitivity analysis and scenario generation is discussed in Chapter V.

2.5 Data Base and Region Program Progress Monitor

In order to perform the studies described in the previous sections, extensive amounts of data are required. The data can be broadly classified into six categories, namely,

- 1) Data relating to the geothermal energy resource,
- 2) Data relating to the utilization of the resource,
- 3) Data relating to legal and institutional factors,
- 4) Data relating to economics of resource exploitation,
- 5) Data relating to technology development, and
- 6) Data relating to regional industry status.

Data are collected as much as possible in all the above areas and are stored in the data base. Part of this data is automated, and is entitled Regional Program Progress Monitor (RPPM). The complete description of the RPPM is given in Chapter VI.

CHAPTER III

LEGAL AND INSTITUTIONAL FACTORS IN THE DEVELOPMENT OF GEOTHERMAL RESOURCES

While the potential for geothermal resources is great, only a very small fraction of this potential has been realized. Virtually everyone agrees that numerous technical and nontechnical factors are impeding the rapid development and utilization of the resource. While not ignoring the technical barriers, this chapter will stress the nontechnical factors which impact upon efforts to accelerate the development of geothermal resources. The nontechnical factors of concern will be restricted to the legal and institutional factors which may inhibit the activities of the geothermal industry.

It has been estimated that over \$75 billion of capital financing will be needed over the next 20 years if the potential for geothermal resources is to be achieved.⁽⁶⁾ There is, however, a great hesitancy on the part of industry to commit this degree of financing to the task. The belief is almost universal that the cause of this hesitance is two-fold: (a) restrictive laws, court decisions, and regulations and (b) actions (and inactions) of a large number of individuals who singly and jointly make decisions that are unresponsive to the needs of the industry. In short many, if not most, developers believe or talk as if they believe that institutional factors are the major cause of the long delays and high costs associated with the development of this natural resource.

That belief has been challenged by others who contend that the principal impediments to the rapid development of geothermal resources spring not from institutional factors but rather are due to uncertainties associated with the resource itself, the technology necessary to develop the resource, and overall economic risk.⁽⁷⁾ Even those promoting this latter point of view recognize, however, that legal and institutional factors can accentuate the uncertainty and risk associated with geothermal potential.

If the number of studies and reports concerned with legal and institutional factors is accepted as a measure of the intensity of the belief that these factors are important, the belief is indeed intense. In July 1976, there were 118 references to articles concerned with legal and institutional issues in a bibliography which cited over 5400 research articles in the area of geothermal resources.⁽⁸⁾ By January 1978, the Department of Energy published a bibliography containing 485 references to legal and institutional research in the area.⁽⁹⁾

Hence, in 18 months there was a 300 percent increase in the number of articles concerned with legal and institutional impediments to geothermal development.

The overall goal of the legal and institutional aspect of the Southwestern Regional Operations Research Program has been to identify the individuals and agencies whose single and mutually interactive participation affect the rate of geothermal resource development. These participants in the development process may be categorized into four major classes as a function of the locus, if not the magnitude of their potential effect: (a) federal agencies and regulations; (b) state agencies and regulations; (c) the policies and decisions of resource developers and utility operators; and (d) the attitudes and actions of local officials and residents.

During the past year the Southwest Regional Program has concentrated on identifying the state agencies and the state laws and regulations that affect geothermal development within the Southwest Region. The issues involved at the federal level and between the federal and state levels of operation were also reviewed. Using the bibliography referred to above, previous studies concerned with the role of policy variables in other states were also analyzed.

The institutional studies conducted by the Southwestern Regional Program had three specific goals. First, it is recognized that institutional factors are a major element in regional aggregated scenarios which depict the time-phased activities required to develop geothermal energy. Hence, these studies were necessary to the creation of those scenarios. Second, it was reasoned that through an analysis of the development scenarios it would be possible to identify factors which act as constraints and other factors which serve as opportunities to the development of geothermal resources. Third, based upon the knowledge acquired from an examination of development scenarios policy initiatives would be recommended which would overcome or mitigate the constraints and exploit the opportunities to geothermal development.

A fourth goal of the program was to assist in the development of a knowledgeable and properly motivated infrastructure that could and would promote the development of geothermal resources within each state in the region. It has been noted that whether the climate for the use of geothermal energy sources will be positive or negative is often directly related not only to state policies but also to the attitudes of elected state officials.⁽¹⁰⁾ Hence, by the very act of conducting these investigations it was hoped that there would be an increase in public perception of the issues at hand and that

these perceptions would lead to a higher degree of political interest and an increase in necessary political leadership.

None of the goals listed are unique to the program centered at New Mexico State University. Significant efforts directed at the same goals have occurred at the national level through the efforts of such groups as the National Conference of State Legislatures,⁽⁶⁾ at regional level by such groups as the Pacific Northwest Regional Commission,^(7,11,12) and at the state level by such groups as the Batelle Human Affairs Research Centers.⁽¹³⁾ In fact the institutional constraints and opportunities identified by the Southwest Operations Research Program are distinctive primarily to the extent that they are often unique to the five states which comprise the regional area. While there is no intention to deemphasize the significance nor the generality of the results to be reported, the most noteworthy accomplishment of these efforts may have been the establishment of knowledgeable proponents of geothermal energy in the executive branch of each state and to have facilitated an interaction among local, state, and regional agencies.

The following discussion of legal and institutional factors affecting geothermal development is organized into three parts: (a) a review of federal laws, regulations and procedures; (b) a review of state and regional studies; and (c) a description of legal and institutional factors in the Southwest Region.

3.1 Federal Geothermal Program

An examination of the federal geothermal program is necessary to obtain an understanding of institutional factors which affect the development of geothermal resources in the Southwest. There are at least four reasons why the federal program has a large impact on regional programs: (a) most identified and expected resources are on federal land; (b) the national energy policies serve as a model for and actually stimulate the formation of state policies; (c) the principal source of economic incentive for geothermal development will be through tax relief, grants, and loans which originate in federal legislation, and (d) the federal government is the originator and the enforcer of most environmental protection and conservation regulations.

This part of Chapter III is divided into three sections. Section 3.2 summarizes federal laws and regulations which affect geothermal development. Section 3.3 describes the activities and responsibilities of different participants at each stage of geothermal development and utilization. Section 3.4

discusses the overall organization and purpose of the federal geothermal program and discusses several activities designed to mitigate legal and institutional barriers to geothermal development.

3.2 Federal Laws and Regulations Relevant to Geothermal Energy

Essentially all major phases of geothermal energy development are subject to federal laws and regulations. The three laws which enable and control the development of geothermal resources on federal lands and which attempt to encourage development on any land are briefly summarized below.

Geothermal Steam Act of 1970

The Geothermal Steam Act of 1970 is one of the most significant laws affecting the pace and direction of geothermal energy development. It controls leasing of federal lands and all phases of post-lease operations on those lands. Pre-lease and leasing requirements are regulated by the Department of Interior, Bureau of Land Management through Title 43, Chapter II of the Code of Federal Regulations (43 CFR, Group 3200). Post-lease operations are administered by the Department of Interior, U. S. Geological Survey through Title 30, Chapter II of the Code of Federal Regulations (30 CFR, Parts 270-271). On other than federal lands, state and local regulations have generally been patterned after those of the Geothermal Steam Act. On federal lands the implementation of federal regulations is guided by Geothermal Resource Operational Orders issued by U. S. Geological Survey. Geothermal Resources Operational Orders have been issued and are titled: Exploratory Operations, Drilling Completion, and Spacing of Geothermal Wells; Pluggings and Abandonment of Wells; General Environmental Protection Requirements; Pipelines and Surface Production Facilities; and Production and Royalty Measurements, Equipment, and Testing Procedures.

Federal Nonnuclear Energy Research and Development Act of 1974

This is the Act which mandated the activities of the Energy Research and Development Administration. One of those activities is the active encouragement of geothermal energy technology development through commercial demonstration. The Act also provides for the acceleration of the commercial demonstration of environmental control systems for energy technologies.

Geothermal Energy Research, and Development, and Demonstration Act of 1974

This act authorizes and defines more specifically the responsibilities of the federal government in developing and demonstrating the commercial viability

of geothermal energy conversion. The objectives of the Act are to be accomplished in concert with private developers through grants, contracts, and loan guarantees.

In addition to enabling and implementing legislation, all geothermal development activity is subject to many environmental protection and conservation laws. The more prominent of these laws are briefly discussed below.

National Environmental Policy Act of 1969

This Act has had profound effects in calling public attention to the environmental consequences of major new projects. The Geothermal Steam Act was the first federal action to which it applied. The Act requires an environmental impact statement for all major federal actions affecting the quality of the human environment. The Act produced a ripple effect in that most states have similar laws for state actions. In most cases of major development, an environmental impact statement can be anticipated at some stage prior to commercial energy production, whether it is on federal, state, or private land. The impact statement must describe adverse impacts including those caused by any kind of pollution, on society and its environment. It also must discuss alternatives to the proposed development and their consequences and must describe irretrievable resource commitments.

Clean Air Act as Amended (1970)

The Clean Air Act also has several sections which may significantly affect geothermal energy development. For example, one section allows and provides for the establishment of intrastate and interstate Air Quality Control Regions in which the states must provide implementation plans for assuring air quality. Under another section the Administrator of the Environmental Protection Agency may publish air quality criteria. Based upon the criteria, he then publishes national primary (to protect public health) and secondary (to protect public welfare) ambient air quality standards for pollutants determined to have adverse effects.

Federal Water Pollution Control Act Amendments of 1972

Several sections of this Act apply to geothermal development. Probably the most significant sections are in Title III - Standards and Enforcement. One of these sections calls for the application of "best practicable control technology currently available" by July 1, 1977, for point sources other than publicly owned treatment works. This section further calls for the application

of "best available technology economically achievable" by July 1, 1983. This section further requires the elimination of all pollutants where technologically and economically achievable. Another section in Title II calls for the definition by the Environmental Protection Agency of such technologies, and effluent limits attainable thereby, through the issuance of "Effluent Guidelines" regulations. For the geothermal energy industry, those regulations have not yet been developed and are not currently scheduled. However, such regulations may be expected when the industry is firmly established and technologies have been demonstrated.

Noise Control Act of 1972

This Act contains broad noise control provisions for regulating and labeling products, many of which are used at geothermal facilities. In addition, the Environmental Protection Agency has been given coordination authority of all programs of other federal agencies relating to noise research and noise control. It has also been given authority to insure that all federal facilities comply with appropriate federal, state, and local noise regulations. Many states and local communities regulate noise, and the U. S. Geological Survey has noise regulations for developers on leased federal lands.

Safe Drinking Water Act (1974)

This Act is administered by the Environmental Protection Agency and allows and provides for state implementation of its provisions. Part C of the Act, "Protection of Underground Sources of Drinking Water," is of greatest significance to geothermal energy development in that it requires the promulgation of regulations to control underground injection. ReInjection is an integral part of most existing and proposed geothermal development.

Resource Conservation and Recovery Act of 1976

The provisions of this Act, administered by the Environmental Protection Agency, are principally concerned with solid wastes. Subpart C - Hazardous Waste Management, important to geothermal energy development, involves regulatory control of storage, treatment, and disposal of potentially hazardous wastes in landfills and surface impoundments. The potentially hazardous wastes may be liquid, solid, or a combination. Wastes considered potentially hazardous are those which may cause or contribute to adverse effects on human health or the environment when not properly controlled. Regulations to be developed under

the Act are likely to have significant ramifications for the geothermal industry in those cases where spent brine surface impoundments are used and where waste sludges are created, such as in the treatment of waters and noncondensable gases.

Toxic Substances Control Act (1976)

This Act is aimed principally at manufacturers and distributors of toxic chemicals in order to control indiscriminate proliferation of such materials in the environment. The provisions of the Act can conceivably apply to minerals which might be commercially produced from geothermal development.

Land Policy and Management Act of 1976; National Forest Management Act of 1976, Fish and Wildlife Coordination Act; Endangered Species Act; Wilderness Act; and Marine Protection, Research and Sanctuaries Act

These federal laws allow for prohibition of or advisory action against certain activities in the interest of preserving land values, wildlife habitats, and esthetic values. They also may allow for or require mitigating measures where harm may occur.

3.3 Activities During Development of a Federal Geothermal Resource

The process of acquiring the right to explore, develop, and produce geothermal resources on federal land is described in detail in a preliminary report by Roschen and Cook.⁽¹⁴⁾ The six phases of development for any given area are described as prelease exploration, competitive or noncompetitive leasing, postlease exploration, development, production, and closeout or abandonment. A brief description of each phase as extracted from the Roschen and Cook report is given below. The responsibility of land management agencies (Bureau of Land Management, BLM; U. S. Forest Service, FS; and U. S. Fish and Wildlife Service, FWS) and the U. S. Geological Survey (GS) at each stage of development is summarized in Table 3.1. Figure 3.1 shows a typical exploration and development sequence, including points at which a company might discontinue or abandon its efforts.

Pre-lease Exploration

Prelease exploration is divided into "Casual Use" and "Exploration Operations."

(1) Casual Use. "Casual Use" as defined in 43 CFR 3209 means "activities that involve practices which do not ordinarily lead to any appreciable disturbance or damage to lands, resources, and improvements." The activities do not

Table 3.1

Stages of Geothermal Development on
Federal Land and Agency Responsibility

Land Management Planning	BLM/FS
Pre-lease Exploration Permit	BLM/FS (Primary) GS and FWS (Consulting)
Pre-lease Environmental Analysis	BLM and/or FS (Primary) GS and FWS (Consulting)
Non-Competitive Leasing Schedule	BLM/FS (Primary) GS/FWS (Consulting)
Non-Competitive Lease Application Review	BLM (Primary) FS/GS/FWS (Consulting)
Competitive Lease Sale Schedule	BLM/FS/GS/ Industry
Competitive Lease Sale	BLM (Primary) FS/GS/FWS/DOE (Consulting)
Development of Lease Stipulations	BLM/FS/GS/DOE
Issuance of Lease	BLM/DOE
Post-lease Environmental Analysis	GS (Primary) BLM/FS/FWS (Consulting)
Post-lease Review of Plans of Operation	GS (Primary) BLM/FS/FWS (Consulting)
Post-lease Permitting	GS (Primary) BLM/FS/FWS (Consulting)

Figure 3.1 Typical Exploration and Development Sequence

Adapted from Raschen and Cook, 1976

involve use of heavy equipment or explosives, and do not involve vehicular movement except over established roads and trails. Casual use does not require a permit or environmental assessment. Casual use generally includes the following: literature review, geological reconnaissance, geochemical survey, and airborne surveys.

(2) Exploration Operations. Exploration operations have been defined in 43 CFR 3209 as "any activity which requires physical presence upon public land and which may result in damage to public lands, or resources." These operations may include, but are not limited to: geophysical operations; drilling of shallow temperature gradient holes (holes of no more than 152 m or 500 feet in depth); construction of roads and trails; and cross-country transit by vehicles over public lands.

Groups who wish to conduct exploration operations on BLM or FS land must file a "Notice of Intent to Conduct Geothermal Resource Exploration Operations" for each operation they propose. This "Notice" must be accompanied by a \$5,000 surety bond or rider to a state-wide or nation-wide bond. The bond ensures compliance with all federal regulations and stipulations governing exploration operations.

Within 30 days after receiving the "Notice of Intent" and the attached bond or rider, the BLM and/or FS prepares an Environmental Assessment Record (EAR) evaluating the impacts of the proposed project. Fish and Wild Life Service and GS provide some input to this document in the form of special stipulations designed to reduce or eliminate anticipated adverse impacts. When this has been done, the BLM's Authorized Officer or the Forest Supervisor will attach all special stipulations necessary to protect the environment to the "Notice of Intent," and will approve the proposed project in writing.

After the exploration project has been concluded, a "Notice of Completion of Geothermal Exploration Operations" must be filed. The Bureau of Land Management will inspect the former project location within 90 days, and will notify the group responsible for the project whether they have complied satisfactorily with all the regulations and stipulations.

Leasing

The process of leasing federal geothermal resources is separated into competitive and non-competitive leasing.

(1) Competitive leasing. Competitive leases are usually issued to the highest qualified bidder on designated tracts of land within a Known Geothermal

Resource Area (KGRA). These tracts of land are selected by surface and sub-surface geological features, drill log data, chemical analysis of water, or by competitive interest in areas.

When a sale is to be conducted, notice is published weekly in a paper of general circulation for four consecutive weeks. The notice specifies time, place, bidding requirements, land descriptions, royalty, rental terms, and any special stipulations. An application, with one-half of the bonus bid, is filed. On the date, at the time and place of the competitive bid, all bids are opened and displayed. The lessor has 30 days to accept or reject the bids. When a bidder is successful, he is required to sign three copies of the lease contract, to pay the first year's rental, to pay the balance of the bonus bid, to file the required bond or bonds, and to submit a proposed "Plan of Exploration." If these requirements are accomplished in the specified time frame, a geothermal lease contract is issued. Failure to comply within the time allowed will result in rejection of the bid and any money submitted with the bid will be forfeited. If a bidder is unsuccessful, the money tendered with the bonus bid is returned to the applicant with the information about the lease sale.

(2) Non-competitive leasing. Non-competitive leases are issued on any available federal lands outside of a KGRA. Geothermal resources supposedly have a lower potential in these areas. Certain lands are, or may be, withheld from leasing. A non-competitive lease is acquired in a manner similar to competitive leasing. An application, bond, or bonds, an application fee, and a proposed "Plan of Exploration" are sent to the proper BLM office. No bonus bids are required on non-competitive geothermal leases. When the application is approved, three copies of the lease contract are sent to the applicant. The applicant must sign the lease contracts and return them along with the first year's rent.

(3) Lease terms. The "Plan of Exploration" is required by federal regulations. This plan should describe briefly the activities that will be conducted on the lands described in the application.

The "Geothermal Resource Lease Contract" allows the federal government to lease geothermal resources and at the same time provides protection for other natural resources. Provisions within the contract require protection of the environment, antiquities, historic values, etc., in compliance with federal regulations. In addition, special stipulations needed to protect unique values of a particular area may be incorporated into the lease contract and compliance becomes mandatory.

Post-lease Exploration

After a lease is issued, federal regulations require that a "Plan of Operation" be filed and approved by the land management agency and GS before any activity other than "casual use" may commence. The "plan," accompanied by maps, will describe all exploration activities that will be conducted on the leased lands. The U. S. Geological Survey, the lead agency, studies the "Plan" and sends copies to the surface managing agency and other interested agencies for comments.

The GS must prepare an Environmental Analysis (EA) covering the specific site of the "Plan of Operation." A discussion of the proposed exploration, such as gravity, resistivity, and temperature gradient surveys, may be included in the "Plan." Generally, the proposal is to drill one or more geothermal resource exploratory wells. An on-site inspection with representatives of the lessee, GS, and the land management agency is then conducted to assess the potential impacts of the proposed operation. The "Plan" and a draft EA are presented to the Geothermal Environmental Advisory Panel (GEAP), who then advises the GS's Area Geothermal Supervisor on the environmental aspects of the "Plan of Operation." The GEAP also recommends mitigating measures to protect the environment. The EA is completed after input is obtained from the GEAP. After considering the effects upon the environment and developing the special conditions or stipulations deemed necessary to protect the environment, the Area Geothermal Supervisor and the appropriate land management agency jointly approve the "Plan of Operation."

Upon approval of the lessee's application(s) for "Permit to Drill," a permit is issued. The lessee then may commence only those operations authorized under the approved "Plan of Operations." The lessee's authorized operations are continuously monitored and inspected by the Area Geothermal Supervisor to ensure that the lessee complies with the applicable regulations and stipulations. Any additional exploratory operations proposed by the lessee require an additional "Plan of Operation." resulting in a procedure essentially the same as the preceding steps.

Pre-lease exploration methods have been defined previously; however, post-lease exploration uses many of these methods on a more intensive basis. For example, exploratory drilling methods, geological information holes and deep exploration wells requiring depths of more than 152 m (500 ft) may be used. These wells require large drilling rigs, a cleared and leveled drilling pad of

one to two acres, and construction of a service road to provide access for men and equipment. If an exploratory well discovers a geothermal reservoir, a series of tests are made to determine whether there is potential for an economically productive well.

Development

Once a successful exploratory well is drilled, plans are made to develop the geothermal resource. A new plan, called a "Plan of Development," must be filed. No development operations will commence until the "Plan" is approved by GS and the appropriate land managing agency. Another EA covering the activities within the "Plan of Development" is prepared by GS. The GEAP again recommends mitigating measures for protection of the environment, which may result in additional stipulations imposed upon the lessee. The lessee then may commence only those development operations authorized by the "Plan of Development."

Again, all activities must be in compliance with the regulations and stipulations. The development of the geothermal resource requires the drilling of a number of development wells. Development wells are drilled and completed in basically the same manner as the exploratory wells, and require the same considerations.

Production

After a sufficient number of development wells are drilled, plans are made for the most economical and feasible use of the geothermal resource. The "Plan of Development" may be revised and submitted to the GS for approval, and no action will proceed until the revised "Plan" is approved.

A number of procedures must be followed before production begins within a geothermal field. Prior to placing the subject wells on prolonged production, the lessee must collect data concerning existing air and water quality, noise, seismic and land subsidence activities, and the ecosystem of the leased lands for at least one year prior to the submission of a "Plan of Production." Additionally, the lessee must submit an annual report of compliance with environmental protection requirements, giving a full account of the actions taken. The use of the leased lands or other federal lands for geothermal production will be authorized only under a separate permit issued by the appropriate agency.

An EAR is a prerequisite to the issuance of a permit for the use of the leased lands or other federal lands for a power generation plant, pipeline, transmission line, or other facility. Granting of a permit is not a license

to construct the facilities. The construction, operation, and maintenance of a power generation plant can only be accomplished by obtaining a "Certificate of Public Convenience and Necessity." This certificate is granted by the Public Utilities Commission of the state having jurisdiction and regulatory authority over the company making application. Pipelines, power plants, and transmission lines may be constructed if the resource is such that electricity can be produced. A power plant and associated wells, similar to those at The Geysers, would occupy about 640 acres or one section of land within a township.

If the production of electricity is not feasible because of the reservoir conditions, the geothermal resource may be used for other purposes, such as greenhouses, hothouses, space heating - air conditioning, food processing, etc. These industrial uses may occur also in conjunction with electrical generating plants.

Close out

A sizable geothermal field would be abandoned gradually; in a small field, an abrupt cessation may be likely. If the exhausted production wells are strategically located, fluids reinjected into the reservoir through the exhausted wells may lengthen the life of the remaining field. If the wells are shut in, tests may reveal that the bottom hole temperatures and fluids have recharged after a lapse of time. Plugging and abandonment of geothermal wells must be done in accordance with Geothermal Resource Operation Order No. 3. In short, close-out or abandonment of all or a portion of a geothermal field requires abandonment of the subsurface, removal of the surface installations, and rehabilitation of the surface.

Summary of Participants and Activities

As just discussed and as shown in Figure 3.1, the process of discovering, developing, and utilizing geothermal resources is quite complex. There are many separate classes of activities, carried out by individuals and agencies with different objectives and responsibilities, and the activities of these individuals occur in a context of potentially conflicting and restrictive rules and regulations.

The objectives of the investors and of industry representatives are to minimize the time and money involved in developing and utilizing geothermal resources, and to maximize their profits. As previously indicated, these individuals may decide to continue or to abandon their efforts at any point in

the process for any number of reasons. A particular resource area may prove to be of unacceptable volume or quality, or the technology required to exploit a resource may not be available or, if available, of uncertain reliability. The time and financial cost involved in preparing a site for drilling, actually drilling the well, developing a production field, and producing and distributing the resultant energy may or may not be acceptable in terms of investment potential.

However, in addition to these minimum costs for conducting their business, other factors also must be considered. These are the costs resulting from institutional issues. Time is required for activities like preparing plans of operation, processing permits, and gathering environmental data. Additional cost factors include the expense of environmental reports, bonds, and fees required by government permits, and mitigating technology required for obtaining permits.

The objectives of government agencies are generally not opposed to geothermal development, indeed they may be supportive of such development. However, by law and regulation, government agencies have the responsibility to assure that any activities associated with geothermal development are compatible with air and water standards, wildlife, and existing patterns of land uses. They must also hold public hearings before granting permits. Generally, they have a responsibility for controlling the pace of development, and they have a desire to achieve a politically acceptable resolution between pro-and anti-growth forces.

Public interest groups and private citizens may differ among themselves in terms of their attitudes toward geothermal development. In general, however, while they tend to have very little knowledge concerning the details of such developments, they are concerned with minimizing adverse environmental and socio-economic impact. (15,16)

Clearly, cooperative activity is required to achieve any degree of geothermal development. Each participant has a set of operating procedures based upon or imposed by a rational set of objectives. Since, however, there is actual or potential conflict, political cooperation is required. (12)

3.4 Federal Response to Legal and Institutional Barriers to Geothermal Development

The Federal Program

The overall purpose of the federal geothermal program is to stimulate commercial development by private industry and local public power authorities.

The program goal is to increase commercial utilization of geothermal energy from the present rate of 0.04 Quads per year to about 6.0 quads per year 2000 and to over 16.0 Quads by the year 2020. ⁽¹⁷⁾

The federal program, which includes the programs of a number of federal agencies, is coordinated by the Interagency Geothermal Coordination Council (Figure 3.2). The council is quite young; it was established and had its first meeting on January 14, 1976. ⁽¹⁸⁾ The bulk of the federal research and development is now carried out by DOE and its Division of Geothermal Energy (DGE), and by the agencies of the Department of Interior (DOI), especially the U. S. Geological Survey. Environmental research, monitoring, and policy development receive the attention of the Environmental Protection Agency (EPA) and DOI's FWS, and the Water Resource Council as well as DOE. Institutional and policy research are being advanced by DOE and the Treasury Department. The Geothermal Loan Guaranty Program has been instituted by DOE.

In support of the commercialization component of the program, the federal government is working closely with state and local governments, industry, municipal authorities, and environmental and other public interest groups in identifying appropriate federal initiatives that would most effectively encourage investment in geothermal energy and promote public acceptance of its development. An Advisory Committee on Geothermal Energy has been established to facilitate exchange of information and advice with the non-federal sector.

Institutional Barriers Panel

As shown in Figure 3.2, three panels were established under the Council's Charter: Resources Panel, Research and Technology Panel, and Institutional Barriers Panel. Each panel was given the responsibility for gathering relevant information and for developing recommendations for council's consideration. Of greatest concern to this chapter was the Institutional Barriers Panel (IBP). This panel was given the following responsibility:

It is responsible for assessing legal, environmental, regulatory, and other aspects of federal, state, and local government policy as they relate to geothermal energy and for developing recommendations for changes and improvements in related laws, policies and procedures, and for examination of other institutional aspects of geothermal energy, including nongovernmental aspects. ⁽¹⁸⁾

*Chairmanship Function

Figure 3.2 Interagency Geothermal Coordinating Council Adapted from 20, p. 128

A number of problems which affected geothermal development were identified by IBP. These problems included the following: federal taxation, federal-state utility rate structuring, and federal-state environmental protection and standard. A rather large number of problems were derived from the Geothermal Steam Act of 1970; these included issues associated with overlapping lease applications, cash bonus competitive leasing, acreage limitations, work requirements, and casual use exploration. Numerous recommendations were made by IBP to the Council. The necessary actions to implement the approved recommendations are underway in the various responsible agencies. (18,19,20)

In particular, the following actions were taken. Several amendments were proposed to the Geothermal Steam Act of 1970 and some of these were incorporated into the energy program the President proposed to Congress. Amendments also were proposed to the regulations designed to implement the Steam Act. In addition, amendments were proposed to the Internal Revenue Code of 1954 and to the Geothermal Research Development and Demonstration Act of 1974. (20)

In short, the action of the IBP through the Council has led to a number of activities which should change certain federal policies that were perceived to be impeding the development of geothermal resources. The panel has also reported that a high degree of interest in their activities was evident in their discussion with industry and in inquiries from members of Congress and others.

Cooperative Arrangements in the Department of Interior

In addition to the problems mentioned above, the IBP identified problems associated with delays in obtaining leases, environmental reviews, and various types of permits. At least in part through the activities of the Council, a Memorandum of Understanding for the Geothermal Program was approved by the directors of BLM, GS, and FWS. (21) This memorandum is an agreement among these DOI agencies to cooperate on a set of procedures for federal land management practices. Figure 3.3 and 3.4 illustrate the various participants and the administrative procedures for geothermal regulatory processes during pre-lease and post-lease activities, respectively.

As may be seen in Figures 3.3 and 3.4, three different offices of BLM, five offices of GS, three offices of FWS, the GEAP, and DOE, all have responsibilities in regulating and controlling geothermal development on lands under DOE control. Some of the activities shown in these two figures were also discussed in reference to Table 3.1, but here the routine steps in the process

COMPETITIVE LEASING PRIMARY RESPONSIBILITY - BLM

NONCOMPETITIVE LEASING PRIMARY RESPONSIBILITY - BLM

ABBREVIATIONS

BLM	- Bureau of Land Management
BLM-DO	- Bureau of Land Management District Office
BLM-SO	- Bureau of Land Management State Office
GS	- U.S. Geological Survey
GS-RCH	- U.S. Geological Survey, Regional Conservation Manager
ACS	- Area Geothermal Supervisor
GS-AG	- U.S. Geological Survey Area Geologist
GS-DC	- U.S. Geological Survey District Geologist
FWS	- Fish and Wildlife Service
FWS-BO	- Fish and Wildlife Service Regional Office
FWS-AO	- Fish and Wildlife Service Area Office
EAR	- Environmental Analysis Record (prepared by BLM)
EA	- Environmental Analysis (prepared by GS)
GEAP	- Geothermal Environmental Advisory Panel
R/C	- Agency Review and Comment
DOE	- Department of Energy

Figure 3-3 Geothermal Regulatory Activities: Pre-Lease Activities

(COMPILED FROM GEOTHERMAL STEAM ACT OF 1970, FEDERAL RULES AND REGULATIONS 43 CFR PART 3000 AND 30 CFR PARTS 270 & 271, AND MEMORANDUM OF UNDERSTANDING FOR THE GEOTHERMAL PROGRAM - USGS, BLM, FWS)

Figure 3-4 Geothermal Regulatory Processes: Post-Lease Activities

such as the requirement of notification, comment, approval, signature, and transmittal among over a dozen agencies are described in considerable detail. The memorandum of understanding among the agencies of DOI and DOE serves as a vehicle for coordination of these activities. The net effect is to expedite pre-lease and post-lease activities and reduce many of the uncertainties associated with federal land management.

Interagency Geothermal Streamlining Task Force

While the Memorandum of Understanding was a major step toward improving the management of federal land, it only applied to the management of land under the control of DOI. In the Southwest Region, very large tracts of land with geothermal potential are on Department of Agriculture (DOA) lands administered by the U. S. Forest Service (FS). An Interagency Geothermal Streamlining Task Force was formed to assist in coordinating the activities of DOE, DOI, and DOA as they related to geothermal development. (22)

Specifically, the Task Force is developing recommendations to IGCC for appropriate action to implement the President's commitment to Congress that:

"The Department of the Interior and Agriculture will streamline leasing and environmental review procedures to remove unnecessary barriers to development of geothermal resources." (22)

This objective was included in the President's comprehensive energy program submitted to Congress in April 1977. The commitment was prompted by the fact that although the Geothermal Steam Act was passed nearly seven and one-half years ago, there is still no commercial production of this resource on federal lands.

The Interagency Geothermal Streamlining Task Force has undertaken a study which includes a) a comprehensive analysis of the elements of the present program designed to identify the sources of delay and quantify delays which are actually occurring; and b) the determination of the potential effects upon program performance of a series of options for program modification. The effectiveness of alternative options will be assessed in terms of their relative ability to support the Department of Energy's projected geothermal power-on-line schedule while adequately protecting the public interest and the environment.

The study will also incorporate input provided by the public, industry, environmental groups, and state agency officials through a series of workshops held in the western states in June. The schedule for these meetings was widely publicized in order to obtain the broadest participation possible.

The Task Force developed a series of options for modifying the geothermal leasing and permitting program (described below) and comments on them were requested from the above groups. In addition, suggestions for additional alternatives were solicited.

Below are listed the three options that were proposed by the Task Force and the program modifications under consideration for each option. Various advantages and disadvantages were discussed for each alternative in the announcement distributed by the Task Force. (22)

Option I. Improve the present system through changes in regulation and administrative procedures.

- A. Use regional or areawide environmental analyses in pre-lease review and conduct site specific studies only during the post-lease permitting process.
- B. Set time limits or timeframes (through administrative directive and/or regulations) for issuance of leases permits.
- C. Improve coordination in all phases of pre and post-lease activities.
- D. Improve uniformity and consistency of policies and procedures with respect to lease stipulation among the involved agencies.
- E. Institute formal nomination procedures for KGRA's and non-competitive areas.
- F. Allow no-surface-occupancy leases in wilderness study areas and other special areas where requested.
- G. Modify KGRA regulations.
- H. Allow issuance of non-competitive leases unless the area is in a KGRA at the time of application.
- I. Provide budgets in proportion to workloads, organizational needs, and priorities.

Option II. Base leasing decisions on areawide environmental assessment in combination with land management plan.

Option III. Provide for separate environmental analysis of exploration and development phases, with initial review of exploratory impacts only and comprehensive review after a discovery is made.

The next part of this chapter reviews some of the studies which led to these recommendations.

3.5 Previous State and Regional Studies of Institutional Factors

The aim of this section is to review the assumptions, procedures, and results of some recent research conducted at the regional and state level on the legal and institutional barriers to geothermal development. Two excellent papers, one by Sacarto⁽⁶⁾ and the other by Schuller et al,⁽¹³⁾ adequately illustrate two approaches used in this type of research. These two papers show that very similar lists of needs and similar sets of recommendations are generated regardless of how the issue of state-level and institutional constraints to geothermal development are studied. The two general types of approach to the study of legal and institutional factors affecting geothermal development may be classified as (a) those which promote or encourage changes in the legal and institutional infrastructure which controls the geothermal process as a means of reducing the uncertainties, the delays, and the cost experienced by the legal and institutional framework so that participants can more efficiently learn the process and the steps required to adapt to it; and (b) those which promote stable policies. These two approaches and the recommendations they generate are discussed below.

Studies Promoting Policy Changes

In State Policies for Geothermal Development, Sacarto reviews for the National Conference of State Legislatures (NCSL) the various technical, economic, and institutional aspects of geothermal development as they exist and as they affect geothermal development in the thirteen western states and the gulf states of Texas and Louisiana.⁽⁶⁾ Sacarto accepts the most optimistic projections for geothermal potential as a working hypothesis. These projections are that the potential for geothermal resources is huge. For electrical generation this energy projection is in the order of 100,000 MW over the next 20-30 years (one-fifth the current U. S. electrical capacity). The nonelectric applications are presumed to have equally great though unspecified potential. It is further assumed that these contributions can occur at prices competitive with energy currently generated from other sources and with relatively little environmental impact.⁽¹⁶⁾

Given those assumptions, Sacarto seeks to explain why the energy industry has not invested large sums of money into the development of geothermal resources. Sacarto recognizes that utilities tend to be wary of new, unfamiliar resources, especially those for which there is a requirement for site specific power plant

construction and for which there is still an uncertain technology for electric power generation. These uncertainties on the part of a generally conservative industry hinder the rapid development of the resource. Sacarto, however, places a major share of the inhibitory forces in state and federal policies. His comments on obstacles to geothermal development at the very beginning of his report set the stage for what follows in his report: . . . "State and federal policies that hobble geothermal development . . . cripple the geothermal industry . . . failed to encourage large scale development . . . accentuate the uncertainty and risk already inherent to geothermal exploration and development."⁽⁶⁾

After examining, in turn, features of the resource, factors which characterize and affect the exploration and development of a geothermal resource area, and the means by which various types of taxes are applied to geothermal development, Sacarto reviews how the states have characterized the resource and how they regulate the leasing of state lands and the development of the resource within the states. Based upon this review of the industry and the state and federal policies which affect the industry, Sacarto identifies six conditions needed by the industry if it is to pursue large scale development; utility confidence in the resource, equitable tax treatment, prompt exploration of extensive land areas, long and secure tenure for productive properties, prompt facility siting and development, and competitive access to various consumers.⁽⁶⁾

Sacarto recommends a set of nine policies which could be enacted by state governments to achieve these conditions. These policies and their objectives are as follows:

1. Policies designed to direct public attention to geothermal resources as an alternative form of energy and power. Both policy makers and the general public need to be exposed to more information concerning the immediate and longterm values available from geothermal resources.

2. Policies designed to create and nurture an interstate geothermal development compact. Such a compact would facilitate communications between the states and other participants in the geothermal process and thereby lead to improvements in geothermal legislation and regulations.

3. Policies designed to clarify the statutory definition of geothermal resources. Such clarification is necessary to remove

uncertainties associated with such issues as resource ownership, taxing policies, and regulatory processes. A distinction between geothermal resources and established water resources is especially important in the water scarce Southwest Region.

4. Policies designed to reduce the need for unreasonably high levels of water appropriation. Statutory assurance is needed by industry that water rights are necessary for only the water that is consumed by the geothermal process, not for the total volume which may be processed.

5. Policies designed to establish more uniform and more realistic provisions for assessing the value of undeveloped geothermal properties for the purpose of taxation. These policies would recognize that no income value can be attributed to prospective geothermal production before commercial quantities of the resource are actually produced and sold.

6. Policies designed to provide state tax benefits and encourage federal tax benefits to the geothermal industry. Income tax deductions for intangible drilling costs and percentage depletion allowance will enable the industry to attract the necessary investment capital.

7. Policies designed to establish more secure leasing provisions for state-owned land and encourage the establishment of federal lease provisions more suited to geothermal development. These provisions would include a reevaluation of terms, renewal arrangements, acreage limitations and lease adjustment clauses.

8. Policies designed to improve the market position of electric power produced from geothermal energy. These policies would encourage utilities to invest in geothermal projects through such means as financial incentives, demonstration projects, and siting priorities.

9. Policies designed to encourage nonelectric application of geothermal resources. The direct application of geothermal resources may, in the long run, be the most efficient and effective use of the resource.

The impact and thoroughness of the NCSL publication can be measured by the extent to which it is referenced by other investigators and by the extent to

which the recommendations made by Sacarto are also made by other independent investigators. For example, a special report by the staff of the Western Governors Regional Energy Policy Office in May, 1976, made recommendations for encouraging geothermal development which are essentially indistinguishable from those made by the NCSL report.⁽¹³⁾

A series of studies commissioned by the Northwest Energy Policy Project (NEPP) came up with conclusions which with one important exception, are in basic agreement with those of Sacarto.^(7,11,12) In one of these studies, Johnson, et al,⁽⁷⁾ agreed with Sacarto that the main hinderances to geothermal development in the Northwest are the economic risks faced by potential developers. They argue, however, that there is little the states can do to significantly mitigate those hindrances other than "to be aware of the potential and of the limitations of geothermal energy."⁽⁷⁾ They emphasize that potential lands for development are federally controlled, the principal tax obligation is federal, and (by implication) the funds needed for effective stimulation of exploration and development must come from the federal treasury.

As part of another study in the same NEPP series of reports Hiatt focused on institutional constraints and opportunities for "unconventional energy sources" including a geothermal energy development.⁽¹⁰⁾ Hiatt reviewed a wide range of state and local governmental actions which could be categorized as negative and positive incentives. He further gives examples of official action which would or could affect the development of geothermal energy sources. These actions, with regard to unconventional energy production, were grouped into four categories: no action, direct economic incentives, indirect efforts at promotion, and direct action toward production. When specifically addressing the public policy options application to geothermal energy Hiatt intensively drew upon Sacarto's work. In fact Hiatt's presentation of policy options and his recommendations were extracted from the State Policies Report published by NCSL.

Before leaving this subsection concerned with the status of and changes required in state policies, reference should be made to NCSL's Geothermal Policy Project. This new project was launched on January 16, 1978. "The objective of the project is to stimulate and assist the review of state policies that affect the development of geothermal resources. Successful completion of the project is to facilitate state statutory and regulatory environments that are consistent with efficient development of geothermal resources."⁽²⁴⁾ Hence, the project is an obvious extension of the previous work performed by Sacarto

for NCSL. The project has selected six states in which to concentrate its efforts during 1978. Two of these six states (New Mexico and Utah) are currently in the Southwest Region. This effort, funded by DOE, will complement the efforts being made by the Southwest Regional Program as reflected by the present chapter.

Studies Promoting Stable Policies

Schuller et al., concentrated on identifying and analyzing the nontechnical problems which hamper the production of electricity from geothermal resources in California.⁽¹³⁾ The assumptions they made in performing that analysis and the possible solutions they proposed are equally appropriate for none electric applications and to regions outside of the state of California.

Schuller et al., like Sacarto and others, notes the discrepancy between the potential and the actual plans for the utilization of geothermal energy. They also accept the conclusion that nontechnical problems such as leasing, financing, and permitting appear to be a major reason for significant and costly delays in geothermal development. However, rather than focusing on the laws and regulations which might create or contribute to these nontechnical problems, Schuller et al., focuses on the behavior of the significant participants who must operate within the constraints imposed by the nontechnical problems.

In particular, Schuller et al., argue that "smoothing or making minor modifications to the existing regulatory process is likely to do more to speed the development of the geothermal industry than attempting wholesale changes to the process."⁽¹³⁾ This argument is based on the concept of institutional learning which holds that in any process certain minimums of time, money, and trouble are required to learn the substance and procedures of the process. When the process is unstable and when the participants cannot devote continuous and undivided attention to the process, the learning will be even less efficient.

Even though there are large areas of uncertainty concerning the impacts of procedural and policy actions, there are a few individuals and organizations who have learned a great deal about the geothermal development process; they have learned what is necessary to operate effectively. Others are in various stages of acquiring the necessary knowledge. If the process remains stable, a type of institutional learning will continue. All the participants will continue to acquire useful knowledge which they can in turn share with others in the process. Hence, even if a policy or regulatory system is not as good in some sense as it might be, the participants can perform well within that system. Any new system of policies and regulations would require that all

participants begin the learning process all over again; the time, cost, and trouble of learning the new system may outweigh the gains the new system were to produce.

Schuller et al., examined the nontechnical problems within each of five technical stages in the development of geothermal resources (leasing, exploration, marketing the resource to a utility, constructing the power plant, and transmitting the electric power to consumers: as well as nontechnical problems associated with financing, environmental impact reporting, and the activity of several agencies unique to California. In each area, these investigators examined proposals made by various participants in the process (federal and state agencies, representatives of industry and public interest groups, and others).

All proposals were evaluated in terms of whether they would help participants adapt to, or promote relatively minor modifications in the existing system. Six classes of proposals were acceptable under that criterion.⁽¹³⁾

(1) Those that emphasized the value of gathering and disseminating information about the substance and procedure to those that need it (e.g., baseline environmental data, resource exploitation technology, mitigation technology, and discussion of procedural rules).

(2) Those that are aimed at refining and codifying substantive and procedural rules that may be a source of delay or difficulty because of their ambiguity (e.g., either more formal statements to increase the stability of a rule or more flexible rules which are sensitive to site specific peculiarities).

(3) Those that emphasize the use of technological or procedural innovations to mitigate problems of legal, institutional, or political nature (e.g., methods such as slant drilling and well head mufflers that can be used to satisfy environmental requirements).

(4) Those that emphasize the value of advance planning to reduce administrative costs, delays, and troubles, (e.g., careful preparation for negotiations between parties).

(5) Those that involve the selective resolution of political and legal problems (e.g., generating public support for the industry).

(6) Those that suggest the direction that should be taken by future research and development (e.g., proposals that encourage DOE and others to provide demonstration grants rather than basic research grants).

These six classes constitute only relatively minor changes that were designed to minimize the need for new institutional learning or to maximize the efficiency of any institutional learning which must occur. With the same criteria in mind, Schuller, et al., also gave support to two kinds of major change. In the latter two instances the criterion was that the change would require the acquisition of only minor amounts of new knowledge. These acceptable proposals for major change are as follows:

(1) Any major change that would increase the relative attractiveness of the geothermal industry in the investment area (e.g., tax credits for geothermal investments).

(2) Any major change that would reduce the number of participants through organizational integration (e.g., reservoir unitization, or vertically integrated companies).

The eight types of proposals listed above all meet the criterion that changes in policy should help participants adopt to, or promote relatively minor modifications in the existing system. Schuller et al., imposed the further restriction that acceptable proposals must in some way reduce the time, money, and trouble associated with (a) the process of bringing the proposal itself into law or into practice and (b) the effect of the proposal once it is put into practice. Clearly, there are proposals such as one which might seek to exempt the geothermal industry from environmental impact legislation, which would accelerate the development and utilization of geothermal resources if they became law, but which probably could not become law or perhaps could but only with large expenditures of time and money and large amounts of trouble.

The criteria developed by Schuller et al., for evaluating proposed changes in the geothermal process seem to recognize the needs of industry and also take into account the probable reactions of special interest groups and the realities of the American political scene. Schuller et al., used these same criteria to identify proposals that should be avoided. These included:

1. Proposals that add more steps in the regulatory process - -
for example, proposals for environmental appeals boards.

2. Proposals aimed at removing geothermal development from local control or the environmental review process.
3. Proposals involving major overhauls of the existing lease system.
4. Proposals involving significant changes in normal patterns of property taxation.
5. Proposals using federal or state "expeditors" to resolve conflicts or to provide information.

3.6 Summary of Previous Regional and State Policy Studies

The difference between those studies which promote changes in state policies and those which encourage caution in accepting proposals for changes in state policy may be more in style than in substance. The major recommendations each derives from their efforts are not significantly different.

Sacarto provides an excellent starting point for one just beginning an analysis of the institutional factors which may affect the development of geothermal resources. His report indicates what to look for, where to look, and what you might find as a result of your efforts. While his proposed policies for state government are clearly designed to most directly benefit the geothermal industry, they are not oblivious to the needs of the governmental and public sectors nor do they ignore the problems associated with adjusting to major revisions in policy and regulation. However, Sacarto's references to the needs of the government and public domains are primarily concerned with the more obvious consequences of geothermal development. For example, the statement that "irresponsible geothermal operations can pose clear dangers to public health and local environments."⁽⁶⁾ Furthermore, the concerns expressed over the effects of major changes in policy are directed at the cost to industry for converting to the new approaches and the seriousness to industry of unforeseen complications which the new procedures may introduce. With respect to major changes in leasing methods, Sacarto notes that "the procedures may fail in practice to protect the explorer."⁽⁶⁾

Schuller et al., provide a careful analysis of over 98 separate proposals for changes in the legal, institutional, and political context of geothermal development. In the process of doing so they provide future researchers with two important guides for success. First, Schuller et al., explicitly underscore the importance of behavior issues which must be taken into account when a decision is to be made concerning the policies and procedures. It

is a generally accepted truth that individuals and groups will react differently in familiar (though perhaps understrable) situations than they will in situations which are unfamiliar and hence within which outcome are more uncertain. It is also true that individuals and organizations representing different legitimate interests will perceive the consequences of a given change in policy in quite different ways. Second, Schuller et al., have developed a systematic procedure for examining proposals for change and a set of well defined criteria for choosing among those proposals which should benefit future researchers in the area of policy regulations.

One proposal is common to both the Sacarto and the Schuller et al. studies. That is the proposal to encourage cooperative activities among the various industrial and governmental participants. This may be an especially important issue for participants operating at the state level. If Johnson et al. are correct in their observation that there is little state and local level policy action can accomplish by themselves,⁽⁷⁾ their only recourse may be for state and local agencies to combine their efforts at promoting geothermal development and at promoting changes in federal policies for land management, regulation, and taxing. Industrial and federal policy making entities sometimes might view local participation as constraints on their ability to proceed responsibly. However, local participation should be viewed as an opportunity for securing local and public input, understanding, and even support.⁽¹¹⁾

Institutional Factors Operating in the Southwest Region

The following discussion of state-level legal and institutional factors in the development of geothermal energy is organized into four sections: objectives, procedures, results concerning the current status of geothermal development, and results in terms of the identification of major participants within each state.

Objectives

The objectives of this section of the report are two-fold. The first objective is to identify for each of the southwest states the current status of geothermal development with the aim of isolating the contribution of legal and institutional factors. The goal is to identify how various state-level statutes or regulations and state level taxing or environmental protection procedures may have affected the rate of leasing, exploring, developing, and utilizing geothermal resources within each state.

The second objective is to identify the principal participants in the geothermal development process within each state. According to this approach, the factors of interest occur as a result of actions of and the interactions among participants in the development process. These actions and interactions are initiated and constrained by various statutes, regulations and policies, but they also may change as a result of institutional learning.

The major theme of the second objective is that the behavior of an individual participant (and the collective behavior of a group of individuals in the same institutional agency) is affected by the experiences that individual (or group) has had. Consequently, the perceptions attitudes, and behavior of participants in the geothermal development process can be predicted on the basis of concepts derived from the behavior sciences.

To underscore the importance of the behavioral aspects of the entire process, it must be emphasized that any given regulation or the consequences of any given action may be perceived quite differently by participants who have different responsibilities. For example, one developer has complained that it may take as long as six months to obtain a permit to drill a geothermal well. On the other hand, a state-level regulator was attempting to be quite positive when he pointed out that a permit to drill a geothermal well can be obtained in as little as twelve to eighteen months. The developer and the regulator should not be expected to automatically perceive the permitting process in the same way. The resulting conflict in goals and operating procedures may be resolved without any special mitigating action by anyone. Resolution of the conflicts may occur through a mutual learning process that will occur as the participants continue to interact with one another. At times, resolution of conflicts can be hastened by a change in technology or in the legal and regulatory content.

Three types of data were needed to achieve an understanding of the role of institutional factors in geothermal development in the Southwest. First, information concerning the status of geothermal development was needed for each state. In particular, it was necessary to determine how much activity was occurring at each stage in the development process. Second, information was needed concerning the current status of laws, regulations, and policies within each state. Third, information was needed about the various participants in the geothermal development process.

Information concerning the status of geothermal leasing, exploration and development was obtained from a number of independent sources. Information of

this type was provided in the resource data sheets the state teams provided for each resource area. Current information on the status of geothermal resource development was also available from BLM lease status reports and from the land departments within each state. Information concerning the legal and regulatory provisions, and the identify and characteristics of participants was obtained from reports prepared by data collectors working for the respective state teams.

Results - Current Status of Geothermal Activity

Leasing of Resource Areas

The issue of whether or not a geothermal resource is developed depends initially upon a developer's ability to acquire stable access to the geothermal reservoir. The relative accessibility of the reservoir depends upon ownership of resource, and that in turn often depends upon how the resource is legally defined.

In this regard, the states may have little control over who, if anyone, has access to the resource. The states generally own relatively small amounts of land surface. Table 3.2 shows the extent of federal, state, and private land ownership among the five southwestern states. No state owns more than about fourteen percent of its surface area and most own less than ten percent. Federal ownership accounts for from one-third to over four-fifths of the land. Private ownership of land is also quite high, ranging from just over thirteen percent to nearly sixty percent.

If the geothermal resource is defined as a type of water or mineral resource, it may be legally separated from the land surface. In this manner, ground water is considered a property of the subsurface estate and is controlled by the state as a public resource. Arizona is the only exception to this rule in the five southwestern states. In Arizona, ground water is generally attached to the surface, and hence its ownership may be determined through court orders.

Minerals are generally attached to subsurface estates, and ownership of these minerals also may be separated from ownership of the land surface. State and federal land management practice has often reserved mineral rights to the government while selling off the surface rights. Consequently, since surface and subsurface estates may be independently owned and controlled, the attachment of the geothermal resource to either estate or to neither estate will determine who has legal custody of the resource. Table 3.3 shows the amount

Table 3.2

Land Ownership in Southwest Region*
In Million Acres

State	Total Acreage	Federal		State		Private	
		Acres (M)	%	Acres (M)	%	Acres (M)	%
Arizona	72.688	32.433	44.6	9.222	12.7	31.033	42.7
Colorado	66.486	24.152	36.3	3.233	4.9	39.101	58.8
Nevada	70.264	60.725	86.4	0.086	0.1	9.453	13.5
New Mexico	77.766	26.388	33.9	11.032	14.2	40.436	51.9
Utah	52.697	35.060	66.5	4.923	9.3	12.714	24.2

*From Sacarto State Policies for Geothermal Development, November, 1976 (Ref. No. 6)

Table 3.3

Mineral Acreage Reserved to the State and to the United States*
In Million Acres

State	Mineral Subsurface Estate	
	Reserved by State	Reserved by U.S.
Arizona	1.000,000	5.662,640
Colorado	1.000,000	12.929,974
Nevada	---	0.738,593
New Mexico	2.000,000	24.275,069
Utah	0.919,000	3.765,561

*Adapted from Sacarto, State Policies for Geothermal Development, November, 1976. The acreage given for state mineral lands are only rough approximations. The acreage given for federal reserves are accurate as shown through 1948; approximately 15% more land was patented with mineral reserves through 1974.

of land acreage in each state reserved to the state and federal governments because of these mineral reservations.

The net effect of mineral and ground water reservations is to create considerable uncertainty about who controls access to the geothermal reservoir. The issue would of course be settled if there were a common definition of what is and is not a geothermal resource. However, as pointed out by Sacarto, there are important differences in how the five southwest states define the resource.⁽¹⁶⁾ New Mexico and Utah explicitly distinguish between the thermal and mineral components of the geothermal resource and the waters which transmit those components. Arizona and Colorado make clear distinction between water, mineral, and geothermal resources. Following the definition used by the federal government, these latter two states include all products (including water) of the geothermal process in their definition of a geothermal process. To complicate the issue further, while Arizona includes any mineral or minerals, exclusive of fossil fuels and helium, in their definition of geothermal resources, Colorado explicitly states that geothermal resources are not mineral. Finally, to complete a summary of the five states, Nevada defines geothermal resources as simply heat and is adopting special regulations to govern their development in the state.

As a result of the widely varying and still unstable definition of geothermal resources across the five states, there is uncertainty concerning which level of government owns the resource and which agencies within the state government have regulatory control over leasing, exploration, and development of the resource.

While these uncertainties remain, leasing has nevertheless occurred. Table 3.4 shows the amount of federal and state lands that have been leased for geothermal exploration and development in the Southwest Region. The numbers in parentheses refer to the number of separate leases in each category. As may be seen, leasing activity varies considerably across the Southwest Region. The status of leasing is moderately high in both Colorado and New Mexico. The total acres leased in Colorado include 40,000 acres which have been dropped after the completion of exploratory drilling.

Taken together, the acreages of state and federal land leased for geothermal activity may appear quite high, suggesting that there are no barriers to geothermal development at the leasing stage. That may be a misleading conclusion. Table 3.5 shows a more detailed breakdown on the status of lease

Table 3.4

Acreage of State and Federal Geothermal Leases*

State	Federal Leases		State Leases
	KGRA	Non-KGRA	
Arizona	- - -	6,508 (?)	- - - -
Colorado	5,036 (3)	28,488 (25)	83,192 (27)
Nevada	152,662 (79)	729,309 (?)	- - - -
New Mexico	70,911 (40)	88,490 (45)	63,374 (147)
Utah	86,447 (50)	340,011 (199)	210,570 (221)
Totals	315,056 (172)	1,192,806 (269)	357,136 (395)

*From State Team Final Reports, August, 1978

Table 3.5

Status of Lease Sales on Federal KGRA's*

State	Theoretically Available for Leasing		Acres Offered		Acres Bid on		Acres Accepted	
	BLM	FS	BLM	FS	BLM	FS	BLM	FS
AZ	3,240	0	780	0	0	0	0	0
CO	11,271	1,513	11,271	0	5,036	0	5,036	0
NV	326,802	4,160	201,988	2,560	148,163	0	145,682	0
NM	190,320	1,224,004	101,693	29,375	62,482	18,050	62,482	18,050
UT	83,215	15,572	78,966	10,852	77,277	10,852	77,277	10,852
Total	614,848	1,245,249	394,698	42,787	292,958	28,902	290,477	28,902

*From Streamlining Task Force, April, 1978

sales of Federal KGRA lands in the Southwest. This table shows KGRA acreage theoretically available, the acreage actually offered for bids, and those for which bids were received and accepted. This breakdown is shown separately for BLM and FS lands.⁽²²⁾ Of the KGRA land under their management and theoretically available for leasing, BLM has offered 64 percent for bids but FS has offered only 3 percent. Clearly, there must either be a large difference in the types of lands these two federal agencies manage or a difference in how they process these lands for the impact of geothermal development activities. Once the KGRA lands are offered they may not have received any bids. The success ratio here does not differ substantially between BLM and FS (73 percent of the acres offered subsequently received bids). The relative success of competitive KGRA land offerings is much higher in the Southwest than it has been across the U. S. For the U. S. as a whole, bids were received for only 45 percent of the KGRA acreage offered. In the Southwest (and the nation as a whole) the land managers generally accepted a bid for a KGRA offer when one was received.

The relative success of non-KGRA leasing parallels that just discussed for KGRAs. As of December 31, 1975, 301 non-competitive lease applications were filled with FS of which 14 (5%) were issued and 121 (40%) were either rejected or subsequently withdrawn. For the same period, 2613 non-competitive lease applications were filed with BLM of which 709 (27%) were issued and 1508 (57%) were rejected. Hence, BLM rejects about fifty percent more non-competitive lease applications than FS, but it also issues 600 percent more non-competitive leases. The difference in success between BLM and FS non-competitive lease application is about the same for the country as a whole as it is for the Southwest. Over both land management agencies, however, percent of non-competitive lease applications issued is much higher in the Southwest than for the country as a whole (26% vs. 16%). Hence, there is a large discrepancy in actual non-competitive leasing activity between BLM and FS, and this difference is probably a reflection of policy or manpower allocations emanating from the federal level of government. However, there is a higher level of Federal non-competitive leasing activity in the Southwest than in the country as a whole. This latter finding may reflect differences in the relative sensitivity of the land, the adequacy of the resource, or competence of the potential lessees.

Table 3.6 illustrates another phenomenon associated with the leasing of federal non-KGRA lands. As shown, there were 928 non-competitive lease applications for federal land as of April 1978. The majority of these pending

Table 3.6

Age of Noncompetitive Lease Application Still Pending for Federal Land*

(as of April, 1978)

State	Less than 12 mos.		12-23 mo.		24-35 mo.		More than 35 mo.		Total	
	BLM	FS	BLM	FS	BLM	FS	BLM	FS	BLM	FS
Arizona	5	27	11	0	2	26	7	1	25	54
Colorado	0	0	0	0	0	0	9	27	9	27
Nevada	53	1	7	0	17	1	197	8	274	10
New Mexico	34	11	24	0	8	3	144	28	210	42
Utah	38	2	34	15	9	3	135	41	216	61
TOTALS	130	41	76	15	36	33	492	105	734	194

*From Streamlining Task Force, April 1978

applications has been pending for three or more years. The indicated long delay in issuing a decision for these non-competitive lease applications is slightly higher for BLM than for FS (67% vs. 54% for 3 or more years). However, as described earlier, about 55 percent non-competitive lease applications to FS are still pending compared to only 29 percent for BLM.

Unfortunately, the status of leasing activity for state lands is not as well documented as is the status of leasing activity for federal lands. The sparsity of information on the leasing status of state-owned geothermal resources is due in part to the small amount of land owned by the states in the Southwest (on the average about 8%). The absence of leasing data for state land is also due to moratoriums on the leasing of state-owned lands in Nevada and Arizona, and the absence of any state geothermal leasing activity in New Mexico since 1974. The absence of activity in this regard is due in part to legal challenges to non-competitive sale of state land (in Arizona), and in part to the need for regulatory policy (in Nevada).

Table 3.7 summarizes the status of procedures governing the leasing of state-owned land for geothermal exploration development. As may be seen the criteria for distinguishing between state KGRAs and state non-KGRAs differs among the southwestern states. Table 3.8 summarizes the terms of leases issued for state geothermal lands, and for comparison, for federal geothermal lands. As may be seen, there are considerable differences in leasing provisions among the southwestern states and between the states and federal government.

Five year primary lease terms are specified in the lease provisions of Arizona and New Mexico while Utah and the federal government allow for a 10 year primary lease term. Furthermore, the frequency with which lease terms may be negotiated is either unspecified (as in Arizona and Nevada), or is required every three, five, or ten years (for Utah, Colorado, and New Mexico, respectively). It is of course, very difficult to get an investor to commit large amounts of capital to develop geothermal resources when there is no guarantee that the developer will continue to have secure access to those resources after the initial primary lease term expires. This is especially true since once a resource is made productive, it may take 20-40 years to amortize the large investments that were required. The current status of leasing and lease adjustment provisions raise too much uncertainty for many prospective investors.

Table 3.7
Leasing of State Land*

State	Non-KGRA		KGRA	
	Newly Offered	If Applications Overlap	Bidding Factor	Designative Criteria
AZ	By Application	Cash Bonus Bidding or Qualification	Cash Bonus	Geology and/or Competitive Interest
CO	Specified by State Land Commissioner			
NV				
	Moratorium since 1974			
NM	Competitive (3-day filing)	By Application	Cash Bonus	Determined by Commissioner of Lands
UT	Cash Bonus (15-day filing)	By Application	No such Designation	

*From Sacarto State Policies for Geothermal Development, November, 1976

Table 3.8

State Geothermal Lease Provisions*

State	Primary Term	Renewal	Renegotiation of Rental and Royalties	Acreage Limits
AZ	5 years	2 years if drilling; for duration of commercial production		maximum lease; 2,560 (4 sections) confirmed to 6 miles square
CO	set in lease	for duration of commercial production; lacking production, at discretion of state land board	Minimum royalty: 5 year intervals	
54 NV	...			
NM	5 years	so long as geothermal resources are produced or capable of being produced in commercial quantities	10-year intervals, beginning 20 years after lease date	minimum lease: 640 acres maximum lease: 2,560 acres maximum state holdings: 25,600 acres
UT	10 years	for duration of commercial production; or 1-year terms, in absence of production, upon payment of \$5/acre advance royalty	3-year intervals	minimum lease: 40 acres maximum lease: 640 to 2,560 acres, at discretion of director of state lands
U.S.	10 years	for duration of commercial production	after production of steam; rentals and royalties at 20 years intervals; other terms at 10 year intervals	minimum lease: 640 acres maximum lease: 2,560 acres maximum state holdings: 20,480 acres

*From Sacarto State Policies for Geothermal Development, November, 1976.

The restrictions on the acreage that a developer may have in a given lease tract and limits on the total acreage a developer may hold in a given state generally follow federal acreage limitations. These state-level limitations are subject to the same criticisms as are levied against those federal acreage limitations. In short, the size of the limits is too small to provide security for any possible discoveries that are made and too small to permit the developer to most efficiently distribute his risks over a wide enough area to optimize his chances of success.

Exploration and Development of Resource Areas

Table 3.9 shows the status of exploration and development in each state. The number of exploratory thermal gradient wells which have been drilled is shown in the upper portion of the table, broken down when possible into shallow and deep wells. The status of applications for drilling permits is shown in the center portion of the table. The lower portion of the table shows the status of active field development within each state.

As may be seen in Table 3.9 the level of exploratory drilling within each of the five states parallels the level of leasing activities shown in Table 3.4. While little exploratory drilling has occurred in Arizona and Colorado, there have been large numbers of exploratory holes drilled in each of the other three states. Deep test wells have been drilled in only the four states in which there has been leasing activity. Relatively large amounts of drilling activity are likely to occur in the near future in the two most active states. Nevada has over 150 Notices of Intent on file, 25 of which are for deep exploratory wells. Developers in Utah have received permits to drill 51 deep wells and only 14 have been drilled.

Development of geothermal resources has progressed considerably on at least four sites: at least two in Nevada, Roosevelt Hot Springs in Utah, and Valles Caldera in New Mexico. In each of those areas, it is projected that there will be 50-55 MW demonstration plants with power on line before the mid 1980's.

It is of course very difficult to know how much progress there might be in the exploration and development of geothermal resources if there were no legal or institutional barriers. On the other hand, the data used in constructing Table 3.9 show that development is occurring and will continue to occur at an even faster rate in the near future. Overall, there is reason for optimism. Not only have plans for future field activity been formulated by

Table 3.9

Exploratory and Development Activities
in the Southwest Region*

Drilling	AZ	CO	NV	NM	UT
Exploratory wells	8	6	1000+	156	225+
Shallow (< 500 ft)	(15)	(5)	(11)	(-)	(-)
Deep (> 500 ft)	(3)	(1)	(51)	(-)	(-)
Deep-Test wells	--	1	64	17	19
Drilling Permits Approved	--	--	166	20	51
Applications on file	50+	6	150	--	--
Development	--	--	Desert Peak	Valles Caldera	Roose- velt

*From State Team Final Reports

developers, there are also several indications of meaningful changes in the structure and response times of agencies responsible for regulation. The activity of the IBP, the memorandum of understanding for cooperative procedures initiated and approved by agencies within DOI, and the activities of the streamlining task force all hold forth the promise of more enlightened behavior if not actual changes in the operating procedures of federal land management agencies.

In addition, the Environmental Protection Agency has produced a set of recommended interim guidelines for environmental standards which hopefully will be uniformly acceptable to all regulatory agencies, and hence, reduce the uncertainty which presumably served to constrain geothermal development. This type of action among the land management and regulatory agencies is extremely meaningful and represents the types of interagency cooperation that should increase as the nature of the problems and benefits associated with geothermal resources becomes better understood.

There is evidence for the existence of the type of institutional learning which is predicted to occur more frequently as all participants acquire more experience in the geothermal development business. For example, in Colorado lease time has decreased from 35 months for some applications filed in January 1974, to only 10 months for some applications filed in March 1975.

Many of the improvements in the status of institutional factors have occurred in the federal arena. It is expected that similar improvements will occur if meaningful integration of objectives and procedures occur among state agencies and between agencies at the state and federal levels.

Results - Identification of Major Participants

In addition to identifying the status of leasing, drilling, and development activities within each state, an attempt was made to identify which state agencies were participants in one or more stages of the geothermal development process. Tables 3.10 through 3.14 summarize the results obtained from the efforts.

These tables show the names of state agencies which become participants and the stage in the development process in which this involvement occurs. Whenever possible, the magnitude and nature of the participants' involvement is also specified in the table. An asterisk is used to indicate that a participant is the lead state agency at a given stage in the development process. The letter P indicates that the agency must issue a formal permit before development may occur. The letter C indicates that the agency must consent or must give its approval before development of a geothermal resource may continue.

Table 3.10

STATE AGENCIES WHICH PARTICIPATE IN GEOTHERMAL DEVELOPMENT IN ARIZONA

STAGE	PARTICIPANT																
	Arizona Oil & Gas Commission	Land Department	Water Commission	Water Quality Control Commission	Air Pollution Control Hearing Board	Office of Environmental Planning	Environmental Planning Commission		Department of Mineral Resources	Power Authority	Power Plant & Transmission Siting Comm.	Tax Commission			County Agencies		
PRELEASE CASUAL EXPLORATION																	
PRELEASE INTENSIVE EXPLORATION	*	C															
LEASING		*							?								
POST LEASE EXPLORATION	*	C P	?	?	?	?			?								
FIELD DEVELOPMENT AND PRODUCTION	*	C		?	?	?	?		?	?	?	?			?		
ABANDONMENT	*	C				?											

Table 3.11

STATE AGENCIES WHICH PARTICIPATE IN GEOTHERMAL DEVELOPMENT IN COLORADO

STAGE	PARTICIPANT																
	Colorado Oil & Gas Commission	Board of Land Commissioners	State Engineer	Department of Health	Dept. of Health Air Pollution Control	Dept. of Health Water Quality Control	Water Conservation Board	Land Reclamation Board	Division of Property Taxation					Department of Regulatory Agencies		Public Utilities Commission	County Agencies
PRELEASE CASUAL EXPLORATION																	
PRELEASE INTENSIVE EXPLORATION	*																
LEASING	A	*						A									A
POST LEASE EXPLORATION	*		C														
FIELD DEVELOPMENT AND PRODUCTION	*		C	?	P	P	?	?	?					?		P	?
ABANDONMENT	*							?									C

CRS 31-32 -201 & 31-12-101 laws establish conditions for municipal govnts.

Table 3.12

STATE AGENCIES WHICH PARTICIPATE IN GEOTHERMAL DEVELOPMENT IN NEVADA

[illegible]

Table 3.13

STATE AGENCIES WHICH PARTICIPATE IN GEOTHERMAL DEVELOPMENT IN NEW MEXICO

STAGE	PARTICIPANT																
	Oil Conservation Division	State Engineer	Commissioner of Public Lands				Natural Resources Department	Water Resources Division	Health & Environment Department	Environmental Improvement Division	Environmental Improvement Board	Water Quality Control Commission			Energy Resources & Development Division	Public Service Commission	County Agencies
PRELEASE CASUAL EXPLORATION																	
PRELEASE INTENSIVE EXPLORATION																	
LEASING			*														
POST LEASE EXPLORATION	*	P								C							
FIELD DEVELOPMENT AND PRODUCTION	X	P					?	?	?	C	C	?			?	?	?
ABANDONMENT	*	P															

TABLE 3.14

STATE AGENCIES WHICH PARTICIPATE IN GEOTHERMAL DEVELOPMENT IN UTAH

STAGE	PARTICIPANT														
	Division of Water Rights	Division of State Lands	Department of Transportation	Department of Business Regulation	Bureau of Water Quality	Bureau of Air Quality	Bureau of Solid Waste Management	Board of State Lands	Public Service Commission	Division of Public Utilities	Tax Commission				County Agencies
PRELEASE CASUAL EXPLORATION	*														
PRELEASE INTENSIVE EXPLORATION	*														
LEASING		*													
POST LEASE EXPLORATION	*							?							
FIELD DEVELOPMENT AND PRODUCTION	*	?	P	P	P	P	P	?	?	?	?				P
ABANDONMENT	*														

The letter A indicates that a state or local agency is requested to provide comment or advice concerning how the lead agency might proceed. A question mark indicates that an agency is probably involved in a given stage of the development process but that the exact magnitude or nature of that involvement is unknown.

Available state documents were analyzed to obtain this latter information. In addition, the quarterly reports of each state team were analyzed to identify any references to state agency involvement in the process. The charts and tables which describe the organization of state governments were analyzed to provide information as to which state agencies were or could be involved as participants in the development of geothermal resources in the state.

Even when a large number of participants is involved, there is reason to question the legal status and the precise nature of the role those participants have in the geothermal development process. Except for the State of California, there have been no fully developed geothermal reservoirs in the United States, hence agencies which are participants at advance stages in the geothermal development process have had no first-hand experience with the activity they are to monitor or regulate. Also, as a result of the relative newness of the development process, it is not clear to what extent or in what manner two or more state agencies will interact while they carry out their respective responsibilities.

Table 3.15 summarizes information concerning the role of various state and local agencies in the geothermal development process in Utah. The table shows the types of permits that must be issued by each of several lead agencies in the State of Utah. Also, shown in the table is the stage of development at which these agencies become participants and the approximate amount of time needed by these agencies to issue a permit.

Figure 3.5 shows time-phased activities of institutional entities which participate in the leasing of state lands for geothermal development in the state of Colorado. Several things should be noted with respect to the information in Figure 3.5: (a) The leasing of state land is under the control of the Board of Land Commissioners whose responsibility is to maximize the income from state lands. (b) Colorado rules and regulations require the Land Commissioners to send copies of the developer's application to at least the three other agencies specified for their review and comment. (c) The leasing of state-owned land may occur through either competitive or non-competitive bidding processes but due to limited interest in geothermal leasing only non-competitive leases have

Table 3.15

Preliminary Assessment of Agencies and Permits Involved
in Geothermal Development in Utah *

	<u>Permit</u>	<u>Required Prior To:</u>	<u>Estimated Time For Issuance</u>	<u>Notes</u>
<u>County Agencies</u>				
County Planning Commission (1,2)	Zoning	Depends on county zoning ordinances	Variable	Already accomplished in some counties
County Clerk (1)	Business License	Sale of electricity		
County Commission or Health Department (1,2,3)	Health Code Enforce- ment Building Inspection	Use of buildings	Varies	
<u>State Agencies</u>				
Division of State Lands (4,5)	Lease State Lands	Exploration or use of lands	Few Days to 2-3 weeks	May be competitive bidding in some cases but that does not sig- nificantly increase issue time
	Special Use Permit	Surface disturbance (Construction of plant)	Not known--possibly about 2 months	Has not yet been applied for in Utah
Department of Trans- portation (6)	Encroachment Permits	Use of state highway lands for utility lines	Few days	Would be necessary for use of or crossing of State Highway Rights of Way with utility lines such as power lines, water mains, sewage pipes etc.
	Oversized Vehicles Permit	Use of highway for oversized vehicles	About a day	
Division of Water Rights (7,8)	Permits for Thermal Gradient Wells	Drilling of thermal gradient wells	Few days to few weeks	Letter of approval
	Permit for Explora- tory "Test" Wells	Drilling of explora- tory wells	Few days to few weeks	Letter of approval

Table 3.15 (Continued)

	<u>Permit</u>	<u>Required Prior To:</u>	<u>Estimated Time For Issuance</u>	<u>Notes</u>
Continued from: Division of Water Rights (7,8)	Notification of Reservoir Test	Reservoir tests		
	Appropriation of Water	Use of water	6 months or longer	May depend on how fast the developer wants approval
	Production and Injection Wells			Covered by Appropriation of water if included in the Plan of Operations
Environmental Health Services				
Bureau of Water Quality (3)	Construction Plan Review and Permit	Construction	About 2 months	Pre-planning work
	Public Water Supply Approval	Use of building	1 to 2 months	
	Draft and Certification of Discharge Permit (Sanitary)	Use of building	1 to 2 months	In conjunction with EPA which issues the permit
	Liquid Waste Disposal System Approval	Use of building	1 to 2 months	
Bureau of Air Quality (9)	Construction Plan Review and Approval	Construction	About 3 months	In conjunction with EPA
	Discharge Permit	Use of plant	About 3 months	Plant discharges
Bureau of Solid Waste Management (3)	Solid Waste Disposal			
Department of Business Regulation (10)	Certificate of Convenience and Necessity or Approval of Contract Between Utility and Electricity Producer	Sale of Electricity	3 to 4 months	Certificate of convenience and necessity if utility owns plant; if utility buys power, approval of contract is required

*From the Utah Final Report (29, pp. 62-63).

Relevant to Geothermal Development

Figure 3.5 Colorado. Time-Phased Activities

been issued. (d) The state team estimates that the entire process of leasing state lands could be completed in seven to eight months.

Except for Colorado, a single office appears to have sole responsibility for leasing state-owned lands. None of the states have any formal regulations for prelease casual exploratory activity. With the possible exception of Colorado, there are no legal and binding provisions at the state level for an environmental assessment before state land is leased for geothermal development. Drilling permits are handled by oil and gas commissions in three states, (Arizona, Colorado, and New Mexico), and in Arizona that commission has sole responsibility for all water and environmental issues that might arise with respect to field exploration and development. Drilling permits are regulated by state engineers assigned to Department of Water Resources or Water Rights in two states (Nevada and New Mexico), and in both cases the state engineer has the lead responsibility for all aspects and impacts of field exploration and development operations.

In summary, there is considerable variability in the status of legal and institutional factors across the five states which comprise the Southwest Region. It appears that each state has developed slightly different procedures for interacting with federal agencies. An informed sampling of opinions conducted by Dr. Richard T. Meyer confirms the extent to which these findings are almost universally accepted by government and industry representatives. (Dr. Meyer's work is in Appendix D.) The bottom line is that leasing and permitting processes are cumbersome and time consuming. Therefore, the successful development of geothermal resources may depend upon the creation of a national policy which will alleviate some of these fragmented policies and procedures.

CHAPTER IV

GEOHERMAL DEVELOPMENT AND THE PRODUCTION OF ELECTRICITY

This section covers the logic underlying the research performed, the tools used, and the results of the research concerning the potential contribution of geothermal development to electricity production in the Southwest Region (Arizona, Colorado, Nevada, New Mexico and Utah). First, the underlying philosophy of the research program is described. Next, the sensitivity of profits to changes in physical and policy variables circumscribing the development of geothermal electric power is discussed. Then, site-by-site profitability as determined by GIRORA-Electric and aggregation of resulting power estimates is described and power-on-line projections are discussed. In addition, the sensitivity of power-on-line estimates to policy initiatives is discussed. Finally, preliminary estimates of electric power supply and demand conditions are presented. The impact of the development of geothermal electric plants is discussed under three possible sets of alternative assumptions. The complete description of the GIRORA-Electric model and the associated computer program (written in FORTRAN IV) is given in Appendix 1. We turn first to a discussion of the philosophy underlying the research accomplished concerning the development of geothermal electric power.

4.1 Research Philosophy

Underlying all considerations of this research was the assumption that electric plants driven by geothermal energy, and the fields which deliver that energy, will be developed by the private or non-federal government sectors. For the most part, this means private developers in conjunction with regulated electric utilities (although exceptions may and will likely exist). A concomitant assumption is that a geothermal resource will be developed only if it is economic to do so (that is, economic feasibility is a necessary but not sufficient condition). Because private developers and electric utilities are the actors, it is necessary to consider economic feasibility (profitability) from their point of view.

The second principal assumption is that geothermal energy is only one of a variety of energy sources at the disposal of an electric utility (or anyone, for that matter, in need of electric power). A concomitant of this second assumption is that geothermal energy must compete in the marketplace for energy. Because geothermal energy is a marginal energy source (marginal in the sense that it is a relatively small source), and in this region enters the scene chronologically late, it must compete at prices established by other fuels (coal, nuclear, oil, gas, and hydroelectric).

The result of the first two principal assumptions is that if geothermal energy is not profitable for both the geothermal developer and the electric utility, at a price which enables the electric power thus generated to be competitive with that generated by other fuels, the resource will not be developed. This is the bottom line. Given other institutional, attitudinal, and economic factors, a particular resource may not be developed, even if it is economically competitive.

Moreover, even though a particular resource is economically competitive and faces no non-economic barriers, being a marginal fuel, it may not be developed for lack of effective demand. This could occur under two conditions: (1) increases in the price of electricity result in sufficient consumer substitutions to reduce quantity of electricity demanded below some critical level, or (2) general economic growth is insufficient to require the capacity that would be added by a geothermal development. The first condition may have some general applicability, while the second might occur only in remote, sparsely populated areas (due to the portability of electricity).

At each juncture, government policy makers may have an option to affect the environment in which private developers make decisions or perceive opportunities. It was the aim of the research effort described below (1) to ascertain what elements under the influence of DOE-DGE could efficiently alter the profitability of geothermal resources as perceived by investors, (2) to identify the magnitude of impact policy action might reasonably be expected to have, and (3) to estimate in a preliminary way the level of market potential for electricity generated by geothermal energy.

Because geothermal energy is not free, it is an economic resource which should be developed efficiently with due concern for its place in a total energy perspective. Private entrepreneurs cannot discount the value of national balance of payments deficits or other social concerns, when considering

the desirability of an investment. It must be DOE-DGE's role to consider this broader perspective and insure the availability of sufficient incentives (or the absence of disincentives) so that private entrepreneurs will perceive geothermal energy as an attractive opportunity.

The criterion for evaluation chosen for this research is the rate of return on equity investment. There are a variety of criteria which could be used, each having its own special strengths and weaknesses. The one chosen for this research seems most appropriate because of the overall capital insensitivity of the process. It should be added that in the process of ranking geothermal sites, or judging the relative effectiveness of policy actions, any criterion of profitability or economic feasibility would yield approximately the same answer as another, so long as the methodology is consistent.

As will be noted in the next section, the simulation model used to evaluate geothermal electric projects uses the rate of return as the basis for comparison rather than the price of electricity. This is due to our assumption that geothermal energy must compete at the margin with established fuels. The price of electricity is then an independent rather than dependent variable. Moreover, using a rate of return on equity as the dependent variable focuses our attention on the profit motive of the developer. The developer can invest in geothermal energy or any other income-yielding prospect. If the rate of return on geothermal energy is not high enough (at a price where it can effectively compete), the developer will place investments elsewhere.

4.2 Sensitivity of Profits to Policy Parameters

Having developed and calibrated GIRORA-Electric (calibrated with other models of the genre), the next step up was to determine the sensitivity of the output, rate of return (R), to changes in policy parameters. This was done by first establishing an estimate of R, given a "baseline" set of policy, geophysical, and market parameters. The "baseline" parameters are not held to be "typical" or "characteristic". Resource areas in Southwest Region could be characterized as being of a wide variety of temperatures, salinity, distance to demand areas, etc. On the other hand, all will be confronted, given the nature of electricity markets, with similar market parameters, and, of course, federal policy parameters. Table 4.1 lists the more important parameters for the "baseline" case.

Table 4.1
Base Case Values
Geothermal Energy Producer

Variable		Value
BR:	Bond Rate	0.085
CRRT:	Investment Tax Credit Rate	0.12
FR:	Flow Rate	585,794 lb/hr
TEMP:	Initial Downhole Temperature	190°C
EPK:	Equity Proportion of Capital	0.30
DPK:	Debt Proportion of Capital	0.70
λ :	Royalty Rate	0.10
Z:	Depletion Allowance Rate	0.0
EXP:	Exploration Period	0 years
DVP:	Development Period	8 years
TXRT:	Income Tax Rate	0.50
IRR:	Internal Rate of Return	0.15

Electric Utility

Variable		Value
CAP:	Capacity	50,000 Kilowatts (Net)
LF:	Plant Factor	0.80
UF:	Plant Use of Power (Proportion)	0.18
PB_e :	Base Price of Electricity (Busbar)	0.021 (\$/kwh; current \$)
$\dot{P}$:	Escalation Rate of Base Price	0.05
EK:	Equity Proportion of Capital	0.50
DK:	Debt Proportion of Capital	0.50
UR:	Regulated Return to Equity	0.12
BR:	Bond Rate	0.085
TXRT:	Income Tax Rate	0.50

The next step was to vary relevant parameters, one at a time, to determine the sensitivity of R to changes in each parameters. The measure used here for such sensitivity is elasticity (E). Elasticity is a concept in economics which means the percent change in one variable given a one percent change in another. The formula used to calculate elasticity is given below, where R is the rate of return and IV is the independent variable. The subscripts 1 and 2 refer to the values of each variable at subsequent positions.

$$E = - \frac{R_2 - R_1}{(R_2 + R_1)/2} \div \frac{IV_2 - IV_1}{(IV_2 + IV_1)/2}$$

The average value is used as a base for both variables so that E takes on the same value whether one is moving from a higher to lower or lower to higher set of variable values. The values of E for selected variables are given in Table 4.2.

Briefly, the elasticity of R with respect to plant capacity in megawatts (CAP) is -0.268. This means that for every 1 percent increase in plant capacity, we might expect about a 0.27 percent decrease in the rate of return. The calculated E for the depletion allowance rate is 0.051. This means that for every 1 percent increase in the depletion rate, there would be a 0.05 percent increase in the rate of return.

The larger the value of E, the greater the impact of changes in a variable on R. Of the various policy variables analyzed in Table 4.2., E ranges from 2.433 for the investment tax credit rate (when resource temperature is 190°C) to 0.051 for the depletion allowance rate. Others are: Bond rate, -1.714 (at temperature 190°C) or -0.156 (at temperature 225°C); Royalty Rate, -0.0208.

Market variables which might be affected by policy action are: Capacity Cost for Binary Plants, -2.625; Exploration Period, -0.044; Development Period, -0.468 and Base Price of Electricity, 0.632.

Those variables which have the highest E are those which impact capital costs in low temperatures (binary) systems. This is due to the greater capital insensitivity of these systems relative to flash systems.

After observing the variability of R with changes in individual independent variables, we must also consider the range of R as several variables are changed simultaneously. This gives a range for expected values of R under a variety of circumstances.

Table 4.2 Elasticity (E) of R with
Respect to Selected Variables at
225°C (437°F)

Variable	E
Power Plant Capacity	-0.268
Depletion Allowance	0.051
Investment Tax Credit at 225°C	0.851
Investment Tax Credit at 190°C	2.433
Royalty Rate	-0.208
Base Price of Electricity \$/kwh	0.632
Load Factor	1.838
Producer Debt/Equity Ratio	0.134
Flow Rate	1.156
Exploration Period, years	-0.044
Development Period, Years	-0.468
Bond Rate at 225°C	-0.156
Bond Rate at 190°C	-1.714
Temperature	2.703

Considering such a range is a more reasonable approach to forecasting than simple point estimates. This is because the future cannot be predicted with any precision and thus those factors which might impact geothermal development cannot be predicted with any great precision. Looking at a range, however, permits us to realistically analyze the likely effects of policy initiatives.

Table 4.3 lists the parameter values for what is here discussed as "pessimistic" and "optimistic" market scenarios and a "baseline" R for each potential electric site (estimate for base temperature over 150°C) in the Southwest Region. In Tables 4.4 through 4.8, megawatt estimates are given for each site under the conditions specified by sets of parameter values. A required return to equity of 15 percent is assumed. Those sites which do not receive a required return under a given set of parameter values are rated at zero megawatts. The estimates are given at three levels: pessimistic, baseline, and optimistic.

If a positive megawatt value is shown, it is the maximum thirty-year usable energy estimate of the resource given estimated temperature and volume. (In many cases the volume is a default value from USGS Circular 726⁽²⁾, thus making the "optimistic" estimate possibly conservative). The optimistic case is the maximum probable energy that could be obtained under any circumstances. Table 4.9 summarizes the megawatt estimate for the Southwest Region from Tables 4.4 through 4.8.

4.3 Aggregated Power On Line Estimates

Under conditions of minimum competition for development inputs (drilling rigs, labor, casing, pipe, etc.), and given the projected scenarios for development of individual sites, a time-phasing of power on line can be constructed for the region. This is illustrated in Figure 4.1. Figure 4.1 contains three basic projections for this time-phasing, one "optimistic", one "baseline", and one "pessimistic". Each is the region-wide aggregation of megawatt estimates for the five states for each year according to site-by-site projections. The range between the two extreme projections represents the most highly probable range for the development of geothermal electricity production, given minimum competition for development inputs.

For a planning outlook, however, this perspective must be modified. The range illustrated in Figure 4.1 could be realized only if sufficient resources are devoted to the production of drilling rigs and the training of geothermal drilling teams. An obvious policy recommendation is that DOE-DGE should assure an environment in which such resources may be readily available.

**Table 4.3 Values of Choice Variables
and Parameters: Optimistic and
Pessimistic Market Scenarios**

	"Pessimistic"	"Optimistic"
Load Factor	60%	75%
Base Price of Electricity	21 mils/kwh	30 mils/kwh
Escalation factor for Price of Electricity	5%	6.5%
Debt/Equity ratio of Utility	1	1
Debt/Equity ratio of Producer	1.5	1.86
Utility's Return (regulated)	15%	12%
Tax Rate	48%	48%
Bond Rate	8.5%	7.5%
Investment Tax Credit	12%	12%
Flow Rate	250,000 lb/hr	400,000 lb/hr
Royalty Rate	10%	5%
Depletion	0%	22%
Exploration Time	5 years	5 years
Development Time	8 years	5 years

Table 4.4 Electric Power Estimated
in Megawatts for Arizona

Site	Temp °C	Estimated Power in Megawatts		
		Pessimistic	Baseline	Optimistic
Power Ranch	184	0	0	50
Clifton H.S.	160	0	0	50
Verde H.S.	150	0	0	50
Statewide (Kingman)	50-200	0	0	0
White Mountains (Flag-staff)	210	0	100	1000
Yuma	150-180	0	50	50
Hyder Valley	200	0	50	500
Wilcox*	205	0	0	100
Springerville*	210	0	100	500
Tucson*	60-120	0	0	50
Safford	210	0	100	100
Total		0	400	2450

* Indicates that the resource is hot dry rock.

Table 4.5 Electric Power Estimated
in Megawatts for Colorado

Site	Temp °C	Estimated Power in Megawatts		
		Pessimistic	Baseline	Optimistic
Mt. Princeton/Cotton- wood Creek	170-200	0	100	100
Poncha Springs	175-200	0	0	200
Cebolla Hot Springs	145	0	0	200
Total		0	100	500

Table 4.6 Electric Power Estimated
In Megawatts for Nevada

Site	Temp °C	Estimated Power in Megawatts		
		Pessimistic	Baseline	Optimistic
The Needles Rocks	200	0	245	245
Surprise Valley	185	0	0	45
South Smoke Creek Desert	200	0	65	65
Anaho Island	185	0	0	45
Dyke Hot Spring	200	0	245	245
Baltazor Hot Spring	185	0	0	45
Bill Creek Reservoir	200	0	65	65
Bog Hot Springs	170	0	0	40
Howard Hot Springs	200	0	65	65
Pinto Hot Springs	185	0	0	45
Cordero Mercury Mine	185	0	0	45
Hot Sulphur Spring	185	0	0	180
The Hot Springs	170	0	0	40
Humboldt Wells	200	0	245	245
Mineral Hot Springs	185	0	0	90
San Emidio Desert	200	0	245	245
Gerlach, N.E.	200	-	-	-
Double Hot Spring/Black Rock Hot Spring	200	0	735	735
Gerlach	200	0	370	370
Colona	185	0	0	45
Fly Ranch	185	0	0	45
Fly Ranch, N.E.	185	0	0	45
Trego	185	0	0	45
MacFairlane's	185	0	0	45
Sulphur	185	0	0	45
Rye Patch	185	0	0	540
Colado	185	0	0	180
South Eugene Mountains	185	0	0	180
Golconda	185	0	0	-
Hot Springs (Tipton) Ranch	200	0	245	245

Table 4.6 (Continued)

Site	Temp °C	Estimated Power in Megawatts		
		Pessimistic	Baseline	Optimistic
Hot Pot	185	0	0	45
Sand Dunes	185	0	0	-
Winnemucca Mountain	90	0	0	-
Leach Hot Springs	200	0	735	735
Kyle Hot Springs	200	0	245	245
Battle Mountain	185	0	0	-
Smith Creek Valley	200	0	245	245
Beowawe Geysers	245	1220	1220	1220
Horseshoe Ranch Spring	185	0	0	45
Hot Springs Point	185	0	0	180
Duff Creek	185	0	0	45
Darrough's Hot Spring	185	0	0	45
Elko Hot Springs	185	0	0	-
Walh Hot Springs	185	0	0	45
Bruffey's Hot Springs	185	0	0	45
Kolbe Hot Springs	185	0	0	45
Spenser Hot Springs	185	0	0	45
Carlin	185	0	0	-
Sulphur Hot Springs	200	0	490	490
Monte Neva Hot Springs	185	0	0	180
Ruby Lake	200	0	245	245
Cherry Creek Hot Spring	170	0	0	40
Steamboat Spring/Huffaker	215	0	400	400
Steamboat Spring/Huffaker	60	0	0	-
Moana Spring/Lawton	60	0	0	-
Comstock Mining District	155	0	0	38
Washoe Valley	60	0	0	-
Desert Peak	215	0	665	665
Brady's Hot Springs	215	0	265	265
Huxley	200	0	65	65
Eagle Salt Works	215	0	-	-

Table 4.6 (Continued)

Site	Temp °C	Estimated Power in Megawatts		
		Pessimistic	Baseline	Optimistic
Hot Springs Mountains	215	0	265	265
Hazen	200	0	65	65
Brady's Hot Springs	215	0	-	-
Carson Sink/Alkali Flat West Side	200	0	65	65
Carson Sink/Alkali Flat East Side	200	0	65	65
Lone Rock	185	0	0	45
Soda Lake/Upsal Hogback	215	0	400	400
Soda Lake/Upsal Hogback	215	0	-	-
Stillwater	215	0	530	530
Carson Lake	185	0	0	65
Lee Hot Springs	185	0	0	63
Eight Mile Flat	185	0	0	63
Stillwater	215	0	-	-
Dixie Hot Springs	200	0	245	245
Sou Hot Springs	185	0	0	135
McCoy Springs	185	0	0	135
Hyder Hot Spring	200	0	145	145
Senator	185	0	0	-
Dixie Comstock Mine/ Humboldt Marsh	185	0	0	135
IXL	170	0	0	-
Buffalo Hot Springs	185	0	0	135
Jersey Valley	200	0	145	145
Wabuska Hot Springs	170	0	0	40
Wabuska Hot Springs	170	0	0	-
Wilson Hot Springs	170	0	0	40
Hind's Hot Springs	155	0	0	-
Dead Horse Wells/Wedell Spgs	170	0	0	165
West Gabbs Valley	170	0	0	165
Sodaville Springs	140	0	0	-
Fish Lake Valley	260	390	390	390

Table 4.6 (Continued)

Site	Temp °C	Estimated Power in Megawatts		
		Pessimistic	Baseline	Optimistic
Silver Peak Hot Springs	200	0	63	63
Silver Peak Hot Springs	200	0	-	-
Southern Clayton Valley	170	0	0	40
Warm Springs	170	0	0	45
Railroad Valley/Pancake Range	170	0	0	45
Hot Creek Canyon	170	0	0	45
Hot Creek Valley	155	0	0	38
Lunar Crater	185	0	0	180
Caliente Hot Springs	65	0	0	-
Sarcobadus Flat/Beatty	65	0	0	-
TOTALS		1610	9478	13600

Table 4.7 Electric Power Estimated
In Megawatts for New Mexico

Site	Temp °C	Estimated Power in Megawatts		
		Pessimistic	Baseline	Optimistic
Lightening Dock	170	10	20	100
Kilbourne Hole	155	10	20	50
Radium Springs	130	0	0	50
Valles Caldera	260	1900	2000	2000
Lower Frisco H.S.	150	0	0	50
TOTALS		1920	2040	2250

Table 4.8 Electric Power Estimated
in Megawatts for Utah

Site	Temp °C	Estimated Power in Megawatts		
		Pessimistic	Baseline	Optimistic
Roosevelt	230	300	500	500
Cove Fort	200	0	200	200
Thermo	185	0	100	100
West Cove Ft.	200	0	200	200
North Cove Ft.	200	0	200	200
TOTALS		300	1200	1200

Table 4.9 Electric Power Estimated
In Megawatts for the Five States

State	Estimated Power in Megawatts		
	Pessimistic	Baseline	Optimistic
Arizona	0	400	2450
Colorado	0	100	500
Nevada	1610	9478	13600
New Mexico	1920	2040	2250
Utah	300	1200	1200
Total for the Region	3830	13218	20000

Figure 4.1 Time-Phased Scenarios Under Conditions of Minimum Competition

However, in the presence of development resource competition one could expect a time-phasing more along the lines of that presented in Figure 4.2. Assuming that the provision of development resources grows at a more or less constant rate, the slope of the initial growth phase must be less steep while the period of maximum output is more extended. Since it is likely that some competition for development resources will exist, we will assume for the sake of policy analysis that the power on line time-phasing suggested in Figure 4.2 is the relevant case. It must be kept in mind, however, that this time-phasing is subject to policy initiatives.

4.4 Policy Analysis and Recommendations

The final step is to consider the sensitivity of the time-phased aggregations to changes in policy parameters. In order to accomplish this, however, the logic of these aggregations must be reviewed. The aggregations are the sum of the parts which are site-specific estimations of power and the time-phasing of those sites.

The three cases illustrated for the time-phased aggregations are the result of an essentially "go" or "no-go" decision for each site. The "optimistic" boundary is the result of a "go" decision for all sites within the region, as a brief review of Tables 4.4 through 4.8 will show. Thus, the upper bound of our range of likely power-on-line estimates can increase or change only subject to the following conditions: (1) the volume or temperature estimates are altered, or (2) as noted earlier, the supply of development resources is increased or decreased. Thus, the effect of DOE-DGE policy can only be to raise the middle estimate and lower boundry of the range or to alter the rate of development by ensuring a timely supply of development resources.

The policy parameters indicated previously, then, can only affect the position of two of the three estimates, the "baseline" and the "pessimistic" projections for power on line, in Figure 4.2. The following policy analysis is, therefore, directed at the sensitivity of these lower two estimates to changes in policy parameters.

It must be recalled that the lower estimates are the result of the confluence of a variety of negative influences on the rate of return (R). Moreover, as a result of this confluence, the "pessimistic" case results in zero or lower

Figure 4.2 Time-Phased Scenarios Under Some Competition for Development Resources

estimates for R for all sites having down-hole temperature of 200°C or lower. If the "go" or "no-go" decision point for a site is at an approximate R of, say 15 percent per annum, substantial increases in R are necessary for sites below 230°C in the pessimistic scenario. Given the very low E of R with respect to either the depletion allowance or the royalty rate, it should not be surprising that substantial changes in either of these policy variables will not noticeably affect the lower bound or the "baseline" case of our estimated range. Eliminating the royalty rate or establishing a 22 percent depletion allowance will accomplish two things: (1) increase the probability that the actual power output will fall within the range given, and (2) increase the profitability of these sites which will be developed in any event. This second result is not meant to indicate criticism. Increasing the cash flow of geothermal enterprises could inspire developers to take on riskier geothermal projects. The impact of this activity cannot, however, be measured at this time.

A further word about result (1) above is necessary. An estimated range of high and low prospects for geothermal development in the Southwest Region has been illustrated. We are saying that it can be expected that, with no assistance beyond what currently exists, the development path for geothermal energy will fall within the indicated range. It cannot be said with any certainty what the likelihood is that this will occur. The likelihood may be a 60 percent probability or a 90 percent probability. We are only saying the probability is somewhat greater than 50 percent that the actual development path will fall within that range. We cannot be more certain than that until more precise estimates of reservoir volume and the distribution of flow rates is obtained. With this information, it would then be meaningful to assign probability weights to other parameters, and through Monte Carlo simulation techniques estimate a probability value for the range and also probability values for paths within that range. In the absence of such information we can specify the magnitude of movement, but not the magnitude of the change in probabilities.

In contrast with the two policy parameters mentioned above, an increase in the investment tax credit of 4 percentage points (say, from 12 percent to 16 percent) or a decrease in the bond rate by 2 percentage points (from 8.5 percent to 6.5 percent) would add perhaps 7,000 megawatts of power onto the total found under the "baseline" case in Table 4.5, and perhaps 4800 megawatts to the "pessimistic" case. The lower two estimates would experience a shift as illustrated in Figure 4.3.

Figure 4.3 Time-Phased Scenarios With Policy Incentives

The occasion for this result is that under the original "pessimistic" case, no site with a temperature below 230°C was "on line" due to the insufficient profit level, nor were sites below 190°C in the "baseline" case. Most of such sites would use a binary cycle plant which is more capital-intensive than flash cycle plants. It is the former plants which would receive the relatively greater incentives from changes in the investment tax credit rate and the bond rate.

A combination of both an increase in the investment tax credit rate by 4 percentage points and a decline in the bond rate by 2 percentage points would perhaps add another 2000 megawatts to the "pessimistic" case and bring the "baseline" case approximately to the maximum. In short, it could be said with a great deal of certainty that altering those two policy parameters in the amounts indicated would result in the possibility of between 11,000 and 20,000 megawatts of geothermally generated electricity being on-line by about the year 2020 within the region. There is almost no doubt that by the year 1990 almost 6,000 megawatts of electricity could be on-line. In the absence of these two policy initiatives, the probability that only 3000 MW would be on-line would be equal to that of 5000 MW being on-line. It should be added here, at least parenthetically, that any policy action which reduces the cost of capital to both the geothermal producers and the electric utilities in an amount equivalent to the policy actions indicated would have a similar result.

4.5 Review and Summary of Policy Analysis

Under "optimistic" conditions for development, almost all resource areas within the Southwest Region will probably develop. Under "pessimistic" conditions, in the absence of financial incentives on the part of government agencies, only those sites with temperatures greater than 230°C are likely to develop. To insure the speedy development of geothermal resources, DOE-DGE should concentrate its efforts on those activities which will enhance the viability of low temperature electric sites. Any activity which will lower the cost of capital by an amount equivalent to an increase in the investment tax credit rate by four percentage points and to decrease in the bond rate by two percentage points would result in an additional 5000 to 7000 megawatts of electricity generated from lower temperature sites in the Southwest Region by the year 2015. This would be a significant addition to the Southwest's electrical-generating capacity.

4.6 The Market for Electricity

As noted under the "Research Philosophy" section above, even if all other conditions are favorable for the development of a geothermally-powered electric plant, the demand for the additional capacity may not exist. Because geothermal energy is a "marginal" power source, in the absence of sufficient demand utilities will probably not substitute geothermal plants, e.g., for coal-fired plants.

In order to estimate the potential utility of geothermally powered electric plants, it was necessary to accomplish two tasks. First, it was essential to estimate the relationship between the quantity of electricity demanded and other casual factors, and project those casual factors to the year 2020 to estimate electricity need through the time period. Second, it was necessary to ascertain the planned generating capacity within the region to determine whether or not a deficiency might develop. We turn first to a discussion of electric energy consumption and its projection.

4.7 Electric Energy Consumption

Economic theory tells us that the quantity purchased of any commodity is a positive function of income, the number of consumers, and the prices of substitutes, and a negative function of price. In addition, the consumption of any commodity should also be a positive function of the consumption of complementary products. In order to economically estimate the relationship between the quantity of electricity and other assumed casual factors, it is necessary to specify a mathematical relationship between variables. This was done following Mount, Chapman, and Tyrrell⁽³⁰⁾.

We begin by specifying that electricity consumption is a function of its own price, the price of natural gas (a substitute), per capita income, population, and the stock of electricity using consumer durables. We furthermore specify a model that constrains electricity consumption to a constant elasticity of growth with respect to its casual variables. This may appear restrictive, but (1) observation of long run trends suggests such an assumption, (2) the resulting model yields a good fit with historical data, and (3) it is the common practice⁽³¹⁾.

$$QE_t = ae^{\lambda t} PE_t^{\beta_1} PNG_t^{\beta_2} PCI_t^{\beta_3} POP_t^{\beta_4}$$

QE_t = Quantity of Electricity consumed in year t

PE_t = Average Price of Electricity in year t

PNG_t = Price of Natural Gas in year t

PCI_t = Per Capita Income in year t , constant dollars

POP_t = Population in year t

a , λ , β_1 , β_2 , β_3 , and β_4 are constants to be estimated

e = Natural logarithm constant

For the purposes of estimation, equation (4.1) is transformed to the linear equation (4.2). The short-run elasticity of QE with respect to each variable i is $(\beta_i/1-N) \times 10^2$. Equation (4.2) was estimated using pooled cross-section and time series data. Estimation of β_1 using strictly time-series data can result in multi-collinearity due to the strong trend element

$$\ln QE_t = \ln a + \lambda t + \beta_1 \ln PE_t + \beta_2 \ln PNG_t + \beta_3 \ln PCI_t + \beta_4 \ln POP_t \quad (4.2)$$

in all independent variables. Estimation using strictly cross section data yields no reason for confidence in projection through time⁽³²⁾. The variable λ is introduced to account for the adjustment of consumers to consumption levels through time and insures homoeasticity of estimated parameters.

Table 4.10 presents the results of the regression analysis and a test calibration of the estimated model.

Using this estimation of the relationship between the quantity of elasticity consumed and the casual variables, the next step was to project the quantity of electricity demand through the year 2020. This, of course, involves first, the projection of casual variable values through 2020, thus engaging the researcher in a guessing game concerning the future. For example, although it is doubtful that the population of the United States will grow much more rapidly than one percent per annum at any time in the future, migration may result in population increases within the area of 1.2 to 1.5 percent. Real per capita income may grow at a rate between 2.5 and 3.5 percent. The range of likelihood around these potential growth rates is fairly small and so 1.35% annual population growth was assumed and a 3% annual growth was assumed for real income.

Table 4.10 Results of the Forecasting Model

$$QE = (1.39)PE^{-.134} PNG^{-.095} PCI^{.234} POP^{1.978} e^{.009t}$$

Percentage of Variance Explained = 100%

Year	Actual (GWH)	Calibration Predicted (GWH)	% error
1961	21.900	21.824	-0.35%
1962	23.500	23.646	0.62%
1963	25.700	27.713	0.05%
1964	27.481	27.210	-0.99%
1965	28.760	28.835	0.26%
1966	29.800	29.910	0.37%
1967	31.519	31.605	0.27%
1968	33.730	33.879	0.44%
1969	37.879	37.709	-0.45%
1970	41.079	40.944	-0.33%
1971	44.679	44.665	-0.03%
1972	49.740	49.491	-0.50%
1973	54.538	54.822	0.52%
1974	57.203	57.524	0.56%
1975	59.211	58.939	-0.46%

The range of uncertainty for projections in the growth of electricity consumption is due then to uncertainty concerning the price of electricity and the price of natural gas. In 1976, National Economic Research Associate (NERA) in a study for the Arizona Nuclear Power Project used company data to arrive at higher and lower estimates for real price escalations in electricity and natural gas⁽³³⁾. NERA estimated a range in real price escalation for electricity of about 1% - 3.5% per annum and in natural gas of about 1.8% - 5% per annum. These are consistent with other estimates⁽³⁴⁾. We have, therefore, produced four projections for electricity consumption using (1) a high growth rate in price for electricity and also a high rate for natural gas, (2) high for electricity, low for gas, (3) low for electricity, high for gas, and (4) low for gas and electricity. These are designated in Table 4.11 as I, II, III, and IV, as well as illustrated in Figure 4.4.

These projections have been translated into megawatts of required capacity and illustrated in Figure 4.5 according to the following formula. The number for GWH has been translated into MW by multiplying GWH by 10^6 8760. This average MW figure has been multiplied by 1.5 in order to account for peak loading. Another 0.15 has been added for reserve capacity.

Electric utilities have been polled within the region and capacity increments already in the planning or building state ascertained. There are currently some 20,708 MW on line and by 1986, an additional 16,083 MW are planned. Assuming that approximately ten percent of the increment is for replacement and that, on average, power plants consume 18 percent of power produced, and an additional ten percent is lost in transmission, planned effective capacity for 1986 is 25,965 MW, where it is currently 15,282 MW. If it is further assumed that the current proportion of export to sales remains constant at about 26 percent, the effective planned domestic (within the subject five states) capacity in 1986 is about 19,214 MW. Given reasonable growth projections as illustrated in Figure 4.5, this capacity should carry the region up to about 1990-1995. Depending upon replacement needs, additional capacity may be required prior to 1990. By the year 2020, this region may require an additional 30,000 MW (net) of electric capacity for domestic consumption alone, and perhaps another 10,000 to 15,000 MW (net) for export. Power plants driven by geothermal steam could provide 15-30 percent of the region's total electric capacity if it can become an economically viable alternative.

Table 4.11 Sensitivity Analysis Parameters
For Projections Of Electricity Consumption

CASE	I	II	III	IV
PCI	3.0%	3.0%	3.0%	3.0%
POP	1.35%	1.35%	1.35%	1.35%
PE	3.5%	3.5%	1.0%	1.0%
PNG	5.0%	1.8%	5.0%	1.8%

Figure 4.4 Projections of Demand for Electricity in the Five State Region

Figure 4.5 Projections of Required Plant Capacity in the Five State Region

CHAPTER V

GEOHERMAL DEVELOPMENT FOR SPACE HEATING

Much of the analysis of geothermal energy potential in the United States in recent years has shifted from the study of electricity generation to non-electrical applications. These latter uses are often referred to as direct applications,⁽³⁵⁾ in contrast to electricity generation which is an indirect application. There are a number of factors which have generated widespread concern for direct applications.

First, recent documentation of geothermal resources in the United States has revealed a large disparity in the endowment of low temperature versus high temperature resource sites. For example, 504 low temperature ($T \leq 150^\circ$) and 80 high temperature ($T > 150^\circ$) sites have now been identified in the region.⁽³⁶⁾ The sheer abundance of low temperature geothermal resources seems therefore, to warrant further investigation.

Early estimates of the energy potential offered by low temperature anomalies were promising. The most widely cited of these estimates was Reistad's.⁽³⁷⁾ Reistad calculated that if all geothermal resources up to 200° , 150° , and 100° C could be used for space heating, 40, 30, and 20 percent, respectively, of total United States energy needs could be met. Although these projections are impressive, some stringent assumptions were employed in the calculations. In particular, many low temperature sites included in these projections could not be harnessed because of the imperfect mapping of market supply and demand sites.

A second reason for the recent upsurge of interest in direct geothermal applications is that such a large proportion of the nation's energy demands are for relatively low temperature space heating needs. Reistad estimated that $10,857 \times 10^{12}$ BTU or 18 percent of the 1968 United States fuel consumption was for space heating alone⁽³⁷⁾. If geothermal energy proves practical, this demand may be easily be met. Further energy needs, such as water heating and cooling, air conditioning, and refrigeration might also be met from low temperature geothermal resources.

Kunze and Richardson combined Reistad's geothermal supply estimates with some energy demand projections combined at the Stanford Research Institute⁽³⁸⁾. The objective of this exercise was to determine the proportion of 1985 space heating needs that could be met with geothermal energy. Ignoring some admittedly

pertinent economic considerations, they estimated that roughly 35 percent of the projected space heating needs could be geothermally supplied.⁽³⁸⁾ Again, however, the locational problem of matching supply and demand sites was ignored.

A final explanation for heightened interest in low temperature geothermal resources is that present and future low temperature energy needs are not efficiently served by existing technology using traditional fossil fuels. For these reasons at least, developmental prospects of low temperature geothermal energy in the Southwest Region will be examined in this chapter.

While the overall research approach for high temperature and low temperature resources is similar, there are, nevertheless, several distinguishing features of each analysis. One such factor which differentiates the analysis of direct from indirect applications is the mere number of candidate sites. As indicated above, the number of low temperature resources exceeds the number of high temperature resources by a margin of roughly 6 to 1. Thus, in the preliminary analytical stages, at least, the breadth of analysis is much greater in considering direct applications.

Another distinguishing feature of low temperature geothermal resources is the nature of the low temperature applications. These anomalies are not considered adequate for electricity generation. However, the range of alternative uses include space heating and cooling, water heating and cooling, and a broad range of potential industrial process applications. Of these, only space heating will be considered in this analysis. Accordingly, the energy consuming sector in the low temperature analysis will be a district heating unit rather than an electric utility company, as in the high temperature analysis. The analytical methodology will differ accordingly.

Finally, the evaluation of low temperature geothermal resource development is characterized by the limited portability of geothermal fluid. Warm air which has been heated with low temperature geothermal fluid cannot be transported interregionally as can electricity produced from high temperature geothermal resources. Thus, differences in the technological characteristics of the ultimate products produced by geothermal resources also influence the analytical framework to be employed.

Given the factors cited above, the examination of the regional potential of low temperature geothermal energy will be organized as follows:

1. A brief review of the limited amount of experience with geothermal space heating in the United States will be presented. Factors which

have been found crucial to the developmental prospects of low temperature space heating will be identified.

2. A complete assessment of the regional resource endowment will be compiled. The resource base will be subdivided into two groups, depending upon whether resources are usable or unusable given current recovery and production technologies.
3. An economic simulation model, GIRORA NON-ELECTRIC, will be employed to evaluate the financial feasibility of existing resources.
4. The significance of numerous policy variables and geophysical resources will be assessed.
5. Regional supply aggregates of low temperature geothermal energy will be forecasted for several sets of circumstances.

5.1 Geothermal Space Heating in the United States: The Historical Record

The historical record of experience with geothermal space heating in the United States is a limited one. Klamath Falls, Oregon, is the sole location in which space heating is presently employed on a broad scale. In order to place the following research in perspective, a brief review of the Klamath Falls experience with geothermal energy will be presented. Since detailed economic and engineering data are available elsewhere, the following discussion will be limited to a general description of the Klamath Falls experience and a summary of some pertinent findings which may prove helpful in the pages to come.

Klamath Falls is located in a KGRA in southern Oregon. Residents in this area have relied upon geothermal energy for space heating and other needs for over 70 years. However, a number of factors have spurred additional local demand since the mid 1960s.

First, the use of geothermal hot water for heating the buildings on the campus of the Oregon Institute of Technology began in 1964. This provided a sort of large scale demonstration project, the results of which have been encouraging. The savings in annual operating costs are estimated to be a full \$225,000 compared to the cost of conventional heating ⁽³⁹⁾. Such evidence of feasibility has no doubt contributed to decisions to heat schools, hospitals, and other large residential and commercial buildings in Klamath Falls.

A second factor which spurred interest in geothermal space heating was the establishment of the Geo-Heat Utilization Center at Oregon Institute of Technology. ⁽⁴⁰⁾ Funding for this undertaking was originally provided by the Pacific Northwest

Regional Commission of Vancouver, Washington, in 1975. With additional support from the state of Oregon, the Center actively disseminates information and prepares research proposals pertaining to geothermal energy. Perhaps its most ambitious undertaking is the current effort to organize and to plan for the implementation of a large scale district heating unit in Klamath Falls.

A third factor which has stimulated interest in geothermal energy in Klamath Falls has grown steadily in recent years. There are now approximately 400 shallow-depth wells being used to heat roughly 500 structures; these range from 27 to 550 meters in depth. Space heating is used to warm private residences, schools, and a broad array of businesses. Water temperature varies between 40° and 110°C, with temperatures over 80° desirable. The principle heat extractive system is the closed loop downhole heat exchanger.⁽⁴¹⁾

Some of the more recent experiences at the Oregon Institute of Technology in Klamath Falls has been fully documented, and it offers evidence of the local potential for further space heating. Several hot water wells have been dug from 400 to 600 meters deep in an area immediately adjacent to the campus. These are used to heat eight buildings of approximately 530,000 square feet. The sum of the annual operating cost plus depreciation is \$25,000 or \$0.005/sq. feet. This compares favorably with the estimated annual cost of \$250,000 (\$0.05/sq. ft.) for conventional fuels.⁽³⁹⁾

The long experience at Klamath Falls have proven sufficient to identify a number of considerations which are germane to developmental prospects of geothermal space heating. The first is the nature of economic costs and benefits. In the case of costs, large capital investment expenses are incurred "up front", i.e., before the system becomes operable. These costs include expenditures for drilling and casing, equipment, and building retrofitting where necessary. The costs are usually written off over 30 years, but the initial expense is sufficiently large to present a potential barrier to smaller users.

In the case of the economic benefits, the results of experience are more encouraging. As mentioned above, the annual operating costs are estimated to be a fraction of that for more conventionally fueled heating systems. In addition, the risk of supply disruption or internationally imposed price increases is eliminated. Thus, a long run incentive from a risk aversion perspective is also present.

A second consideration in evaluating the space heating potential of geothermal energy is the size of the user market. Given current production techniques,

the technical efficiency of a space heating system is greater and the economic cost is lower as the market size, (i.e., population) grows. The pivotal factor in this relationship is the potential for raising the load factor of the geothermal physical plant. Insofar as a larger market permits the fuller utilization of system capacity, the incentive for harnessing geothermal energy for district heating will be stronger. In the analysis to follow, therefore, only the development of geothermal energy for district heating will be considered.

A final consideration is the nature of the resource itself. Two properties in particular are important: the temperature and the location of the resource vis à vis the market. Given the existing state of production technology, the hotter the resource and the closer the resource to the point of consumption, the more financially attractive geothermal investment becomes. Conversely, the cooler the resource and the farther it is from the point of consumption, the less profitable geothermal investment is.

All the considerations discussed above are recognized in the following analysis. The nature of the revenues and cost flows are included in the specifications of the model. The user population, resource, temperature, and the distance to the market are explicitly considered below in evaluating prospective resources. The complete description of the GIRORA-Nonelectric and the associated computer program written in FORTRAN IV is given in Appendix 2.

5.2 A Technical Screening of the Regional Low Temperature Resource Endowment.

A complete compilation of known low temperature anomalies identified by the Core Team and state personnel is presented in the data base section of the report. For each of these sites, the location (state and county), the latitude and longitude, a set of estimated temperatures, and the estimated reservoir volume are presented.

The distribution by state of low temperature geothermal resource sites is summarized in Table 5.1. In addition, the estimated energy potential in MBtuh is calculated for each state. The distribution of neither is balanced. For example, 328 of the 504 (65 percent) known anomalies are found in Nevada. Each of these resource sites is designated with a dot (.) in Figure 5.1. Viewed from another perspective, if the energy supply potential of these resources is calculated in MBtuh, a full 78 percent of the total is located in Nevada. Thus, just as in the case of the high temperature resources, Nevada is also rich in low temperature geothermal resources as well.

TABLE 5.1

Distribution of Low Temperature Geothermal
Resources by State

State	Number of Resource Sites	Estimated Supply Potential in MBtuh
Arizona	40	1892
Colorado	45	1460
Nevada	328	30423
New Mexico	46	2969
Utah	45	2201
Total	504	38945

Figure 5.1 Low Temperature Sites in Southwestern Region

The large number of resource sites and the estimated Megawatt years of energy designated in Table 5.1 present a misleading impression of the true geothermal energy potential in the Southwest region. Given the nature of resources and the state of production technology, many of these resources offer no current energy potential. The first task which must be undertaken, therefore, is to eliminate from further consideration any resource which, for one reason or another, is not a feasible supply site.

Accordingly, the initial inventory of low temperature resource sites was subjected to a technological screening. The objective of this exercise was to divide the population of sites into two samples. The first sample consists of sites which are currently usable given the existing state of production technology in the industry. Those sites which fall in the second subgroup are resources which, for one reason or another, are not considered usable given the present state of "know how." As production techniques advance, however, these latter resources may in time become of substantive importance.

Three criteria were employed to partition the total resource base. The first is the temperature of the resource. A minimum resource temperature is required for effective space heating just as a minimum temperature is required for electricity generation from hotter resources. Earlier space heating experience in Klamath Falls, Oregon, and Boise, Idaho, were consulted in designating a minimum temperature.

The second criterion is the distance between the geothermal resource and the nearest user market. This consideration is intended to exclude from further study all resources which are not sufficiently proximate to a market to be realistically employed.

The final criterion employed for partitioning low temperature resources is the size of the potential market. A minimum feasible market size, which is measured in terms of population, is defined. If there is or is not a market of sufficient size, within the designated distance, a resource will or will not be considered usable.

The preliminary values for the technological screening criteria are presented in Table 5.2.

The technological screening described above was 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

TABLE 5.2

Preliminary Values for Technological
Screening Criteria

Distance	≤ 50 Miles
Market Population	≥ 1000 persons
Resource Temperature (T)	$65^{\circ} \leq T \leq 150^{\circ}\text{C}$

technological supply potential of low temperature resources is known. This estimate is certainly more realistic than earlier estimates (e.g., by Reistad), in that the locational configuration of supply and demand sites is explicitly recognized.

The technological screening also allows for the evaluation of the impacts of future technological innovations. The initial partitioning process can easily be reiterated for various temperatures, distances, and demand measures. Each successive iteration will thus provide a new estimate of the regional technological supply potential given a different state of production "know how."

The results of the preliminary technological screening are informative. The original cost of candidate sites has been reduced to 82. The complete list of the remaining sites is presented in Table 5.3; the sites are distributed by state, and the estimated supply potential is also calculated. Figure 5.2 then presented a visual summary of the location of each of these resources.

Both Table 5.3 and Figure 5.2 convey a noteworthy impression: of the original 504 sites, only 16 percent are feasible given current production expertise. Thus, a rough but realistic evaluation of the regional geothermal supply potential considerably depresses earlier estimates. A set of histograms presented in Figure 5.3 effectively portrays the reduction in the aggregate supply potential attributable to the technological screening.

Each of the remaining sites will next be considered to evaluate its economic potential for space heating. A number of economic considerations which have not yet been introduced will contribute to this judgement. In effect this exercise will constitute a second screening on the basis of economic rather than technological criteria.

The primary output of the GIRORA-Nonelectric model then is the calculated internal rate of return, R . This estimate of profitability is analytically useful for a number of reasons. First, of course, the estimated value of R provides a general measure of market profitability. As technologically feasible geothermal resources are more or less profitable, private firms are more or less likely to develop them. Second, if an internal rate of return can be calculated for each geothermal site, then an ordinal ranking of resource areas may be compiled on the basis of estimated profitability. Assuming that the most profitable sites will be developed first, this ranking will provide a unique ordering of sites to be brought "on line." Such information is already in demand to facilitate planning and development efforts.

Table 5.3

Distribution by State of Low Temperature Geothermal
Resources Which Pass Initial Technological Screening

State	Site	Estimated Supply Potential, MBtuh
Arizona	Gillatd H.S.	70
	Eagle Creek H.S.	82
	Coolidge H.S.	117
	Coffers H.S.	30
	Cat Tank	35
	Safford Area	22
	Castle H.S.	110
	Yuma	156
	Littleton	160
	Wilcox	29
	Casa Grande (North)	120
	Casa Grande (South)	114
Colorado	Craig Warm Water	21
	Roub H.S.	20
	Steamboat Springs	54
	Hot Sulphur Springs	27
	Idaho H.S.	50
	Glenwood H.S.	16
	South Canyon H.S.	4
	Colonel Chinn H.S.	3
	Hartsell H.S.	17
	Brown Canyon Thermal	37
	Poncha H.S.	54
	Don K Ranch	30
	Mineral H.S.	41
	Shaws Warm Spring	4
	Dutch Crawley	8
	Pagosa Springs	15
	Wagon Wheel Gap	22
	Cebolla H.S.	37
	Orvis	3
	Duray	20
	Lemon	18
	Rico	60
	Pinkerston	7
	Tripp & Trimble	20
Nevada	Cherry Creek H.S.	78
	Hot Pot Blossom	32
	Mineral H.S.	7
	Hot Springs Point	8
	Warm Springs	10
	Sou H.S.	9
	Elko H.S.	44

Table 5.3 (cont.)

Nevada (cont.)	Sodaville Springs	40
	Walley H.S.	116
	Hind's H.S.	110
	Carson Lake	35
	Wilson H.S.	85
	Eightmile Flat	35
	Wellington	63
New Mexico	Radium Springs	141
	Ojo Caliente	141
	Gila H.S. (Below Bridge)	63
	Gila H.S. (Middle Fork)	14
	Montezuma H.S.	141
	Mamby's H.S.	90
	Turkey Creek	34
	Las Alturas	129
	Berino-Mesquite	129
	Ponce De Leon	40
	T or C	25
	W. Mesa - Black Mountain	98
	Derry Warm Spring	27
	Guadalupe Spring	128
	Hot Well	104
	San Ysidro	104
	Hueco-S. Tularosa	66
Utah	Aleman	116
	Sandiego Mts.	134
	Joseph H.S.	153
	Red Hill H.S.	147
	Crystal H.S.	147
	Abraham H.S.	136
	Wasatch H.S.	130
	Monroe H.S.	130
	Ogden H.S.	117
	Stinking Springs	117
	Meadows Springs	110
	Hooper H.S.	110
	Utah H.S.	99
	Becks H.S.	92
	Crystal H.S.	92

Figure 5.2... Technologically Feasible Low Temperature Sites in Southwestern Region

Figure 5.3 Estimated Energy Potential of Low Temperature Geothermal Energy before and after Technological and Economic Screening

The calculation of a site specific internal rate of return is invaluable for yet another reason. By altering the values of selected variables and parameters within the model, the sensitivity of the rate of return to a number of pertinent factors can be determined. In the following pages, the results of such simulation exercises are presented.

5.3 Simulation Results

Simulation experiments with GIRORA have yielded a number of interesting and highly informative results. Three exercises were undertaken. First, a baseline scenario was proposed, and the resulting internal rate of return was estimated. This might be considered the case of a hypothetical geothermal developer working on a hypothetical geothermal resource site. The second exercise consisted of conducting sensitivity analysis. Changes in selected parameters of the model were proposed, and the resulting impacts upon the internal rate of return were measured. Finally, several market scenarios were proposed and the rates of return were forecasted. An "Optimistic" and a "Pessimistic" scenario were specified based upon selected values of key determinates of R. The purpose of this exercise was to define, insofar as possible, practical limits to the bounds of potential geothermal resource development.

The Baseline Case

The baseline case depicts a geothermal resource being harnessed to provide space heating. Table 5.4 summarizes the values specified for all manual inputs and major choice and parametric model variables.

A geothermal resource with a temperature of 100°C is assumed to be the candidate resource. It is located five miles from a population center of 5,000 persons for whom space heating is to be provided. The load factor of the unit is assumed to be 0.6 and the price of natural gas with which geothermal energy must compete is \$3.00/10⁶ BTU. As for the geothermal producers, an investment tax credit rate of 0.12 is assumed; a royalty rate of 0.15 is assumed; the depletion allowance is zero; and the cost of debt capital is 8.5 percent. Finally, a debt equity ratio of 0.7/0.3 is assumed.

The estimated rate of return for this baseline case is 11.0%. Under the conditions specified, therefore, the prospects for space heating appear to be encouraging. Accordingly, the results of the sensitivity analysis become increasingly important, since they will reveal which factors might prove most influential in altering the internal rate of return on investment.

TABLE 5.4

The Baseline Case Values

Parameter or Variable	Base Case Value
Temperature	100°C
Distance	5 miles
Population	5,000
Load Factor	0.6
Price of Natural Gas (\$/10 ⁶ BTU)	\$3.00
Investment Tax Credit Rate	0.12
Royalty Rate	0.15
Depletion Allowance	0.0
Producer Bond Rate	0.085
Equity Capital Share	0.3
Internal Rate of Return (R)	11.0%

The Sensitivity Analysis

The values of the physical, geophysical and policy factors specified in Table 5.4 are variables in this model. Each of these factors exerts impacts upon the rate of return which are, for the most part, clearly defined but quantitatively unspecified. For the sake of convenience, these factors have been grouped into several classes. The first class includes the geophysical factors, and the second class includes policy variables and parameters. The role of the geophysical factors in influencing R will be examined first.

Consider the ramifications of variations in resource temperature upon the estimated rate of return. In this analysis, the temperature span considered ranges from 80° to 150° C. The differing values of R at each temperature are illustrated in Figure 5.4.

The changes in resource temperature clearly exert only minimal impacts upon R. If all other parameters and variables considered are maintained at their base case values, the rate of return is 11 percent at 80°C, and it rises to just over 12.5 percent at a temperature of 150°C. Such a finding, that lower temperature resources generate nearly as high a return as the hotter resources is encouraging given the the abundance of relatively lower temperature anomalies in the Southwest.

Consider next the importance of the distance to the market as a determinant of the internal rate of return. Given the potentially large size of the transmission expense, changes in distance can be expected to exert substantial impacts upon R. Figure 5.5 depicts the effects of differences in distance between 0 and 25 miles when all other base case values are held constant. In order to maximize the information provided, the estimated rate of return is plotted against the resource temperature. In this manner, the interactive impacts of changes in distance and temperature become evident.

The distance over which geothermal fluid must be transported strongly influences R values for a given resource site. For example, at distance of 5, 15, and 25 miles, the rate of return falls from 12.75 to 10.0 to -0.25 percent at 120°C. In the case of a user who is located on site (distance = 0), an estimated 21.5 percent return would be earned. For space heating purposes, therefore, the distance between the resource and the user is of major importance in determining the financial return on investment in geothermal energy development.

The third geophysical parameter in which we are interested is the population of the district heating unit. Variations in population will alter both revenues

Figure 5.4. Sensitivity of R to Changes in Temperature.

Figure 5.5. Sensitivity of R to Changes in Distance (in miles)

earned and investment costs sustained. To clarify the net impacts upon R, population sizes of 1000, 2000, 3000, 4000, 5000, 10,000, 15,000, and 25,000 have been proposed. Figure 5.6 summarizes the results for various temperatures between 80° and 150°C.

The results are highly informative. Changes in the rate of return are directly related to changes in population at all temperatures. For example, at 120° C, the return on investment rises from 1000 to 25,000. These findings indicate that sizeable financial incentives exist for investment in space heating for relatively larger versus smaller communities.

The analysis above of the roles of the physical and geophysical resource characteristics in determining the return on investment in geothermal energy provided clear results: for anomalies with temperatures between 80° and 150°C, those which are closer to the largest populations offer the greatest financial incentive. Among the other factors in the model which are of concern are a class of parameters and variables which are, in some sense, policy tools. Some of these have been traditionally employed for stimulating natural resource development. Six policy tools are considered here. These include the royalty rate, the bond rate of the producer, the price of home heating fuels with which geothermal energy must compete, the depleting allowance, the investment tax credit rate, and the system load factor. The role of each of these in determining R is considered below.

The influence of the royalty rate in determining R is ascertained by altering its value from 0.10 to 0.20. Figure 5.7 presents the results of these calculations. Changes in royalty rates appear to exert quite modest impacts upon R. A reduction of royalty rates from 0.20 to 0.10 raises the rate of return from 12 percent to 13.75 percent. In and of itself, therefore, changes in the royalty rate do not appear to be of major importance in influencing the rate of return.

Consider next the results of alterations in the bond rate of the producer in revising the internal rate of return. Government loan guarantee programs are frequently considered as a means for insuring a supply of venture capital at a minimum cost. In this manner, reductions in interest charges from such programs reduce the cost of financial capital, thereby raising the internal rate of return.

Figure 5.8 reveals that relatively large changes in the bond rate generate relatively small absolute variations in the rate of return. For example, at 120° C, reducing the bond rate from 8.5 percent to 6.5 percent raises the return

Figure 5.6. Sensitivity of R to Changes in Population

Figure 5.7. Sensitivity of R to Changes in Royalty Rates

Figure 5.8. Sensitivity of R to Changes in Bond Rate

from 12.75 to 13.75 percent. Furthermore, the leverage which financial capital rates exert upon R is limited at all temperatures between 80° and 150° C. Clearly, reductions in the bond rate do enhance the attractiveness of geothermal investment, in the expected manner, but these effects are of relatively minor importance.

A third policy variable is the price of natural gas. This is the space heating fuel with which geothermal energy must compete throughout much of the Southwest. As natural gas prices rise, the potential revenue recoverable from geothermal energy will rise as well. Accordingly, dollar increments in gas prices from \$3.00 to \$8.00/10⁶ BTU have been proposed.

Figure 5.9 reveals that increases in the price of competing fuel bear heavily upon the rate of return to geothermal investment. At 120°C, an increase in natural gas prices from \$3.00 to \$6.00 raises the rate of return from 13 percent to 24.5 percent. On average, each one dollar rise in price generates an increase in R of four percentage points. Deregulations of energy prices in the U.S. would clearly provide strong impetus to geothermal energy development.

The depletion allowance is yet another potential policy option which may influence the return to geothermal energy development. The depletion allowance was assumed zero in the base case, and its value was raised to 0.11 and 0.22 in the sensitivity analysis. The results, illustrated in Figure 5.10, are similar to those for the royalty and bond rates. Although the direction of the changes in R are as expected, the magnitude of the absolute change is limited. Increasing the depletion rate from 0 to 0.22 raises the rate of return roughly 2.5 percentage points at all temperatures. By itself, therefore, the depletion allowance offers relatively limited policy potential as a means of improving the profitability of geothermal energy investment.

A final traditional policy variable which is considered is the investment tax credit rate. A range of investment tax rates has been specified between 0.04 and 0.20. Figure 5.11 verifies that this is also a relatively insignificant factor in affecting the absolute value of R. Raising the tax credit rate from 0.04 to 0.20 only increases R by 1.5 percentage points, from 12.25 to 13.75 percent. As in the case of the royalty rate, bond rate and depletion allowances, the tax credit alone is also of little consequence in determining the profitability of low temperature resources.

A parameter in the model which might be loosely considered a policy option is the load factor. The load factor is a measure of the efficiency of utilization

Figure 5.9. Sensitivity of R to Changes in Energy Prices

Figure 5.10. Sensitivity of R to Changes in Depletion Allowances

Figure 5.11. Sensitivity of R to Changes in Investment Credits

of the entire physical plant. For a space heating system of a given capacity, the greater or lesser the load factor, the greater or lesser will be the revenues earned; and the greater or lesser the revenues earned for a given investment outlay, the more or less profitable the investment will be. Although the load factor has not been a traditional policy tool, increases in system load factors are subject to policy manipulation.

Figure 5.12 illustrates the impacts of variations in the user load factor at 120° C, the rate of return for load factors of 0.5, 0.6, 0.7, and 0.8 are 10.5 percent, 12.75 percent, 15 percent, and 17.25 percent respectively. Thus, raising the load factor by 40 percent raises R by roughly 70 percent, a highly favorable trade-off. Insofar as the load factor potential may vary from community to community, these findings suggest that the fullest appreciation should be granted the load factor.

5.4 Scenario Forecasts

In the sensitivity analysis above, the impacts of altering a single variable or parameter value were calculated. A more meaningful analysis could be provided if a number of properties of the base case scenario could be varied simultaneously. This exercise would provide valuable information on two counts. First, it would elucidate the interactive impacts upon R of several variables or parameters; and second, if the complete set of policy factors are altered simultaneously, the results would infer the full potential of public policy in influencing the profitability of investment in geothermal energy.

Accordingly, Pessimistic and Optimistic forecasting scenarios were prepared. Each scenario consisted of a designated set of policy variable values, with all other values assuming their base case magnitudes. The Pessimistic scenario posited an energy market in which policy conditions are relatively hostile to geothermal energy development. In return the Optimistic scenario pictured an environment which is relatively receptive to geothermal development. The differences in the return on investment between each case provide a measure of the potential of public policy for influencing geothermal energy development.

The scenario values specified for the six policy variables are presented in Table 5.5. The estimated internal rates of return between the scenarios differ dramatically at all temperatures as seen in Figure 5.13. In the Pessimistic setting, with circumstances generally hostile to development R is 9.5 percent at 120°. At the same temperature in the Optimistic scenario, R is a healthy 50 percent. Quite evidently, the combined efforts of all of the policy variables

Figure 5.12. Sensitivity of R to Changes in Load Factor

TABLE 5.5
Optimistic and Pessimistic Scenarios

Parameter or Variable	Pessimistic	Optimistic
Load Factor	0.5	0.9
Price (\$/10 ⁶ BTU)	\$3.00	\$8.00
Royalty Rate	0.2	0.1
Tax Credit	0.0	0.2
Bond Rate	0.085	0.065
Depletion Allowance	0.0	0.22

Figure 5.13. Estimated R for Optimistic and Pessimistic Scenarios

considered in Table 5.5 are sufficient to generate a large range of possible return on investment. This finding suggests that a carefully orchestrated mix of policies is capable of inducing space heating applications of geothermal energy on a much broader basis than would otherwise occur.

5.5 Summary of Simulation Results

A simulation model has been developed which evaluates the financial feasibility of harnessing geothermal energy for district space heating. The output of the model consists of an estimated internal rate of return for any specific geothermal anomaly. This rate of return is the discount rate which equates present values of estimated net revenues earned with investment costs incurred throughout the investment life of a geothermal reservoir. Ceteris paribus, the greater the estimated internal rate of return, the more financially attractive geothermal energy becomes for direct heating applications.

For a hypothetical geothermal anomaly, i.e., a baseline reservoir, sensitivity analysis has revealed a number of important findings. First, the geophysical characteristics of low temperature resources, including the reservoir temperature, the distance to market, and the market size, collectively impose severe constraints upon the development of geothermal resources. Specifically, unless a space heating district of good size is located quite near to a relatively "hot" geothermal reservoir, the internal rate of return will be very low or even negative.

A second finding relates to the effectiveness of the traditional policy tools for enhancing the financial return to geothermal energy development. By and large, most of the policy options considered, including the royalty and investment tax credit rates, the depletion allowance, and the cost of capital, are of limited individual effectiveness in raising the internal rate of returns. Increases in alternate fuel prices and geothermal plant load factors are the exceptions.

Several contrasting market scenarios were proposed, and the rates of return for each were estimated. The purpose of this exercise was to identify the range of possible returns given a most favorable and a least favorable set of circumstances. The results indicate that under such market extremes, effectively combined policy initiatives and efficient load factors may generate moderate improvements in rates of return.

5.6 Scenario Forecasts of Low Temperatures Geothermal Energy Potential in the Southwest

The modeling analysis presented above has provided experience factors for the expected profitability of a hypothetical low temperature geothermal resource

which has been harnessed for district space heating. The findings (i) present a "ballpark" estimate of expected profitability under certain conditions; (ii), identify the release or retention of a number of factors as determining profitability; and (iii), evaluate the effectiveness of public policy in altering profitability. All of these finds are relevant, however, only for a hypothetical service.

The profitability of geothermal resources which are actually located in the Southwest may now be examined. Those resources which passed the technological screening (Table 5.3) are of greatest concern. Ceteris paribus, the most profitable among these will be developed first and the least profitable will be developed last; those resources which will not earn some minimum return will not be developed at all. GIRORA-Nonelectric will differentiate the former from the latter.

For each of the technologically feasible sites, an internal rate of return will be estimated. The return will be unique to each site, calculated on the basis of its temperature, distance to market, and market population. The minimum acceptable return has been designated as 12 percent. This is the return frequently allowed non-profit, publicly regulated enterprises, and it is considered the minimum acceptable figure for a privately financed business.

The geothermal resources which are expected to earn an internal rate of return greater than or equal to 12 percent are presented in Table 5.6. The number is relatively small: of the 82 candidate sites, only 30 (36 percent) will earn at least 12 percent. Alternatively considering potential of the original 5602 only 2071 (37 percent) successfully pass the economic screening. Thus, only one-third of the geothermal sites (and one-third of the potential MBtuh) which survived the technological screening will generate a minimum acceptable return on investment.

On the basis of the technological and economic screening exercises, several geothermal supply scenarios may be proposed. The first of these depicts the gross energy potential (MBtuh) of the low temperature resources located in the Southwest. The second scenario presents the expected energy potential of the technologically usual resources, as defined earlier. The final scenario measures the energy potential of geothermal resources subject to the technological and economic screenings. Each of these scenarios provides an increasingly realistic appraisal of the true potential of low temperature geothermal energy in the Southwest.

Table 5.6

Distribution by State of Low Temperature Geothermal Resources
Which Pass Technolgical and Economic Screening

State	Site	Estimated Supply Potential, MBtuh
Arizona	Gillard H.S.	24
	Safford Area	22
	Yuma	116
	Littleton	160
	Casa Grande (North)	18
	Casa Grande (South)	24
Colorado	Idaho H.S.	50
	Poncha H.S.	54
	Don K Ranch	30
	Pagosa Springs	15
	Lemon	18
	Rico	60
	Pinkerton	7
Nevada	Cherry Creek H.S.	30
	Elko H.S.	40
	Walley Hot Springs	116
New Mexico	Radium Springs	25
	Montezuma H.S.	30
	Las Alturas	129
	T or C	25
	Hot Well	40
	Sandiego Mountains	134
Utah	Crystal H.S.	147
	Wasatch H.S.	130
	Ogden H.S.	117
	Stinking Springs	117
	Hooper H.S.	110
	Utah H.S.	99
	Becks H.S.	92
	Crystal H.S.	92

The scenarios are illustrated in Figures 5.14 and 5.15. The former summarizes the MBtuh potential by state, and the latter identifies the resources which pass both screenings. The summary table, Table 5.7, conveys a sobering impression. Only 6 percent of the regional low temperatures sites, providing 6 percent of the MBtuh in the Southwest, survive both screening processes.

Figure 5.14 Estimated Energy Potential of Low Temperature Geothermal Energy before and after Technological and Economic Screening

Figure 5.15 Economically Feasible Low Temperature Sites in the Southwestern Region

Table 5.7

**Summary Table of Technological and Economic
Feasibility of Low Temperature Geothermal
Resources in the Southwest**

State	Total		Technological Feasibility		Economic Feasibility	
	No. of Sites	Available Heat MBtuh	No. of Sites	Heat MBtuh	No. of Sites	Heat MBtuh
Arizona	40	1892	12	1045	6	364
Colorado	45	1460	24	588	7	234
Nevada	328	30423	14	672	3	186
New Mexico	46	2969	19	1724	6	383
Utah	45	2201	13	1573	8	904
Total	504	38945	88	5602	30	2071

Technological Feasibility:

Temperature: $65^{\circ} \text{C} \leq T < 150^{\circ} \text{C}$

Population: 1000

Distance: 50 miles for single population center

Economic Feasibility:

Rate of Return $\geq 12\%$ from GIRORA

CHAPTER VI

DATA BASE AND REGIONAL PROGRAM PROGRESS MONITOR

The computing support described here has been provided by the Regional Program Progress Monitor (RPPM) Group of the Physical Science Laboratory (PSL) of New Mexico State University (NMSU). This support falls into two categories. The first includes the work connected with design, development, implementation, and validation of the geothermal data base, which is the first phase in achieving the goal of a computerized Regional Program Progress Monitor for the project. The second category encompasses the computing required for various economic and scientific investigations conducted by the Core Team.

Soon after the project was started, the state teams were requested to gather information about their resources and send it to the Core Team. To aid in recording the data, a Resource Area Data Sheet (Figure 6.1) and a Drilling Data Sheet (Figure 6.2) were distributed to the state teams. While data were being gathered by the state teams, the core team was considering the question of data storage. It was decided that geothermal data which would be used regularly in calculations and reports should be put in computer storage. The remaining data would be kept on file until the demand for it increased to a point that would justify electronic storage. By mid-1977 interactive (conversational) terminals, such as the IBM 2741, were available in some work areas at NMSU. These allowed quick computer response in jobs which could be processed using the APL computer language. Consequently, this particular language was adopted as standard for use on short geothermal data processing jobs.

6.1 Market Area Determination

In November and December 1977, the accomplishment of market studies required that the number of people living within 50 miles of certain geothermal sites be determined. A computer file was created which contained population center information consisting of city name, county, state, population, latitude, and longitude. Most of the data were obtained from U. S. Census reports; some position information was obtained from atlases. Distance were calculated using the APL functions shown in Appendix 3 of this report.

Thus, the approximate number of people living within a specified distance of a site could be calculated. Repeated studies were made using various distances. The recurring demand for such information established the need to keep the 'city and population' tables in computer storage.

**SOUTHWEST REGIONAL
GEOTHERMAL O/R PROJECT**

Classification:

Open

RESOURCE AREA DATA SHEET

Common Name: _____ **Project I.D. No.** _____
County _____ **State** _____
Location _____ **Township/Section** _____

Lat./Long _____
Nearest Community _____ **Population** _____ **Distance** _____
Nearest Metro Area _____ **Population** _____ **Distance** _____
Designated KGRA? _____ **by (Agency)** _____ **Date** _____

Leasing Status:

Location _____ **Surface Ownership:** _____ **Lessor:** _____ **Lessee:** _____ **Access:** _____ **Cost** _____ **Terms:** _____

Information Source _____
Person Compiling _____ **Date** _____ **Revision** _____
Agency _____ **Page** _____ **of** _____

Information Source: _____

Reliability Assessment: _____

Figure 6.1 Resource Area Data Sheet

Drilling Data Sheet No.'s: _____

Environmental Aspects:

Effluent Gases: _____

Effluent Solubles: _____

Subsidence: _____

Reinjection: _____

Other seismic: _____

Disturbance of Terrain: _____

Co-Use With: _____

Resource Quantification: _____

Probable Available Energy:

Rate _____ MWe $\pm$ _____ MWe _____

Expected Life _____ Years $\pm$ _____ Years _____

CUM Energy _____ MWe Years $\pm$ _____ MWe Years _____

Distance to:

Nearest Power Transmission Line _____

Nearest Use Point: _____

Development Status/Schedule:

Figure 6.1 Resource Area Data Sheet (Continued)

**SOUTHWEST REGIONAL
GEOTHERMAL O/R PROJECT**

Classification:

Open _____

DRILLING DATA SHEET

Well Name/No. _____ Project I.D. No. _____

Resource Area Name/No. _____

Location _____ Township/Section _____

County _____ State _____

Operator _____

Drilling: _____ Diam. _____ deep, through downhole conditions of: _____

Finds: _____

Energy Quality: Temp _____ $\pm$ _____ Flow Rate _____ $\pm$ _____ Pressure _____ $\pm$ _____

By Test _____

By Calc : _____

Estimated Lifetime: _____

Effluent Quality:

Gases (Composition, %) _____ $\pm$ _____ (cc's/kw) _____ $\pm$ _____

_____ $\pm$ _____

_____ $\pm$ _____

Solubles Suspended Solids (Composition _____ (kg/kw) _____
or PPM, %): _____

Figure 6.2 Drilling Data Sheet

Status: Drilling in Progress ☐ Completed _____ (Date)
Producible ☐ In production _____ ± Suspended ☐ Abandoned ☐ Observation ☐ Injection ☐
(Date)
From (Source) _____
Drilling Contractor/address _____
Cost of drilling: _____

Adjacent Drilling:

Name/No. _____ Project I. D. No. _____

Notes:

Information Source

Person Compiling _____ Date _____ Revision _____
Agency _____ Page _____ of _____
Information Source: _____
Reliability Assessment: _____

Figure 6.2 Drilling Data Sheet (Continued)

6.2 Data Base Design

Also in November and December a tentative format for geothermal site information was adopted and data were entered as APL files into computer storage through the terminals. The format included basic site information such as name, location, reservoir volume, and temperature. Using APL commands and functions it was easy to manipulate the data and make useful calculations. Current demand was the primary factor in determining what should go into the data base. In January, estimates of recoverable energy were calculated for each hydrothermal site and results, which indicated sites with good potential for development, were sent to state teams to help them in writing site scenarios. This job utilized practically all of the data in the geothermal site file. The equations for calculation of stored heat, electric potential, and thermal potential (recoverable energy) were obtained from the U. S. Geological Survey Circular 726. The formatting of the report was done with APL and typing took place at the terminal under computer control.

The geothermal data base is relatively small. The SITE relation, which contains all of the geothermal site information, consisted of approximately 250 geothermal sites and about a dozen domains (data fields) for each site in January. In March at the quarterly meeting in Reno, Nevada, an explanation of the data base structure was made to the state teams and consultants, and samples of the data base were displayed. Later in March new data provided by the state teams were entered in the data base. Then the entire geothermal site portion of the data base was arranged into tables, reproduced, and copies were sent to state teams and Core Team investigators for comments and verification. As a consequence, the state teams sent in additional data which enabled correction of the entries already in the data base.

A complete description of the entire data base was begun in April, continued into May and was published as a 62 page volume called the RPPM Data base. This report lists all of the data in the three divisions of the data base. The report also explains how information may be retrieved from the data base using a terminal connected to the New Mexico State University computer. The report was distributed to the state and core teams during the fourth quarterly meeting of the project in Las Cruces, NM, on May 31 and June 1, 1978. A copy of the report is included as Appendix 3 in this report.

6.3 The Data Base Management System

In 1977 a data base management system called Educational Data Base System (EDBS) was obtained by the NMSU Computing Center from the University of Toronto.

EDBS used the APL language and files so it appeared to be well suited for geothermal data base management. However, EDBS proved to be too slow in retrieving information from the data base. It was not possible at that time to determine whether the computer system or EDBS was responsible for the delays. The use of EDBS for the geothermal data base was postponed. Instead, some APL functions such as 'GET', which is described in Appendix 3, were used for retrieval and update purposes.

6.4 Leasing and Drilling Information

Since leasing and drilling information is of great importance in estimating future sites development, it should be incorporated into the data base. To put all such data into a data base would require a substantial amount of manpower, which would be justified only if the data were used frequently in development scenarios. Detailed leasing data has not been needed thus far by project analysts and as a consequence it has not yet been entered into computer storage. Alternate designs for including lease data are now being considered. One approach is to create a new relation, based on townships, giving detailed information about leases near each geothermal site. Similar methods are being considered for drilling data.

6.5 Data Base Functions

Many APL functions have been developed especially for the geothermal project. The following pages in this chapter contain listings of these functions together with explanations of how they work, their input and output, and their limitations. More information about the functions can be obtained from the Core Team.

Group Name: UTILITYGROUP

WS Name: 310733401 PJLIB

Group Description: These functions are designed to assist in many applications. They are of two types, those written expressly for the project and those found in edit packages in public workspaces at the UCC (indicated by an asterisk).

Functions Used: TIEaFILE, CHECKaLIB, STaNAMEs, STaABBRv, CNTZaNAMEs, SUBMIT*, STATUS*, JOB*, AI, DUMP, RESHAPE, RAVEL, DATE, SORT.

Variables Used: FILEPRT

Function Name: TIEaFILE

Global Variables Used: none

Global Variables Created: none

Local Variables: FN (input as described below)
TN (output as described below)

Input: A right argument, FN, containing the library number and name of file to be tied. This argument (a vector) must resemble a row in the explicit result of system function `FLIB`, ie:

<u>column</u>	<u>description</u>
1	blank
2-10	library number
11	blank
12-22	file name

Output: An explicit result, TN, a scalar. 2 is a 0 if the file could not be tied; if the file was tied, 2 is the tie number.

Subroutines: CHECKaLIB

Calling Routines: MARKET

Function Name: CHECKaLIB

Global Variables Used: none

Global Variables Created: none

Local Variables: FN (input as described below)
X (output as described below)

Input: See input description for function TIEAFILE in this group.

Output: An explicit result, X, a scalar. X is a -1 if the file doesn't exist. X is a 0 if the file exists, but is not tied. X is the file tie number if the file is tied.

Subroutines: none

Calling Routines: TIEAFILE

Special Coding:

<u>line</u>	<u>coding comments</u>
2	If file exists, X will be 0; otherwise, X will be -1.
4	X is assigned the file tie number.
5	If file was not tied, X will be an empty vector or a result of line 4.
6	File not tied, so reassign X to be 0.

Function Name: STANAMES

Global Variables Used: Codes

Global Variables Created: 2

Local Variables: none

Input: A matrix of numbers; for one state name it could be used as follows:
STANAMES 1 1 4 which gives Arizona. To get the entire matrix of state names the following will do it: STANAMES 13 2 4 5 6 7 8 9 10 11 12 13 14 15 16'.

Output: Will be one or however many the first dimension of the matrix is.

Subroutines Used: none.

Special Coding: none.

Function Name: SUBMIT*

Input: A right argument, X, a vector containing card images (they needn't be 80 characters) separated by carriage returns, representing a job deck.

Output: An explicit result, R, containing the name of the job submitted.

Function Name: STABBRV

Global Variables Used: CODES

Global Variables Created: 2

Local Variables: none

Input: A matrix of numbers. For New Mexico the function could be used as follows: STABBRV 1 1@'7'. To get the entire matrix of state abbreviations: STABBRV 13 2@' 4 5 6 7 8 910111213141516'.

Output: Will be one or however many the first dimension of the matrix is.

Subroutines Used: none

Special Coding: none

Group Name: MARKETGROUP

WS Name: 310733401 PJLIB

Group Description: For user documentation, refer to the variable MARKETHOW in this group. The user routines are MARKET and MARKETSTATUS. The group can be divided into two subsets: those routines written specifically for the O/R project effort and those routines available from various editing packages (notably, 501 EEEDIT) in public workspaces at the UCC (These are noted below with an asterisk).

Functions Used: MARKET TIEAFIL CHECKALIB STAABBRV CNTYANAMES SUBMIT*
MARKETSTATUS STATUS* JOB*.

Variables Used: MARKETHOW, MKTMSG MKTDMP

FUNCTION NAME: MARKET

Input: Refer to user documentation variable, MARKETHOW, in this group.

Output: Either a summary of output directed to terminal or a detail of output directed to the line printer at UCC. This detail is dumped through an APL file called 'MKTOUT' which must contain approximately 100,000 bytes of unused file space.

Subroutines: TIEAFIL, CHECKALIB, STAABBRV, CNTYANAMES, SUBMIT, STATUS.

Calling routines: none.

Special Coding:

<u>line</u>	<u>coding comments</u>
9	If user doesn't request a detail dump, the next few operations are unnecessary.
13	If the MKTOUT file is not empty, request instructions.
15	If the user requests the file to be erased, fall through and drop all components.
13-19	If the user requests the file be left as is, change DMP condition to false and PRISUM to true.
20	Reserve a component for the job summary.
25	Since we have 2 temp domains ETEMP and MTEMP, we must combine them into 1.
26-27	Eliminate from input those sites and temps which don't meet input criteria.

<u>line</u>	<u>coding comments</u>
29	If no sites result skip processing.
30-36	format summary
37-38	Read appropriate site latitude and longitude.
39	Construct a rectangular boundary around the site.
40-50	Construct a file of cities within this rectangular boundary.
47	If no cities found within boundaries in the state, don't try and change pop. to numeric form.
51	If no cities are found within this rectangular boundary, skip ahead.
52-65	Intermediate results of the calculations to determine the straight line distance between the site and each city within the rectangular boundary.
66	MI is that distance rounded to the nearest mile.
67-68	Eliminate those cities not within the specified radius.
70	If no cities within radius, skip ahead.
71-74	format summary
75	If no dump requested, skip ahead.
79-80	If there is more than one county name in CST, skip ahead; else, reshape a single name into a matrix.
81-93	format detail
94	Append format detail.
95-97	Compress the last processed site and its temp from the input.
98	If sites remain, go back; else,
99	If no dump requested, skip ahead.
100	Replace reserved component with summary.
101	Submit the program to dump the detail output.
102	Append job number of dump onto end of file.

<u>line</u>	<u>coding comments</u>
103	Check dump job status.
104	If no summary, skip ahead.

Function Name: MARKETSTATUS

Global Variables Used: JOB (contains job name)

Global Variables Created: none.

Local Variables: TN (tie number of output file)

Function Description: This function is used to report the current status of the job which prints the detail output at the UCC.

Input: No arguments.

Output: A status message.

Subroutines: TIEFILE, STATUS

Calling Routines: none

Special Coding:

<u>line</u>	<u>coding comments</u>
3	Assign <u>JOB</u> the job name as prviously stored in output file.
4	Check status.
5	Untie file.

Group Name: MARKETGROUP and UTILITYGROUP

Function Name: CHECK&LIB

Refer to documentation in UTILITYGROUP.

Function Name: TIEAFIL

Refer to documentation in UTILITYGROUP.

Function Name: STAABBRV

Refer to documentation in UTILITYGROUP.

Function Name: CNTYANAMES

Refer to documentation in UTILITYGROUP.

Note: Although this routine actually does nothing once county codes are substituted for names in the file NCITY (if ever), the program needn't be rewritten; simply modify this routine to make the conversion from code to name.

Function Name: SUBMIT

Refer to documentation in UTILITYGROUP.

Function Name: STATUS

Refer to documentation in UTILITYGROUP.

Function Name: JOB

Refer to documentation in UTILITYGROUP.

```

V CITYS STN
[1] OPEN 'CITY' * -(ERROR=1)/LO
[2] G← 1 8 7 6 2 3 4 5 GET 1,0,(1000*STN),(((STN+1)*1000)-1)
[3] G←G[(G[1;]*',')/(OG)[2]]
[4] G←ABC G
[5] G2←pG * MAX*MAX1*MAX2*MAX3*MAX4*MAX5*MAX6+0 * I-COUNT+1 * SZ+p(v,STN) * -(SZ=2)/NXT * NAME*STANAMES 1 1 p(v,STN) * →N
[6] NXT:NAME*STANAMES 2 2 p(v,STN)
[7] NXT2:→((G2[1]>50)^(G2[1]≤100))/CK1
[8] →((G2[1]>100)^(G2[1]≤150))/CK2
[9] →((G2[1]>150)^(G2[1]≤200))/CK3
[10] →((G2[1]>200)^(G2[1]≤250))/CK4
[11] →((G2[1]>250)^(G2[1]≤300))/CK5
[12] MAX←G2[1]
[13] ΔL1:Z1← 1 70 p((30p' '),NAME,(10p' ''))
[14] Z1+Z1,[1] 1 70 p('CITY',(10p' ''),'CITY NAME',(9p' ''),'COUNT NAME POPULATION LAT LONG ')
[15] Z1+Z1,[1] 1 70 p('ID',(60p' ''))
[16] CONT:A1← 1 5 pG[I;15] * A2← 1 24 pG[I;5+124] * A3← 1 12 pG[I;29+112] * A4← 1 6 pG[I;41+16] * A5← 1 2 pG[I; 48 49]
[17] A6← 1 2 pG[I; 50 51] * A7← 1 3 pG[I;51+13] * A8← 1 2 pG[I; 55 56] * ARRAY←A1,A2,A3,A4,A5,A6,A7,A8
[18] FMT←'5A1,X1,24A1,Y2,12A1,X1,6A1,X5,2A1,X1,2A1,X3,3A1,X1,2A1'
[19] Z1+Z1,[1] 1 70 p(FMT [FMT ARRAY])
[20] I←I+1
[21] →(I≤MAX)/CONT
[22] Z1+Z1,[1] 2 70 p' '
[23] Z1+Z1,[1] 1 70 p('TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE',(8p' ''))
[24] Z1+Z1,[1] 1 70 p('9p' ''),'AND LONGITUDE',(39p' '' ) * LL←[] * Z1 * LL←[]
[25] →(MAX2=0)/LO * →(MAX3=0)/C1 * →(MAX4=0)/C2 * →(MAX5=0)/C3 * →(MAX6=0)/C4 * →C5
[26] C1:MAX←MAX1+MAX2 * COUNT←COUNT+1 * →(COUNT<3)/ΔL1 * →LO
[27] C2:MAX←MAX1+MAX2 * COUNT←COUNT+1 * →(COUNT<3)/ΔL1 * MAX←MAX1+MAX2+MAX3 * →(COUNT<4)/ΔL1 * →LO
[28] C3:MAX←MAX1+MAX2 * COUNT←COUNT+1 * →(COUNT<3)/ΔL1 * MAX←MAX1+MAX2+MAX3 * →(COUNT<4)/ΔL1 * MAX←MAX1+MAX2+MAX3+MAX4
[29] →(COUNT<5)/ΔL1 * →LO
[30] C4:MAX←MAX1+MAX2 * COUNT←COUNT+1 * →(COUNT<3)/ΔL1 * MAX←MAX1+MAX2+MAX3 * →(COUNT<4)/ΔL1 * MAX←MAX1+MAX2+MAX3+MAX4
[31] →(COUNT<5)/ΔL1 * MAX←MAX1+MAX2+MAX3+MAX4+MAX5 * →(COUNT<6)/ΔL1 * →LO

```

310733401 PJLJB MARKETHOW

THE FUNCTION 'MARKET' IS DESIGNED TO ASSIST IN DETERMINING THE MARKET POTENTIAL FOR LOW TEMPERATURE GEOTHERMAL APPLICATIONS.

THE FUNCTION ACCEPTS AS INPUT A LEFT AND RIGHT ARGUMENT. THE LEFT ARGUMENT IS A SCALAR SPECIFYING THE STATE WITHIN WHICH THE GEOTHERMAL SITES ARE LOCATED. ONLY THE FOLLOWING VALUES ARE VALID.

- 4 ARIZONA
- 5 COLORADO
- 6 NEVADA
- 7 NEW MEXICO
- 8 UTAH

THE RIGHT ARGUMENT IS A THREE ELEMENT VECTOR INDICATING

- 1 RADIUS OF MARKET AREA IN MILES
- 2 MINIMUM SUBSURFACE TEMPERATURE IN DEGREES C
- 3 MINIMUM POPULATION.

THE FOLLOWING COMMAND INITIATES EXECUTION FOR THE STATE OF ARIZONA. THE RADIUS OF THE MARKET AREA IS 50 MILES, THE MINIMUM TEMPERATURE IS 150 DEGREES CENTIGRADE, AND THE MINIMUM POPULATION IS 1000.

4 RADIUS 50 150 1000

AFTER INITIATING EXECUTION, THE USER WILL BE PROMPTED FOR OUTPUT INSTRUCTIONS. EACH QUESTION SHOULD BE ANSWERED Y (YES) OR N (NO).
OUTPUT OPTIONS INCLUDE

- (1) A SUMMARY OF OUTPUT DIRECTED TO THE USER'S TERMINAL.
- (2) A SUMMARY AND DETAILED OUTPUT DIRECTED TO THE LINE PRINTER AT THE UNIVERSITY COMPUTER CENTER.

IF OPTION (2) IS SELECTED, THE SUMMARY AND DETAILED OUTPUT ARE 'DUMPED' TO THE UNIVERSITY COMPUTER IN A BATCH MODE, AND MAY NOT BE PRINTED IMMEDIATELY. TO CHECK THE STATUS OF THE 'DUMP', ENTER THE COMMAND MARKETSTATUS. THE SYSTEM WILL RESPOND WITH A TIME ESTIMATE IF THE JOB HAS NOT YET BEEN PRINTED. IF THE RESPONSE IS 'MARKETSTATUS JOB NOT FOUND', YOU WILL FIND YOUR LISTING IN THE OUTPUT BOX MARKED 29 IN THE USER AREA OF THE UCC. THE LISTING WILL HAVE THE NUMBERS 2429 AT THE TOP, BUT TO BE CERTAIN IT IS YOURS, LOOK FOR THE WORD 'MARKET' JUST BELOW THE

MARKET

```

V STATE MARKET LIMITS
[1]  +(1=+/STATE= 4 5 6 7 8)/AL10
[2]  'INVALID STATE CODE'
[3]  +0
[4]  AL10:TNS+STN+TIEΔFILE ' 310733401 NSITE'
[5]  TNS+TNS,CTN+TIEΔFILE ' 310733401 NCITY'
[6]  +(3>STN+CTN)/0
[7]  'PRINT SUMMARY ?' * PRISUM-'Y'=1+□, ' '
[8]  'DUMP ?' * DMP-'Y'=1+□, ' '
[9]  +(DMP=0)/AL30
[10] OTN+TIEΔFILE ' 310733401 MKTOUT'
[11] +(0>OTN)/AL100
[12] TNS+TNS,OTN
[13] +(0=SOTN[2]-(SOTN-□FSIZE OTN)[1])/AL25
[14] MKTMSG
[15] +('E'=1+FLAG+□, ' ')/AL12
[16] □FDROP OTN,-SOTN[2]-SOTN[1]
[17] +AL25
[18] AL12:→('C'=1+FLAG)/AL100
[19] DMP+0 * PRISUM+1 * +AL30
[20] AL25:(0p0) □FAPPEND OTN
[21] AL30:RLIM+LIMITS[1] * TLIM+LIMITS[2] * PLIM+LIMITS[3]
[22] SITES+□FREAD STN,STATE
[23] ETEMP+2,SITES[; 73 74 75 76]
[24] MTEMP+2,SITES[; 77 78 79 80]
[25] ETEMP[CTEMP]+MTEMP[CTEMP+(ETEMP=0)/1pETEMP]
[26] SITES+(ETEMP≥TLIM)+SITES
[27] ETEMP+(ETEMP≥TLIM)/ETEMP
[28] (pSITES)[1]; ' SITES'
[29] +(0=(pSITES)[1])/AL100
[30] SUMMARY+ 2 73 p' INPUT PARAMETERS',146p' '
[31] ST+STAABRY SITES[1;1], ' '
[32] SUMMARY+SUMMARY,[1] 1 73 p'STATE',(20p' '),ST,73p' '
[33] SUMMARY+SUMMARY,[1] 1 73 p'MARKET AREA RADIUS ',(▼RLIM),
    MILES',73p' '
[34] SUMMARY+SUMMARY,[1] 1 73 p'MINIMUM TEMPERATURE ',(▼TLIM),
    DEGREES C',73p' '
[35] SUMMARY+SUMMARY,[1] 4 73 p'MINIMUM POPULATION ',(▼PLIM),((
    47-p▼PLIM)p' '), (206p' '), 'AREA ' ,9p' '

```



```

[36] SUMMARY-SUMMARY,[1] 2 73 p'ID      NAME',(21p' '), ' LAT
      LONG      POPULATION      TEMP',146p' '
[37]  $\Delta L40:SLA+(z,SITES[1; 31\ 32\ 33])+(z,SITES[1; 34\ 35\ 36])+60$ 
[38]  $SLO+(z,SITES[1; 37\ 38\ 39\ 40])+(z,SITES[1; 41\ 42\ 43])+60$ 
[39]  $BOUND+(SLA+RLIM+60),(SLA-RLIM+60),(SLO+(RLIM*1.2)+60),(SLO-(RLIM$ 
       $*1.2)+60)$ 
[40] CITIES+ 0 64 p' ' = CN+4
[41]  $\Delta L50:X+CFREAD\ CTN,CN$ 
[2]  $LA+(z,X[; 6\ 7\ 8])+(z,X[; 9\ 10\ 11])+60$ 
[43]  $LO+(z,X[; 12\ 13\ 14\ 15])+(z,X[; 16\ 17\ 18])+60$ 
[44]  $LALOC+(LA\leq BOUND[1])\wedge(LA\geq BOUND[2])$ 
[45]  $LOLOC+(LO\leq BOUND[3])\wedge(LO\geq BOUND[4])$ 
[46]  $CITIES+CITIES,[1](LALOC\wedge LOLOC)+X$ 
[47]  $+(0=(pCITIES)[1])/\Delta L55$ 
[48]  $CITIES+(PLIM\leq z,CITIES[;19+17])\wedge CITIES$ 
[49]  $\Delta L55:CN+CN+1$ 
[50]  $+(CN\leq 16)/\Delta L50$ 
[51]  $+(0=(pCITIES)[1])/\Delta L70$ 
[52]  $SLA+SLA+57.29578$ 
[53]  $SLO+SLO+57.29578$ 
[54]  $CLA+((z,CITIES[; 6\ 7\ 8])+(z,CITIES[; 9\ 10\ 11])+60)+57.29578$ 
[55]  $CLO+((z,CITIES[; 12\ 13\ 14\ 15])+(z,CITIES[; 16\ 17\ 18])+60)+57.295$ 
      78
[56]  $A+20925831 * B+20854891 * C+0.006768658$ 
[57]  $SN+A+(1-(C*10SLA)*2)*0.5$ 
[58]  $CN+A+(1-(C*10CLA)*2)*0.5$ 
[59]  $SX+(20SLA)*(20SLO)*SN$ 
[60]  $CX+(20CLA)*(20CLO)*CN$ 
[61]  $SY+(20SLA)*(10SLO)*SN$ 
[62]  $CY+(20CLA)*(10CLO)*CN$ 
[63]  $SZ+(10SLA)*SN*(B*2)+A*2$ 
[64]  $CZ+(10CLA)*CN*(B*2)+A*2$ 
[65]  $\Delta+(((SX-CX)*2)+((SY-CY)*2)+(SZ-CZ)*2)*0.5$ 
[66]  $MI+[-3957.7719*^{-30\Delta}+20897037$ 
[67]  $CITIES+(MI\leq RLIM)\wedge CITIES$ 
[68]  $MI+(MI\leq RLIM)/MI$ 
[69]  $\Delta L70:POP+0$ 
[70]  $+(0=(pCITIES)[1])/\Delta L80$ 
[71]  $POP+z,CITIES[;19+17]$ 

```

```

[72] AL80:LINE+SITES[1;14],(5p' '),SITES[1;5+120],(5p' '),SITES[1;30+1
5]
[73] LINE+LINE,' N',(5p' '),SITES[1;36+16], ' W',(3p' '),((2p 7 0)W+/P
OP),(2p 9 0)W1+ETEMP
[74] SUMMARY+SUMMARY,[1] LINE
[75] +(DMP=0)/AL90
[76] +(0=(pCITIES)[1])/AL87
[77] NAMES+CITIES[;39+125]
[78] CST+STAABBRV CITIES[;12]
[79] +(2=ppCST)/AL85
[80] CST+ 1 2 pCST
[81] AL85:COUNTY+CNTYANAMES CITIES[;26+112]
[82] MI+(2p 3 0)W((pMI),1)pMI
[83] AL87:DETAIL+ 1 73 p'PROJECT ID NO. ' ,SITES[1;14],51p' '
[84] ST+,STAABBRV SITES[1;1], ' '
[85] DETAIL+DETAIL,[1] 1 73 p'SITE NAME ' ,SITES[1;5+120], ' '
,ST,31p' '
[86] DETAIL+DETAIL,[1] 1 73 p'LOCATION ' ,SITES[1;30+15], ' N
,SITES[1;36+16], ' W',35p' '
[87] DETAIL+DETAIL,[1] 1 73 p'TEMPERATURE ' ,((2p 3 0)W1+ETEMP),
' DEGREES C',70p' '
[88] DETAIL+DETAIL,[1] 1 73 p'AREA POPULATION ' ,((2p 7 0)W+/POP),55
p' '
[89] +(0=(pCITIES)[1])/AL89
[90] DETAIL+DETAIL,[1] 2 73 p' '
[91] DETAIL+DETAIL,[1] 2 73 p(10p' '), 'CITY',(14p' '), 'STATE',(7p' ')
, 'COUNTY',(6p' '), 'POPULATION DISTANCE',73p' '
[92] POP+(2p 7 0)W((pCITIES)[1],1)pPOP
[93] DETAIL+DETAIL,[1] NAMES,SP,CST,SP,COUNTY,SP,POP,(SP+((pMI)[1],5)
p' '),MI,((pMI)[1],4)p' '
[94] AL89:DETAIL [FAPPEND OTN
[95] AL90:'END SITE ',SITES[1;14]
[96] ETEMP+(0,((pETEMP)-1)p1)/ETEMP
[97] SITES+(0,((pSITES)[1]-1)p1)/SITES
[98] +(0<(pSITES)[1])/AL40
[99] +(~DMP)/AL95
[100] SUMMARY [FREPLACE OTN,([FSIZE OTN])[1]
[101] DUMMY+SUBMIT MKTDMP
[102] DUMMY [FAPPEND OTN
[103] STATUS
[104] AL95:+(PRTSUM=0)/AL100
[105] 'POSITION PAPER, THEN RETURN CARRIAGE TO RECEIVE SUMMARY' * DUMM
Y+Q
[106] SUMMARY
[107] AL100:[FUNTIE TNS

```

▼

```

      ▽ X←CHECKALIB FN
[1]  FN←FN,(22-ρFN)ρ' '
[2]  X←1+/(□FLIB 310733401)∧.=FN
[3]  +(X=-1)/0
[4]  X←(□FNAMES∧.=FN)/□FNUMS
[5]  +(1=ρX)/0
[6]  X←0
      ▽

```

```

      ▽ TN←TIEFILE FN
[1]  TN←0
[2]  +(1 0 =CHECKALIB FN)/ΔL1,ΔL2
[3]  'FILE ',FN,' MUST NOT BE TIED' ▯ →0
[4]  ΔL1:'FILE ',FN,' DOESN'T EXIST' ▯ →0
[5]  ΔL2:FN □FSTIE TN←1+1/0,□FNUMS
      ▽

```

```

      ▽ Z←CNTYANAMES CODES
[1]  Z←CODES
      ▽

```

MKTMSG

OUTPUT FILE CONTAINS DATA FROM A PREVIOUS RUN.
 ENTER E TO ERASE EXISTING DATA.
 C TO CONTINUE WITH ONLY A PRINTED SUMMARY, OR
 RETURN CARRIAGE TO END EXECUTION.

```

      ▽ R←SUBMIT X
[1]  R←JOB+□SUBMIT X
      ▽

```

```

      ▽ Z←STATUS
[1]  Z←□HASPIW('I':12+'$D''',JOB)
      ▽

```

MKTDMP

```

/**GPN0001L,585-66-2429-0,MARKET
// EXEC FILEPRT
- FILE 310733401 MKTOUT
- CEJECT
- SELECT ALL

```

▽ MARKETSTATUS:TN

```

[1] TN←TIEΔFILE ' 310733401 MKTOUT'
[2] →(TN≤0)/0
[3] JCB←FREAD TN,((FSIZE TN)[2]-1
[4] STATUS
[5] FUNTIE TN
▽

```

▽ Z←JOB;RX

```

[1] RX←'RM * →'
[2] →(2≠WC 'JOB')ρNG
[3] →(¬(ρρJOB)ε 0 1)ρNG
[4] →(¬∧/JOBεAV)ρNG
[5] →(∧/' '=JOB)ρNG
[6] Z←JOB * →0
[7] NG:'JOBNAME ERROR' * →
▽

```

▽ Z←STAABRV CODES

```

[1] Z← 16 2 ρ' AZCONVNMCAIDKANBOKORTXWY'
[2] Z←Z[(ε,(((ρCODES)[1],1)ρ' '),CODES);]
▽

```

Group Name: DBGROUP
WS Name: 310733401 PJLIB

This group allows simple retrieval of data from the RPPM Database. Using the GET function a retrieval may search a maximum of two domains, (provided one domain is ID as specified by the second element of Arg2 of the GET function. Refer to user documentation for that function.)

For detained examples of the use of these functions, refer to the user manual.

User functions are OPEN, CLOSE, GET.

)FNS: OPEN CLOSE GET EDITRELNAME VERIFYACCESS

)VARS: RELATION contains a valid relation name for use by other functions.
ERROR a variable which should be checked after each database operation performed within a user's function. If a database function terminates normally with a database error message, execution of the user function should be halted as results are unpredictable.
ERROR = 1 if an error was detected.
ERROR = 0 if no error was detected.

Function Name: OPEN
Group Name: DBGROUP

Input: a right argument RELNAME containing the name of the relation to be accessed.

Output: none

Global vars used: ERROR, RELATION
Global vars created: none
Local vars: TIES a vector (or scalar) of tie numbers

Subroutines: EDITRELNAME
VERIFYACCESS

Calling routines: none

Coding comments

Line	
1	set ERROR condition to true; if execution is terminated before the end of program then ERROR condition will be true.
2-4	if user hasn't been given access to the data element dictionary, end.
5-7	if tie numbers 99 or 100 are in use, end.
9	check for valid relation name
10	check for proper access rights (type 0 access is read only)
11-12	(if invalid relation name or access rights not granted) untie data element dictionary and end
15	no error has been detected thru this point, so ERROR condition is false

Function name: CLOSE Group name: DBGROUP
 Input: none Output: none
 Global vars used: none Global vars created: none
 Local vars: none Subroutines: none
 Calling routines: none

Line	Comments
1-3	if file tie numbers 99 and 100 are not in use it is assumed no relation is open, and execution ends, else
4	files untied.

Function name: GET Group name: DBGROUP
 Input: see users documentation
 Output: an explicit result, Z, which contains the domains specified
 for every tuple meeting the input specifications. If no tuples
 meet the specs, Z is a matrix of shape 0 rows and 0 columns.
 Each domain is separated by a comma.
 Global vars used: RELATION, ERROR
 Global vars created: none

Local vars:
 D the qualifying domain
 DX the domain directory
 ID the primary key of the open relation
 L vector of 1's and 0's, where 1's represent those tuples in a
 domain which meet the specified restrictions.
 Z the output, as described above
 ARG1, ARG2 input as described above.
 LOC ordinal position of info relating to their relation in the
 dictionary.

Subroutines: VERIFYACCESS
 Calling routines: none

Function name: GET (continued)

Line	Coding comment
1	initialize result
2	set ERROR condition to true so that if execution terminates during editing, an ERROR condition will be indicated.
3	if read only access is not approved, and; if LOC is greater than zero, it represents the ordinal location of info relating to this relation in the dictionary.
4-5	reshape the left argument into a vector if it isn't already.
6	read domain information of the open relation
7-9	if an invalid domain was included in the left argument, and.
10-12	if an invalid state code or not enough elements included in right argument, end.
13-15	if the qualifying domain is not valid, end.
16	if execution has reached this point, it is assumed no error condition will occur, so ERROR is set to false (actually a workspace full condition may occur during further processing, but this error cannot go undetected and the user will not benefit from setting the ERROR flag to true if the condition did occur).
17	read and convert qualifying domain to numeric data.
18	L is assigned a logical vector, where ones indicate ID's meeting specified requirements.
19	if no tuples meet qualifications, end.
20	if no restrictions by state, skip the next section.
21	read ID domain, convert to numeric data.
22	L is reassigned to be one only where originally one and where ID's also meet specified restrictions.
23	initialize result.
25	assign result
27	remove trailing commas

Function name: EDITRELNAME Group name: DBGROUP
Input: none
Output: 1 if RELNAME is a valid relation name, 0 if not;
 Z is an explicit result containing this value.
Global vars used: RELNAME
Global vars created: none
Local vars: none
Subroutines: none
Calling routines: OPEN

Line	Coding comments
3	reassign RELNAME to include library number and reassemble the results of DFNAME and DFLIB system functions.
4	if name is valid,end.

RPFMED PASSNUMBER 924266585

Component	Contents
1	valid relation names, one per line of the matrix. The location of each relation in the matrix determines the location of other info in the DED.
2	a vector of ones and zeros corresponding ordinally to the relation names in component 1. 1 represents availability 0 represents unavailability
3-20	empty
21	(20 + LOC) access matrix for relation CITY.
22	(20 + LOC) access matrix for relation COUNTY.
23	(20 + LOC) access matrix for relation SITE. 0 is read only access 1 is read and update access
24-40	empty
41	(40 + LOC) domain description for relation CITY
42	" " " " COUNTY
43	" " " " SITE

column	description
1	valid domain numbers
2	1 is numeric and 0 is character data
3	domain size (length)

Function name: VERIFYACCESS Group name: DBGROUP
Input: left argument, RELNAME, containing a valid relation name and library number.
right argument, TYPE, containing access type. See RPPMED structure for discussion of access types.
Output: an explicit result, Z, which is zero if access is not approved.
If access is approved, Z contains a positive integer used to locate data regarding the open relation in the RPPMED.
Global vars used: none
Global vars created: none

Local vars: RELNAME input as described above
TYPE input " "
Z output " "
AM the relation access matrix (not to be confused with the APL access matrix) for the specified relation.
ACCESS a matrix containing all possible access types, one per row.
LOC the ordinal location of data in the RPPMED for a particular relation.
NAMES a matrix of tied file names.

Subroutines: none
Calling routines: OPEN GET

Line	Coding comments
1	assign result to indicate no access.
2	determine position of relation name, which will later be used to locate data in the RPPMED
3	read RPPMED access matrix for the specified relation
4-7	if requested access not approved, print message and end.
8,11,12	if the specified relation is not available for use, print message and end, else
13	return an ordinal position (indicating access verified) as described in 2 above.
9,10	if these lines are executed the data in the components read in line 8 are not ones and zeros.
	0 indicates unavailability of relation
	1 indicates availability "

```

      ▽ OPEN RELNAME;TIES
[1]  ERROR+1
[2]  →(1=+/(□FLIB 310733401)∧.= ' 310733401 RPPMD' )/ΔL10
[3]  'NO, ACCESS NOT APPROVED'
[4]  →0
[5]  ΔL10:→(0=+/ 99 100 εTIES+□FNUMS)/ΔL20
[6]  'NO, IMPROPER USE OF TIE NUMBER 99, 100 OR A RELATION IS ALREADY OPEN'
[7]  →0
[8]  ΔL20:'310733401 RPPMD' □FSTIE 99 924266585
[9]  →(0=EDITRELNAME)/ΔL25
[10] →(0<RELNAME VERIFYACCESS 0)/ΔL30
[11] ΔL25:□FUNTIE 99
[12] →0
[13] ΔL30:RELNAME □FSTIE 100,924266585
[14] RELATION←RELNAME
[15] ERROR←0
      ▽

```

```

      ▽ CLOSE
[1]  →(2=+/ 99 100 ε□FNUMS)/ΔL10
[2]  'NO RELATION OPEN'
[3]  →0
[4]  ΔL10:□FUNTIE 99 100
      ▽

```

```

      ▽ Z-EDITRELNAME
[1]  RETURNS 1 IF RELNAME IS A VALID RELATION NAME
[2]  0 IF INVALID
[3]  RELNAME←22+ ' 310733401 ',11+RELNAME,11p ' '
[4]  →(1=Z+/(□FREAD 99 1 924266585)∧.=RELNAME[11+;11])/0
[5]  'NOT A VALID RELATION NAME'
      ▽

```

VGET[]V

```

V Z+ARG1 GET ARG2;D;DX;IP;L;LOC
[1] Z+ 0 0 0 ' '
[2] ERROR+1
[3] +(0≥LOC+RELATION VERIFYACCESS 0)/0
[4] ΔL5:→(0< pARG1)/ΔL10
[5] ARG1+1 pARG1
[6] ΔL10:DX+[]FREAD 99,(40+LOC),924266585
[7] →((pARG1)=+/ARG1<DX[;1])/ΔL20
[8] 'INVALID DOMAIN IN LEFT ARGUMENT'
[9] →0
[10] ΔL20:→((4=pARG2)^(ARG2[2]∈ 0 4 5 6 7 8))/ΔL30
[11] 'INVALID RIGHT ARGUMENT'
[12] →0
[13] ΔL30:→(DX[ARG2[1];2]>0)/ΔL40
[14] 'INVALID QUALIFYING DOMAIN'
[15] →0
[16] ΔL40:ERROR+0
[17] D+2,(((pD)[1],1)p' '),D+[]FREAD 100,ARG2[1],924266585
[18] L+(D≥ARG2[3])^(D≤ARG2[4])
[19] →(1>+/L)/0
[20] →(0=ARG2[2])/ΔL55
[21] ID+2,(((pID)[1],1)p' '),ID+[]FREAD 100,1,924266585
[22] L+L^((ID>ARG2[2]*1000)^(ID<1000+ARG2[2]*1000))
[23] ΔL55:Z+((+/L),0)p' '
[24] ΔL60:Z+Z,(L+[]FREAD 100,(1+ARG1),924266585),(+/L)p' '
[25] ARG1+1+ ARG1
[26] →(1≤pARG1)/ΔL60
[27] Z+Z[;:(pZ)[2]-1]
V

```

✓VERIFYACCESS[]✓

```

✓ Z←RELNAME VERIFYACCESS TYPE;AM;ACCESS;LOC;NAMES
[1]  Z←0
[2]  LOC←(NAMES^.=RELNAME[11+;11])/;(pNAMES+PFREAD 99.1,924266585)[1]
[3]  AM←PFREAD 99,(20+LOC),924266585
[4]  +(TYPE≤AM[(AM[;1]=PAI[1])/;(pAM)[1;2])/ΔL20
[5]  ACCESS← 2 6 p'READ UPDATE'
[6]  'NO. ',ACCESS[TYPE+1;],' ACCESS NOT APPROVED'
[7]  →0
[8]  ΔL20:→(0 1 =(PFREAD 99,2,924266585)[LOC])/ΔL30,ΔL40
[9]  '*****SYSTEM ERROR AT ΔL20 IN FUNCTION VERIFYACCESS.',PAV[
157], ' NOTIFY DATABASE ADMINISTRATOR'
[10] →0
[11] ΔL30:'RELATION UNAVAILABLE. TRY AGAIN LATER'
[12] →0
[13] ΔL40:Z←LOC

```

7

Group name: ENPGROUP
Ws name: 310733401 PJLIB

This group of routines is used to estimate the electric and nonelectric potential of geothermal sites. Output produced by this group is used as input to the SCENARIO GROUP.

The two user functions are EP (electric potential), which processes data for sites with a temperature greater than 150 degrees celsius, and NP (non-electric potential), which processes data for sites with a temperature less than 150 degrees celsius.

)FNS EP NP EDITAENP FORMATAEP FORMATANP MWPESS MWOPT

)VARS (none)

Refer to instructions from DR. RAO for program specifications.

Function name: EP

Group name: ENPGROUP

Input: requires a right argument ,X, which is a character matrix of at least one row and 36 columns.

<u>columns</u>	<u>field name</u>
1-4	site id
5	filler
6-25	site name
26	filler
27-32	reservoir volume in cubic kilometers
33	filler
34-36	temperature in degrees celsius

Output: produces an explicit result in character matrix form which may be assigned to a variable name. This result is a table containing site id, site name, temperature, reservoir volume, megawatt equivalent (MWE) for 30 years, MWE pessimistic estimate, MWE optimistic estimate. The optimistic and pessimistic estimate for MWE are used as input to functions in the SCENARIO GROUP.

For information regarding source formulas, refer to program specifications from Dr. Rao.

Global variables used: none

Global variables created: none

Local variables:

X	input as described above
Z	output as described above
SID	site id
SNAME	site name
T	temperature in degrees celsius
RV	reservoir volume- if not known, use default value of 2.25 cubic kilometers.
ER	recovery factor.
ERI	recovery factor index
Q	calories
MWE100	megawatt centuries
MW30	megawatts for 30 years
S	number of sites in input
MWO	megawatt estimate optimistic
MWP	megawatt estimate pessimistic

Subroutines:

EDITAENP	edits input
FORMATAEP	formats output
MWOPT	calculates optimistic MWE estimate
MWPES3	calculates pessimistic MWE estimate

Calling routines: none

Function name: NP
Group name: ENPGROUP

Input: requires a right argument, X, which is a character matrix of at least one row and 36 columns.

Columns	Field name
1-4	site ID
5	filler
6-25	site name
26	filler
27-32	reservoir volume in cu km
33	filler
34-36	temperature, deg C

Output: produces an explicit result in character matrix form which may be assigned to a variable name. This result is a table containing site ID, site name, temperature, reservoir volume and megawatt equivalent for 30 yrs.

Local vars

X	input as described above
Z	output " "
SID	site ID
SNAME	site name
T	temp in deg C
RV	reservoir vol
Q	thermal potential
MWTH30	megawatt thermal potential for 30 yrs
S	number of sites in input

Subroutines: EDITAENP edits input
 FORMATANP formats output

Calling routines: none

Global vars: none

Function name: EDITAENP Group name: ENPGROUP
 This function edits the input to the EP and NP routines; however,
 no error checking is performed.

Input: requires a right argument, X. Refer to input description for
 functions EP and NP.

Output: none

Global vars used: none

Global vars created:

SID	site ID
SNAME	site name
RV	reservoir volume
T	temperature

Subroutines: none

Calling routines: EP, NP

Function name: MWOPT Group name: ENPGROUP
 This function calculates the optimistic megawatt equivalent estimate.

Input: requires a right argument, MW30, which is a numeric vector of
 megawatt equivalent for 30 years estimated. It contains one ele-
 ment for each site being processed.

Output: an explicit result in numeric vector form, containing an optim-
 istic estimate of megawatt equivalent for each MW30 value input.

Global vars used or created: none

Local vars: none

Subroutines: none

Calling routines: EP

Coding comments: Line 1. Each element of MW30#0 is reassigned the value
 -1 so that when adjusted to the next highest 30MW those values will
 remain zero.

Function name: FORMATAEP Group name: ENPGROUP
This function formats the output of the EP function.

Input requires a right argument, X, a numeric matrix of at least one row and 5 columns.

Column	Description
1	T temperature
2	RV, reservoir vol
3	MW30, megawatt estimate for 30 yrs
4	MWO, optimistic MW estimate
5	MWP, pessimistic MW estimate

Output: an explicit result in character matrix form containing site ID, site name, temp, reservoir vol, MW30, MWO, MWP.

Global vars used: SID site ID
 SNAME site name

Global vars created: none

Local vars: none

Subroutines: none

Calling routines: EP

Function Name: FORMATANP

Group Name: ENPGROUP

Function Description: This function formats the output of the NP function.

Input: Requires a right argument, X, a numeric matrix of at least one row and 3 columns.

<u>column</u>	<u>description</u>
1	T (temperature)
2	RV (reservior volume)
3	MWTH30 (megawatt thermal potential for 30 years)

Output: An explicit result in character matrix form containing site id, site name, temperature, reservoir volume, and MW thermal potential estimates for 30 years.

Function Name: FORMATANP

Group Name: Endgroup

Global Variables Created: none

Local Variables: none

Subroutines: none

Calling Routines: NP

Function name: MWPESS Group name: ENPGROUP
 This function calculates the pessimistic megawatt equivalent estimate.
 Input: requires a right argument, MW30, which is a numeric vector
 of megawatt equivalent for 30 yrs estimates. It contains
 one element for each site being processed.
 Output: an explicit result in numeric vector form containing an
 optimistic estimate of megawatt equivalent for each MW30
 value input.
 Global vars used or created: none
 Local vars: MWP an intermediate result
 Subroutines: none
 Calling routines: EP
 Coding comments.
 Line 2 each element of MWP#0 is reassigned the value -1
 so that when adjusted to the next highest 50 MW,
 those values will remain zero.
 Line 3 same as line 2, but for those sites with temp-
 eratures less than 200 deg C.

)GRP ENPAGROUP

EP NP EDITAENP FORMATAEP FORMATANP MWPESS MWOPT

```

VVP[[]]V
V Z+EP X;SID;SNAME;T;RV;ER;ERI;Q;MW100;MW30;S;MWO;MWP
[1] EDITAENP X
[2] ER+ 0.03 0.025 0.02
[3] ERI+ (T≤200)+(T≤300)+T≤300
[4] Q+0.6×RV×T-15
[5] MW100+(Q×ER[ERI])+0.753
[6] MW30+MW100+0.3
[7] MWO+MWOPT MW30
[8] MWP+MWPESS MWO
[9] X+(SpT),(SpRV),(SpMW30),(SpMWO),((S+(pT),1)ρMWP)
[10] Z+FORMATAEP X

```

```

VNP[[]]V
V Z+NP X;SID;SNAME;T;RV;Q;MWT30;S
[1] EDITAENP X
[2] Q+0.06×RV×T-15
[3] MWT30+(Q×0.25×0.24×1327+100)+0.3
[4] X+(SpT),(SpRV),((S+(pT),1)ρMWT30)
[5] Z+FORMATANP X

```

```

VEDITAENP[[]]V
V EDITAENP X
[1] SID+X[;14] ⇐ SNAME+X[;5+120]
[2] RV+2,X[;26+16],((pX)[1],1)ρ'
[3] T+2,X[;33+13],((pX)[1],1)ρ'

```

```

VFORMATΔEP[[]]V
V Z+FORMATΔEP X
[1] Z+ 1 61 ρ'SITE',(30ρ' '), 'RSVR MWE MWE MWE '
[2] Z+Z,[1] 1 61 ρ'ID SITE NAME',(13ρ' '), 'TEMP VOLUME 30 YRS OPT PESS'
[3] Z+Z,[1] 1 61 ρ' '
[4] X+'I5,2F9.2,2I6' [FMT X
[5] X+('4A1,X2,20A1' [FMT SID,SNAME),X
[6] Z+Z,[1] X

```

```

VFORMATΔNP[[]]V
V Z+FORMATΔNP X
[1] Z+ 1 48 ρ'SITE',(29ρ' '), 'RSVR MWE '
[2] Z+Z,[1] 1 48 ρ'ID SITE NAME',(12ρ' '), 'TEMP VOLUME 30 YRS'
[3] Z+Z,[1] 1 48 ρ' '
[4] X+'I4,2F9.2' [FMT X
[5] X+('4A1,X2,20A1' [FMT SID,SNAME),X
[6] Z+Z,[1] X

```

```

VMWOPT[[]]V
V Z+MWOPT MW30
[1] MW30[(MW30≤0)/1 ρMW30]+~0.1
[2] Z+50×1+[MW30+50

```

```

VMWPRESS[[]]V
V Z+MWPESS MWO ; MWP
[1] MWP+~117.762+1.01×MWO
[2] MWP[(MWP≤0)/1 ρMWP]+~0.1
[3] MWP[(T<200)/1 ρT]+~0.1
[4] Z+50×1+[MWP+50

```

Sample Input to EP Function

4001,POWER RANCH AREAS	2.50,184
4002,CLIFTON HOT SPRINGS	2.25,160
4003,VERDE HOT SPRINGS	2.25,150
5020,COTTONWOOD CREEK JUM.	1.09,170
5021,CHALK CR MT PRINCETN.	2.48,200
5022,CHALK CREEK WRIGHT H.	2.25,170
5023,CHALK CREEK HORTENSE.	2.25,170
5024,CHALK CREEK WOOLMING.	2.25,170
6001,BEOWAVE H S	42.00,240
6002,BRADY HOT SP	30.00,214
6003,STEAMBOAT SP	16.00,210
6004,SAN EMIDIO	2.25,200
6005,SULPHUR HS	10.00,190
6006,KYLE H S	2.25,190
6007,JERSEY VALLEY HS	2.25,185
6008,HOT SULPHUR SP	2.25,180
6009,HOT SP NEAR WELLS	2.25,180
6010,HOT SP RANCH	2.25,180
6011,LEE H S	2.25,175
6012,PINTO H S	7.50,175
6013,GREAT BOILING H S	25.00,170
6014,LEACH HS	10.00,170
6015,PERNLEY HS	2.25,170
6016,BALTAZOR HS	3.00,170
6017,SODA LAKE	12.50,165
6018,STILLWATER	25.00,165
6019,SMITH CREEK VALLEY	2.25,160
6020,WABUSKA HS	2.25,155
6021,NEEDLE ROCKS	3.00,150
6022,BLACK ROCK DESERT	2.25,150
6023,DIXIE VALLEY HS	3.00,150
7001,VALLES CALDERA	130.00,240
7002,LIGHTNING DOCK	2.25,170
7003,LWR SAN FRANCISCO HS.	2.25,150
7004,KILBOURNE HOLE	2.25,155
8001,ROOSEVELT HS	8.00,250
8002,COVE FORT-SULPHURDAL.	22.50,200
8003,THERMO HS	2.25,185

Sample Output of EP Function

SITE ID	SITE NAME	TEMP	RSVR VOLUME	MWE 30 YRS	MWE OPT	MWE PESS
4001	POWER RANCH AREAS	184	2.50	22.44	50	0
4002	CLIFTON HOT SPRINGS	160	2.25	17.33	50	0
4003	VERDE HOT SPRINGS	150	2.25	16.14	50	0
5020	COTTONWOOD CREEK JUM	170	1.09	8.97	50	0
5021	CHALK CR MT PRINCETN	200	2.48	24.37	50	0
5022	CHALK CREEK WRIGHT H	170	2.25	18.53	50	0
5023	CHALK CREEK HORTENSE	170	2.25	18.53	50	0
5024	CHALK CREEK WOOLMING	170	2.25	18.53	50	0
6001	BROWNE H S	240	42.00	627.49	650	550
6002	BRADY HOT SP	214	30.00	396.41	400	300
6003	STEAMBOAT SP	210	16.00	207.17	250	150
6004	SAN EMIDIO	200	2.25	22.11	50	0
6005	SULPHUR HS	190	10.00	92.96	100	0
6006	KYLE H S	190	2.25	20.92	50	0
6007	JERSEY VALLEY HS	185	2.25	20.32	50	0
6008	HOT SULPHUR SP	180	2.25	19.72	50	0
6009	HOT SP NEAR WELLS	180	2.25	19.72	50	0
6010	HOT SP RANCH	180	2.25	19.72	50	0
6011	LEE H S	175	2.25	19.12	50	0
6012	PINTO H S	175	7.50	63.75	100	0
6013	GREAT BOILING H S	170	25.00	205.84	250	0
6014	LEACH HS	170	10.00	82.34	100	0
6015	PERNLEY HS	170	2.25	18.53	50	0
6016	BALTAZOR HS	170	3.00	24.70	50	0
6017	SODA LAKE	165	12.50	99.60	100	0
6018	STILLWATER	165	25.00	199.20	200	0
6019	SMITH CREEK VALLEY	160	2.25	17.33	50	0
6020	WABUSKA HS	155	2.25	16.73	50	0
6021	NEEDLE ROCKS	150	3.00	21.51	50	0
6022	BLACK ROCK DESERT	150	2.25	16.14	50	0
6023	DIXIE VALLEY HS	150	3.00	21.51	50	0
7001	VALLES CALDERA	240	130.00	1942.23	1950	1900
7002	LIGHTNING DOCK	170	2.25	18.53	50	0
7003	LWR SAN FRANCISCO HS	150	2.25	16.14	50	0
7004	KILBOURNE HOLE	155	2.25	16.73	50	0
8001	ROOSEVELT HS	250	8.00	124.83	150	50
8002	COVE FORT-SULPHURDAL	200	22.50	221.12	250	150
8003	THERMO HS	185	2.25	20.32	50	0

Group Name: SCENARIOGROUP

WS Name: 310733401 PJLIB

Group Description: This group of routines provides a graphical representation of megawatts on line for each year, 1982 through 2021, for a single site or for a group of sites. The user functions are SCENARIO, which accepts only a single site as input, and AGGREGATE, which processes a group of sites. All 5 states are required. AGGREGATE also calculates annual totals of megawatts on line for each state included in input and a grand total.

Functions Used: AGGREGATE, GRAPH, READSITE, SCENARIO, STANAMES, SITZTIMELINE, SPREAD, SCENARIOHEADER, FORMAT.

Variables Used: none

Function Name: AGGREGATE

Input: Requires a left argument, TYPE, containing either the characters 'OPTIMISTIC' or 'PESSIMISTIC'. It also requires a right argument, X, which is a character matrix of at least two rows and 33 columns. Refer to documentation for function READSITE in this group for input description. Input must be sorted by state, though it needn't be in ascending or descending order; input must also contain sites in more than one state.

Output: Produces a character matrix containing a report of processing which is appended to an APL file tied with the tie number 1. This file should contain at least 75,000 bytes for an input data set containing 40 sites. Each page of the report contains 135 columns and a maximum of 51 lines, and is appended as a separate component of the file. When the printed report is reduced to 74% of original size, it is suitable for 8 1/2 by 11 inch paper.

Global Variables Used: none

Global Variables Created: none

Local Variables:

TYPE	Input as described above.
X	Input as described above.
Z	Output as described above.
STAT	State annual total of megawatts on line (MWOL) as a 40 element vector.
STT	State total MWOL as a scalar.
RAT	Region annual total MWOL as a 40 element vector.

RT	Region total is a scalar.
STTS	State totals MWOL as a 5 element vector, one for each state.
SAT	Site annual total MWOL as a 40 element vector.
SID	Site ID currently being processed.
OLDSID	Last site ID processed.
LINE	Last line on current page of output.
MW	Megawatt equivalent estimate for current site.
START	
SNAME	

Subroutines: FORMAT, READSITE, SITETIMELINE

Calling Routines: none

Special Coding:

<u>line</u>	<u>coding comments</u>
1-6	Initialization
7	Read site data.
8	Process site data.
9-10	Accumulate totals.
11	Read next site data.
12	If next site is in same state as last site repeat 8-11, else
13	Format state totals.
14-17	Accumulate region totals, and reinitialize state totals.
18	If last site has been processed, begin final formatting operations, else
19	If the current page of output contains only the header, do not print the next state name, as it has already been printed, but repeat 8-13.
20	Print next state name.

<u>line</u>	<u>coding comments</u>
21	Repeat 8-18.
22-24	Begin final format operations.
25	Append final page.
26	Indicate to user normal termination of execution.

Function Name: SCENARIO

Global Variable Used: none

Global Variables Created: none

Local Variables:

X	Input as described above.
Z	Output as described above.
SID	Site ID
SNAME	Site name
MW	Megawatt equivalent estimate.

Input: Requires a right argument, X, which is a character matrix of exactly one row and 33 columns. Refer to documentation of function READSITE in this group for input descriptions.

Output: An explicit result, Z, which is a character matrix containing a report of processing.

Subroutines: SITETIMELINE

Calling Routines: none

Function Name: GRAPH

Global Variables Used: none

Global Variables Created: none

Local Variables:

N	Input as described below.
M	Input as described below.
Z	Output as described below.

W Contains the number of rows in the output to which a row in the input is to be expanded.

X The number of rows in the input.

Y index

Input: A right argument, X, which is a matrix of ones and zeros, having at least one row, and 40 columns. Each column represents a year between 1982 and 2021. Each row represents a 50 megawatt geothermal plant; each 1 in a row indicates a year in which that plant is generating electricity, a zero, a year in which it is not. A left argument, N, which is a single character. This character will replace each one in the matrix, X, while a blank will replace each zero.

Output: An explicit result, Z, containing a graphical representation of megawatts on line and where during the 40 year period, 1982-2021. The output is a character matrix of any number of rows and 100 columns.

Subroutines: none

Calling Routines: SITETIMELINE

Function Name: READSITE

Global Variables Used: SID, OLDSID

Global Variables Created: SNAME, MW, START

Local Variables: none

Input: No arguments.

Output: No explicit result, or printed output. The function operates on a global variable, X, a matrix of at least two rows, and 33 columns.

<u>column</u>	<u>description</u>
1-4	SID (site ID)
5	filler
6-25	SNAME (site name)
26	filler
27-30	MW (megawatt equivalent estimate)
31	filler
32-33	START (starting date; if no date available, default is 0)

Subroutines: none

Calling Routines: AGGREGATE

Function Name: STANAMES

Global Variables Used: none

Global Variables Created: none

Local Variables:

CODES	input as described below
Z	output as described below

Input: A right argument, CODES, a character matrix of at least one row, and exactly 1 column. Each element of codes must be one of the characters 4, 5, 6, 7, 8. No error checking is performed.

Output: An explicit result, Z, in character matrix form, of at least one row and exactly 10 columns with as many rows as the input. Each row contains an underscored name of a state in the Southwest Region corresponding to the appropriate state code in the input.

Subroutines: none

Calling routines: AGGREGATE, SCENARIOHEADER

Function Name: SITETIMELINE

Global Variables Used: SNAME

Global Variables Created: SAT (site annual total)

Local Variables:

Z1	A matrix of ones and zeros; refer to input description of the right argument of the function GRAPH in this group.
MW	Input as described below.
Z	Output as described below.
Y	Graphical representation of megawatts on line; refer to output description of function GRAPH in this group.

Subroutines: SPREAD, GRAPH

Calling Routines: SCENARIO, AGGREGATE

Input: A right argument, MW, a scalar estimate of megawatt equivalent.

Output: An explicit result, Z, in character matrix form, which includes site name, a graphic representation of megawatts on line during the 40 year period 1982 through 2021, and an annual total of megawatts on line.

Special Coding:

<u>line</u>	<u>coding comments</u>
2	Site annual total is assigned the value of the odd subscripts of Z1 summed through the columns (the odd subscripts represent the even numbered years from 1982 through 2021).
3-4	Format site name and graph.
5	If MW is less than or equal to 0, there is no need to print a site annual total line, so, end, else.
6	Format site annual total.

Function Name: SPREAD

Global Variables used: START

Global Variables Created: none

Local Variables:

MWE	Input as described below.
Z	Output as described below.
PLN	No. of 50 megawatt plants needed, given input.
PLNY	No. of 50 MW plants needed per year.
DELAY	No. of years from 1982 until a plants begins production.
APL	Actual plants producing.
APLY	Actual plants producing during the current year.
SCHED	A vector indicating delay between plants, after the first begins producing.

Input: A right argument, MWE, a scalar to estimate megawatt equivalent.

Output: An explicit result, Z, a matrix of ones and zeros representing megawatts on line. Refer to input description for function GRAPH in this group.

Subroutines: none

Calling Routines: SITETIMELINE

Special Coding:

<u>line</u>	<u>coding comments</u>
1	Megawatt equivalent divided by 50 megawatts is number of plants needed.
2	If start date not specified, generate
3	A random number and calculate a start date.
8	If plants needed is less than 1, end.
12	If actual plants equal plants needed or if the delay is greater than 40 years (in which case it won't appear in output), end; else
13	If actual plants for the current year is less than plants needed for the current year, add another, else
15	Increase the delay, and add another plant.

Function Name: SCENARIOHEADER

Global Variables used: SID, TYPE

Global Variables Created: none

Local Variables: Z (output as described below)

Input: none

Output: An explicit result, Z, a matrix of 8 rows, 135 columns containing the report header.

Subroutines: STANAMES

Calling Routines: AGGREGATE, FORMAT

Function Name: FORMAT

Global Variables used:

LINE	Last line on current page.
Z	Current page.
SID	
OLDSID	

Global Variables Created: none

Local Variables: none

Input: A right argument, X, a character matrix of at least one row and exactly 135 columns. The matrix may contain any portion of the output report.

Output: Adds the input to the current page unless the page will then have more than 50 lines. In this case, the current page is appended. A new page complete with header, is begun and the input is added to the new current page.

Subroutines: SCENARIOHEADER

Calling Routines: AGGREGATE

Special Coding:

<u>line</u>	<u>coding comments</u>
1	If adding input to current page would push the current page over 50 lines, fall through.
2	Append current page.
3	If last site has been processed, prepare report header for final summary, else,
4	Replace current page with header.
6	If next site is not in same state, don't add CONT'D to header.
12	Add input to current page.

VAGGREGATE[[]]V

V TYPE AGGREGATE X;STAT;STT;RAT;RT;STTS;SID;OLDSID;LINE;Z;MW;SNAME

;SAT;START

[1] STAT+STT+RT+0

[2] STTS+10

[3] RAT+ 0 20 p0 * SID+X[1;14]

[4] LINE+0

[5] Z+ 0 135 p' ' * OLDSID+'0000'

[6] FORMAT SCENARIOHEADER

[7] READSITE

[8] AL10:FORMAT SITETIMELINE MW

[9] STT+STT+MW

[10] STAT+STAT+SAT

[11] READSITE

[12] +((1+OLDSID)=1+SID)/AL10

[13] FORMAT 4 135 p(35p' '),(100p' '),(8p' '),'STATE TOTALS',(

8 0 vSTT),(6p' '),(5 0 vSTAT),'',(135p' '),135p' '

[14] RT+RT+STT

[15] RAT+RAT,[1] STAT

[16] STTS+STTS,STT

[17] STAT+STT+0

[18] +(4=+/SID='0000')/AL20

[19] +((pZ)[1]≤8)/AL10

[20] FORMAT 3 135 p(135p' '),(STANAMES 1 1 p1+SID),135p' '

[21] +AL10

[22] AL20:FORMAT((51-LINE),135)p' '

[23] FORMAT(10p 1 0)\(STANAMES 5 1 p'45678'),(18 0 v 5 1 pSTTS),(

5 7 p' '), 5 0 vRAT

[24] FORMAT 2 135 p(35p' '),(100p' '),(7p' '),'REGION TOTALS',(

8 0 vRT),(6p' '),(5 0 v+RAT)

[25] Z ||FAPPEND 1

[26] 'DONE'

V

Sample Input to AGGREGATE Function

4001,POWER RANCH AREAS	. 50, 0
4002,CLIFTON HOT SPRINGS	. 50, 0
4003,VERDE HOT SPRINGS	. 50, 0
5020,COTTONWOOD CREEK JUM.	. 50, 0
5021,CHALK CR MT PRINCETN.	. 50, 0
5022,CHALK CREEK WRIGHT H.	. 50, 0
5023,CHALK CREEK HORTENSE.	. 50, 0
5024,CHALK CREEK WOOLMING.	. 50, 0
6001,BEOWAVE H S	. 650,84
6002,BRADY HOT SP	. 400,82
6003,STEAMBOAT SP	. 250, 0
6004,SAN EMIDIO	. 50, 0
6005,SULPHUR HS	. 100, 0
6006,KYLE H S	. 50, 0
6007,JERSEY VALLEY HS	. 50, 0
6008,HOT SULPHUR SP	. 50, 0
6009,HOT SP NEAR WELLS	. 50, 0
6010,HOT SP RANCH	. 50, 0
6011,LEE H S	. 50, 0
6012,PINTO H S	. 100, 0
6013,GREAT BOILING H S	. 250, 0
6014,LEACH HS	. 100, 0
6015,FERNLEY HS	. 50, 0
6016,BALTAZOR HS	. 50, 0
6017,SODA LAKE	. 100, 0
6018,STILLWATER	. 200, 0
6019,SMITH CREEK VALLEY	. 50, 0
6020,WABUSKA HS	. 50, 0
6021,NEEDLE ROCKS	. 50, 0
6022,BLACK ROCK DESERT	. 50, 0
6023,DIXIE VALLEY HS	. 50, 0
7001,VALLES CALDERA	. 1950,82
7002,LIGHTNING DOCK	. 50, 0
7003,LWR SAN FRANCISCO HS,	. 50, 0
7004,KILBOURNE HOLE	. 50, 0
8001,ROOSEVELT HS	. 150,82
8002,COVE FORT-SULPHURDAL,	. 250, 0
8003,THERMO HS	. 50, 0

```

VSCENARIO[ ]V
  Z←SCENARIO X;SID;SNAME;MW
[1]  SID←X[14] * SNAME←X[5+120] * MW←X[26+14]
[2]  Z←SCENARIOHEADER
[3]  Z←Z,[1] SITETIMELINE MW

```

```

VGRAPH[ ]V
  Z←N GRAPH M;W;X;Y
[1]  Z←(O,X+(oM)[1])o' ' * Y+1
[2]  ΔL10:W← 3 2[1+Y=2×[Y+2]
[3]  Z←Z,[1](W,X)oM[1;Y]
[4]  Y←Y+1
[5]  +(Y≤(oM)[2])/ΔL10
[6]  Z←(' ',N)[1+1=OZ]

```

```

VREADSITE[ ]V
  READSITE
[1]  +((oX)[1]>0)/ΔL10
[2]  SID←'0000'
[3]  →0
[4]  ΔL10:OLDSID←SID * SID←X[1;14]
[5]  SNAME←X[1;5+120] * MW←X[1;26+14]
[6]  START←X[1; 32 33]
[7]  X←(O,((oX)[1]-1)o1)X

```

```

VSTANAMES[ ]V
  Z←STANAMES CODES
[1]  Z← 8 10 o(30o' '), 'ARIZONA COLORADO NEVADA NEW MEXICOUTAH
[2]  Z←Z[(Z,(((oCODES)[1],1)o' '),CODES);]

```

```

▽ FORMAT X
[1] →((ρX)[1]≤51-LINE)/ΔL10
[2] Z □FAPPEND 1
[3] →(4=+/SID='0000')/ΔL5
[4] Z←SCENARIOHEADER
[5] LINE←(ρZ)[1]
[6] →((1↑OLDSID)≠1↑SID)/ΔL10
[7] Z[7;12+18]←'(CONT'D)'
[8] →ΔL10
[9] ΔL5:Z←Z[16;]
[10] Z[4;5+19]←' '
[11] LINE←6
[12] ΔL10:Z←Z,[1] X
[13] LINE←LINE+(ρX)[1]

```

▽

```

▽ Z←SPREAD MWE;PLN;PLNY;DELAY;APL;APLY;SCHED
[1] PLN←MWE÷50
[2] →(START≠0)/ΔL5
[3] START←83+?4
[4] ΔL5:DELAY←START-82
[5] PLNY←[PLN÷40-DELAY
[6] Z← 0 40 ρ0
[7] SCHED← 3 4 ,27ρ3
[8] →(PLN<1)/0
[9] APL←APLY←0
[10] ΔL10:Z←Z,[1] 1 40 ρ(DELAYρ0),(30ρ1),10ρ0
[11] APL←APL+1 * APLY←APLY+1
[12] →((APL=PLN)∨(DELAY≥40))/0
[13] →(APLY<PLNY)/ΔL10
[14] APLY←0
[15] DELAY←DELAY+1↑SCHED←1φSCHED
[16] →ΔL10

```

▽

```

▽ Z←SITETIMELINE MW;Z1;Y
[1] Z1←SPREAD MW
[2] SAT←50×(+Z1)[(2×120)-1]
[3] Z←((ρY)[1],35)ρSNAME,(8 0 ▼MW),((ρY)[1]×35)ρ' ',Y←'>' GRAPH Z1
[4] Z←Z,[1] 1 135 ρ' '
[5] →(MW≤50)/0
[6] Z←Z,[1] 3 135 ρ' ' SITE ANNUAL TOTAL',(14ρ' '), (, 5 0 ▼ 20 1 ρSAT),270ρ' '

```

```

▽ Z←SCENARIOHEADER
[1] Z← 2 135 ρ(50ρ' '), 'POWER ON LINE ESTIMATE (' ,TYPE,')',195ρ' '
[2] Z←Z,[1] 1 135 ρ(24ρ' '), 'TOTAL',(135ρ' ')
[3] Z←Z,[1] 1 135 ρ'STATE AND SITE',(11ρ' '), 'MW',(8ρ' '), (100+▼1980+2×120)
[4] Z←Z,[1] 2 135 ρ(135ρ' _'),135ρ' '
[5] Z←Z,[1] 2 135 ρ(STANAMES 1 1 ρ1+SID),270ρ' '

```

The five functions: TABLE5, TABLE6, TABLE7, CITYS and COUNTYS are so very similar that they will all be explained here.

Input: A right argument, 'STN', contains the state number on which the searching is to be done in the files to get the desired output. The files that are used for the searching are: SITE, CITY and COUNTY. The first three functions use the SITE file and the fourth function uses the CITY file and the last function uses the COUNTY file.

output: The output is listed out in equivalent portions such that each page has an equivalent number of lines. The output is formatted in columns containing information depending on the function used. TABLE5 gives GEOTHERMAL SITE LOCATIONS. TABLE6 gives GEOTHERMAL SITE TEMPERATURES. TABLE7 gives RESERVOIR VOLUME, THERMAL GRADIENT, DISSOLVED SOLIDS and FLOWRATE. CITYS gives CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE and LONGITUDE. COUNTYS gives COUNTY ID and COUNTY NAME.

SUBROUTINES USED: ABC, EDITRELNAME, GET, OPEN, STANAMES, VERIFYACCESS.

VARIABLES USED: RELATION

```

V Z1=TABLE5 STN
[1] OPEN 'SITE'
[2] G=(10) GET 1,STA,(1000*STN),((STN+1)*1000)-1
[3] G=ABC G
[4] S5=5p' ' * S3=3p' ' * G2=pG * MAX+MAX1+MAX2+MAX3+MAX4+0 * I+COUNT+1 * NAME+STANAMES 1 1 p(7,STN)
[5] +((G2[1]>50)^(G2[1]≤100))/CK1
[6] +((G2[1]>100)^(G2[1]≤150))/CK2
[7] +((G2[1]>150)^(G2[1]≤200))/CK3
[8] MAX+G2[1]
[9] AL1:Z1+ 1 70 p((30p' '),NAME,(10p' ''))
[10] Z1+Z1,[1] 1 70 p((55p' '),TOWN',(11p' ''))
[11] Z1+Z1,[1] 1 70 p(' 1D',(4p' '),SITE NAME',(13p' '),COUNT',(4p' '),LAT',(4p' '),LONG',(5p' '),SHIP RANGE SEC ')
[12] CONT:A1+G[I;14] * A2+G[I;5+120] * A3+G[I;26+13] * A4+G[I; 31 32] * A5+G[I; 34 35] * A6+G[I;36+13]
[13] A7+G[I; 41 42] * A8+G[I;43+14] * A9+G[I;48+14] * A10+G[I; 54 55]
[14] Z1+Z1,[1], 1 70 p(A1,' ',A2,S5,A3,S5,A4,' ',A5,' ',A6,' ',A7,S3,A8,' ',A9,S3,A10,' ')
[15] I+I+1 * →(I≤MAX)/CONT
[16] Z1+Z1,[1] 2 70 p' '
[17] Z1+Z1,[1] 1 70 p('TABLE 5. GEOTHERMAL SITE LOCATIONS.',(34p' '')) * Z1 * LΔ[1]
[18] →(MAX2=0)/L0 * →(MAX3=0)/C1 * →(MAX4=0)/C2 * →C3
[19] C1:MAX+MAX1+MAX2 * COUNT+COUNT+1 * →(COUNT<3)/ΔL1 * →L0
[20] C2:MAX+MAX1+MAX2 * COUNT+COUNT+1 * →(COUNT<3)/ΔL1 * MAX+MAX1+MAX2+MAX3 * →(COUNT<4)/ΔL1 * →L0
[21] C3:MAX+MAX1+MAX2 * COUNT+COUNT+1 * →(COUNT<3)/ΔL1 * MAX+MAX1+MAX2+MAX3 * →(COUNT<4)/ΔL1
[22] MAX+MAX1+MAX2+MAX3+MAX4 * →(COUNT<5)/ΔL1 * →L0
[23] CK1:MAX+MAX1+(I(G2[1];2)) * →(MAX1=(I(G2[1];2)))/CH1 * MAX2+MAX1-1 * →ΔL1
[24] CH1:MAX2+MAX1 * →ΔL1
[25] CK2:MAX+MAX1+(I(G2[1];3)) * →(MAX1=(I(G2[1];3)))/CH2
[26] →((MAX1-(G2[1];3))>0.4)/CH3 * MAX2+MAX1 * MAX3+MAX1-1 * →ΔL1
[27] CH2:MAX2+MAX3+MAX1 * →ΔL1
[28] CH3:MAX2+MAX3+MAX1-1 * →ΔL1
[29] CK3:MAX+MAX1+(I(G2[1];4)) * →(MAX1=(I(G2[1];4)))/CH4
[30] →(((MAX1-(G2[1];4))=0.75),((MAX1-(G2[1];4))=0.5))/K1,K2 * MAX2+MAX1 * MAX3+MAX4+MAX2-1 * →ΔL1
[31] K1:MAX4+MAX3+MAX2+MAX1-1 * →ΔL1
[32] K2:MAX3+MAX2+MAX1 * MAX4+MAX1-1 * →ΔL1
[33] CH4:MAX4+MAX3+MAX2+MAX1 * →ΔL1
[34] L0:COUNT 100

```

V

```

V Z1=TABLE6 STN
[1] OPEN 'SITE'
[2] G← 1 2 11 12 13 14 15 16 17 18 GET 1,STN,(1000×STN),((STN+1)×1000)-1
[3] G←ABC G
[4] G←G[(G[1];1)≠',')/(ρG)[21]
[5] G2←ρG * MAX+MAX1+MAX2+MAX3+MAX4+0 * I+COUNT+1 * NAME+STANAMES 1 1 ρ(τ,STN)
[6] →((G2[1]>50)^(G2[1]≤100))/CK1
[7] →((G2[1]>100)^(G2[1]≤150))/CK2
[8] →((G2[1]>150)^(G2[1]≤200))/CK3
[9] MAX←G2[1]
[10] ΔL1:Z1← 1 70 ρ((30ρ' '),NAME,(10ρ' ''))
[11] Z1←Z1,[1] 1 70 ρ((27ρ' ''),'-----TEMPERATURE IN DEGREES CELSIUS-----')
[12] Z1←Z1,[1] 1 70 ρ('SITE',' ','SITE NAME',(10ρ' ''),'SUBSUR- SOU- SURFACE SOU- CS CS ')
[13] Z1←Z1,[1] 1 70 ρ('ID',(25ρ' ''),'FACE RCE RCE EST MEAS')
[14] CONT:A1← 1 4 ρG[I;14] * A2← 1 20 ρG[I;4+120] * A3← 1 6 ρG[I;24+16] * A4← 1 2 ρG[I; 31 32] * A5← 1 3 ρG[I;32+13]
[15] A6← 1 2 ρG[I; 36 37] * A7← 1 3 ρG[I;37+13] * A8← 1 2 ρG[I; 41 42] * A9← 1 3 ρG[I;42+13] * A0← 1 3 ρG[I;45+13]
[16] Z1←Z1,[1] 1 70 ρ('A1,X1,20A1,X2,3A1,X5,2A1,X6,3A1,X5,2A1,X6,3A1,X4,3A1,X1' [FMT(A1;A2;A5;A6;A7;A8;A9;A0)])
[17] I←I+1 * →(I≤MAX)/CONT
[18] Z1←Z1,[1] 2 70 ρ' ''
[19] Z1←Z1,[1] 1 70 ρ('TABLE 6. GEOTHERMAL SITE TEMPERATURES.',(30ρ' '')) * Z1 * LΔ+[]
[20] →(MAX2=0)/LO * →(MAX3=0)/C1 * →(MAX4=0)/C2 * →C3
[21] C1:MAX+MAX1+MAX2 * COUNT←COUNT+1 * →(COUNT<3)/ΔL1 * →LO
[22] C2:MAX+MAX1+MAX2 * COUNT←COUNT+1 * →(COUNT<3)/ΔL1 * MAX+MAX1+MAX2+MAX3 * →(COUNT<4)/ΔL1 * →LO
[23] C3:MAX+MAX1+MAX2 * COUNT←COUNT+1 * →(COUNT<3)/ΔL1 * MAX+MAX1+MAX2+MAX3 * →(COUNT<4)/ΔL1 * MAX+MAX1+MAX2+MAX3+MAX4
[24] →(COUNT<5)/ΔL1 * →LO
[25] CK1:MAX+MAX1←(I(G2[1];2)) * →(MAX1=(I(G2[1];2)))/CH1 * MAX2+MAX1-1 * →ΔL1
[26] CH1:MAX2+MAX1 * →ΔL1
[27] CK2:MAX+MAX1←(I(G2[1];3)) * →(MAX1=(I(G2[1];3)))/CH2
[28] →((MAX1-(G2[1];3))>0.4)/CH3 * MAX2+MAX1 * MAX3+MAX1-1 * →ΔL1
[29] CH2:MAX2+MAX3+MAX1 * →ΔL1
[30] CH3:MAX2+MAX3+MAX1-1 * →ΔL1
[31] CK3:MAX+MAX1←(I(G2[1];4)) * →(MAX1=(I(G2[1];4)))/CH4
[32] →(((MAX1-(G2[1];4))=0.75),((MAX1-(G2[1];4))=0.5))/K1,K2 * MAX2+MAX1 * MAX3+MAX4+MAX2-1 * →ΔL1
[33] K1:MAX4+MAX3+MAX2+MAX1-1 * →ΔL1
[34] K2:MAX3+MAX2+MAX1 * MAX4+MAX1-1 * →ΔL1
[35] CH4:MAX4+MAX3+MAX2+MAX1 * →ΔL1
[36] LO:[FUNTIME 100

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V


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V Z1=TABLE7 STN
[1] OPEN 'SITE'
[2] G= 1 2 11 12 19 20 21 22 23 24 GET 1,STN,(1000*STN),((STN+1)*1000)-1
[3] G=ABC G
[4] G=G;(G[1:]#',')/(PG)[2]]
[5] G2=PG * MAX+MAX1+MAX2+MAX3+MAX4+0 * I+COUNT-1 * NAME+STANAMES 1 1 PG(v,STN)
[6] +((G2[1]>50)^(G2[1]≤100))/CK1
[7] +((G2[1]>100)^(G2[1]≤150))/CK2
[8] +((G2[1]>150)^(G2[1]≤200))/CK3
[9] MAX=G2[1]
[10] ΔL1:Z1+ 1 70 P((30P' '),NAME,(10P' ''))
[11] Z1+Z1,[1] 1 70 P('SITE',' ', 'SITE NAME',(9P' ''),'RSVR SOU THRM SOU- DISS SOU- FLOW SOU-')
[12] Z1+Z1,[1] 1 70 P('TD',(24P' ''),'VOLUME RCE GRAD RCE SLDS RCE RATE RCE ')
[13] Z1+Z1,[1] 1 70 P((26P' ''),'CU KM',(7P' ''),'C/KM',(7P' ''),'PPT',(8P' ''),'L/SEC',(5P' ''))
[14] CONT:A1+ 1 4 PG[I;14] * A2+ 1 20 PG[I;4+120] * A3+ 1 6 PG[I;24+16] * A4+ 1 2 PG[I; 31 32] * A5+ 1 3 PG[I;32+13]
[15] A6+ 1 2 PG[I; 36 37] * A7+ 1 3 PG[I;37+13] * A8+ 1 2 PG[I; 41 42] * A9+ 1 3 PG[I;42+13] * A0+ 1 2 PG[I; 46 47]
[16] ARRAY+A1,A2,A3,A4,A5,A6,A7,A8,A9,A0
[17] FMT='4A1,X1,20A1,X1,6A1,X1,2A1,X3,3A1,X2,2A1,X4,3A1,X2,2A1,X4,3A1,X3,2A1,X2'
[18] Z1+Z1,[1] 1 70 P(FMT [FMT ARRAY])
[19] I=I+1
[20] →(I≤MAX)/CONT
[21] Z1+Z1,[1] 2 70 P' '
[22] Z1+Z1,[1] 1 70 P('TABLE 7. RESERVOIR VOLUME, THERMAL GRADIENT, DISSOLVED SOLIDS',(9P' ''))
[23] Z1+Z1,[1] 1 70 P((10P' ''),'AND FLOW RATE',(47P' '')) * LA+□ * Z1 * LA+□
[24] →(MAX2=0)/L0 * →(MAX3=0)/C1 * →(MAX4=0)/C2 * →C3
[25] C1:MAX+MAX1+MAX2 * COUNT+COUNT+1 * →(COUNT<3)/ΔL1 * →L0
[26] C2:MAX+MAX1+MAX2 * COUNT+COUNT+1 * →(COUNT<3)/ΔL1 * MAX+MAX1+MAX2+MAX3 * →(COUNT<4)/ΔL1 * →L0
[27] C3:MAX+MAX1+MAX2 * COUNT+COUNT+1 * →(COUNT<3)/ΔL1 * MAX+MAX1+MAX2+MAX3 * →(COUNT<4)/ΔL1 * MAX+MAX1+MAX2+MAX3+MAX4
[28] →(COUNT<5)/ΔL1 * →L0
[29] CK1:MAX+MAX1+((G2[1]÷2)) * →(MAX1=((G2[1]÷2)))/CH1 * MAX2+MAX1-1 * →ΔL1
[30] CH1:MAX2+MAX1 * →ΔL1
[31] CK2:MAX+MAX1+((G2[1]÷3)) * →(MAX1=((G2[1]÷3)))/CH2
[32] →((MAX1-(G2[1]÷3))>0.4)/CH3 * MAX2+MAX1 * MAX3+MAX1-1 * →ΔL1
[33] CH2:MAX2+MAX3+MAX1 * →ΔL1
[34] CH3:MAX2+MAX3+MAX1-1 * →ΔL1
[35] CK3:MAX+MAX1+((G2[1]÷4)) * →(MAX1=((G2[1]÷4)))/CH4
[36] →(((MAX1-(G2[1]÷4))-0.75),((MAX1-(G2[1]÷4))=0.5))/K1,K2 * MAX2+MAX1 * MAX3+MAX4+MAX2-1 * →ΔL1
[37] K1:MAX4+MAX3+MAX2+MAX1-1 * →ΔL1
[38] K2:MAX3+MAX2+MAX1 * MAX4+MAX1-1 * →ΔL1
[39] CH4:MAX4+MAX3+MAX2+MAX1 * →ΔL1
[40] L0:[FUNIT] 100
V

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[32] C5:MAX*MAX1+MAX2 * (COUNT*COUNT+1 * →(COUNT<3)/ΔL1 * MAX*MAX1+MAX2+MAX3 * →(COUNT<4)/ΔL1 * MAX*MAX1+MAX2+MAX3+MAX4
[33] →(COUNT<5)/ΔL1 * MAX*MAX1+MAX2+MAX3+MAX4+MAX5 * →(COUNT<6)/ΔL1 * MAX*MAX1+MAX2+MAX3+MAX4+MAX5+MAX6 * →(COUNT<7)/ΔL1
[34] →L0
[35] CK1:MAX*MAX1+(↑(G2[1]↑2)) * →(MAX1=(↑(G2[1]↑2)))/CH1 * MAX2*MAX1-1 * →ΔL1
[36] CH1:MAX2*MAX1 * →ΔL1
[37] CK2:MAX*MAX1+(↑(G2[1]↑3)) * →(MAX1=(↑(G2[1]↑3)))/CH2
[38] →((MAX1-(G2[1]↑3))>0.4)/CH3 * MAX2*MAX1 * MAX3*MAX1-1 * →ΔL1
[39] CH2:MAX2*MAX3*MAX1 * →ΔL1
[40] CH3:MAX2*MAX3*MAX1-1 * →ΔL1
[41] CK3:MAX*MAX1+(↑(G2[1]↑4)) * →(MAX1=(↑(G2[1]↑4)))/CH4
[42] →(((MAX1-(G2[1]↑4))=0.75),((MAX1-(G2[1]↑4))=0.5))/K1,K2 * MAX2*MAX1 * MAX3*MAX4+MAX2-1 * →ΔL1
[43] K1:MAX4+MAX3*MAX2*MAX1-1 * →ΔL1
[44] K2:MAX3*MAX2*MAX1 * MAX4*MAX1-1 * →ΔL1
[45] CH4:MAX4*MAX3*MAX2*MAX1 * →ΔL1
[46] CK4:TEM+G2[1]↑5 * →((((↑TEM)-TEM)=0.2),((((↑TEM)-TEM)=0.4),((((↑TEM)-TEM)=0.6),((((↑TEM)-TEM)=0.8))/Δ1,Δ2,Δ3,Δ4
[47] MAX*MAX1+MAX2*MAX3*MAX4+MAX5*TEM * →ΔL1
[48] Δ1:MAX*MAX1+MAX2*MAX3*MAX4+↑TEM * MAX5*↑TEM * →ΔL1
[49] Δ2:MAX*MAX1+MAX2*MAX3+↑TEM * MAX4*MAX5*↑TEM * →ΔL1
[50] Δ3:MAX*MAX1+MAX2*↑TEM * MAX3*MAX4*MAX5*↑TEM * →ΔL1
[51] Δ4:MAX*MAX1+↑TEM * MAX2*MAX3*MAX4*MAX5*↑TEM * →ΔL1
[52] CK5:TEM+G2[1]↑6 * →((((↑TEM)-TEM)<0),((((↑TEM)-TEM)=0.5))/Δ,B
[53] →((((↑TEM)-TEM)<0.5)^(↑TEM)-TEM<0.2),((((↑TEM)-TEM)>0.5)^(↑TEM)-TEM>0.7))/C,D
[54] →((((↑TEM)-TEM)<0.5),((((↑TEM)-TEM)>0.5))/LΔ1,LΔ2
[55] Δ:MAX*MAX1+MAX2*MAX3+MAX4+MAX5+MAX6*TEM * →ΔL1
[56] B:MAX*MAX1+MAX2*MAX3+↑TEM * MAX4*MAX5+MAX6*↑TEM * →ΔL1
[57] C:MAX*MAX1+MAX2*MAX3*MAX4+MAX5*↑TEM * MAX6*↑TEM * →ΔL1
[58] D:MAX*MAX1+↑TEM * MAX2*MAX3*MAX4*MAX5+MAX6*↑TEM * →ΔL1
[59] LΔ1:MAX*MAX1+MAX2*MAX3*MAX4+↑TEM * MAX5*MAX6+↑TEM * →ΔL1
[60] LΔ2:MAX*MAX1+MAX2+↑TEM * MAX3*MAX4+MAX5*MAX6+↑TEM * →ΔL1
[61] L0:↑FUNTIE □FNUNS

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V COUNTY'S STN
[1] OPEN 'COUNTY' * , (ERROR=1)/LO
[2] G← 1 2 GET 1,0,(100*STN),(((STN+1)*100)-1)
[3] G←G[(G[1];)≠',')/(pG)[2]]
[4] G2←pG * MAX+MAX1+MAX2+MAX3+MAX4+MAX5+MAX6+0 * I+COUNT+1 * →((p(τ,STN))=2)/NXT * NAME+STANAMES 1 1 p(τ,STN) * →NXT2
[5] NXT:NAME+STANAMES 1 2 p(τ,STN)
[6] NXT2:DUMM+G2[1];3 * DUMM2+((DUMM)*2 * →(((DUMM)-DUMM)>0.5)/FIX1 * G←G,[1] 1 16 p' ' * →FIX2
[7] FIX1:G←G,[1] 2 16 p' '
[8] FIX2:→((G2[1]>150)^(G2[1]≤300))/CK1
[9] →((G2[1]>300)^(G2[1]≤450))/CK2
[10] →((G2[1]>450)^(G2[1]≤600))/CK3
[11] →((G2[1]>600)^(G2[1]≤750))/CK4
[12] →((G2[1]>750)^(G2[1]≤900))/CK5
[13] MAX←DUMM
[14] ΔL1:Z1← 1 70 p((30p' '),NAME,(10p' '))
[15] Z1←Z1,[1] 1 70 p('COUNTY COUNTY NAME | ')
[16] Z1←Z1,[1] 1 70 p('ID',20p' '),'| '
[17] CONT:A1← 1 4 pG[I;14] * A2← 1 12 pG[I;4+112] * A3← 1 4 pG[(DUMM)+I;14] * A4← 1 12 pG[(DUMM)+I;4+112]
[18] A5← 1 4 pG[I+DUMM2;14] * A6← 1 12 pG[I+DUMM2;4+112] * A7←'| ' * ARRAY←A1,A2,A7,A3,A4,A7,A5,A6
[19] FMT←'4A1,X4,12A1,X2,1A1,X2,4A1,X4,12A1,X2,1A1,X2,4A1,X4,12A1'
[20] Z1←Z1,[1] 1 70 p(FMT [FMT ARRAY])
[21] I←I+1
[22] →(I≤MAX)/CONT
[23] Z1←Z1,[1] 2 70 p' '
[24] Z1←Z1,[1] 1 70 p('TABLE 9. COUNTY ID AND COUNTY NAME',(39p' ')) * LL←I * Z1 * LL←I
[25] →(MAX2=0)/LO * →(MAX3=0)/C1 * →(MAX4=0)/C2 * →(MAX5=0)/C3 * →(MAX6=0)/C4 * →C5
[26] C1:MAX+MAX1+MAX2 * COUNT+COUNT+1 * →(COUNT<3)/ΔL1 * →LO
[27] C2:MAX+MAX1+MAX2 * COUNT+COUNT+1 * →(COUNT<3)/ΔL1 * MAX+MAX1+MAX2+MAX3 * →(COUNT<4)/ΔL1 * →LO
[28] C3:MAX+MAX1+MAX2 * COUNT+COUNT+1 * →(COUNT<3)/ΔL1 * MAX+MAX1+MAX2+MAX3 * →(COUNT<4)/ΔL1 * MAX+MAX1+MAX2+MAX3+MAX4
[29] →(COUNT<5)/ΔL1 * →LO
[30] C4:MAX+MAX1+MAX2 * COUNT+COUNT+1 * →(COUNT<3)/ΔL1 * MAX+MAX1+MAX2+MAX3 * →(COUNT<4)/ΔL1 * MAX+MAX1+MAX2+MAX3+MAX4
[31] →(COUNT<5)/ΔL1 * MAX+MAX1+MAX2+MAX3+MAX4+MAX5 * →(COUNT<6)/ΔL1 * →LO

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[32] C5:MAX*MAX1*MAX2 * COUNT*COUNT+1 * →(COUNT<3)/ΔL1 * MAX*MAX1*MAX2*MAX3 * →(COUNT<4)/ΔL1 * MAX*MAX1*MAX2*MAX3*MAX4
[33] →(COUNT<5)/ΔL1 * MAX*MAX1*MAX2*MAX3*MAX4*MAX5 * →(COUNT<6)/ΔL1 * MAX*MAX1*MAX2*MAX3*MAX4*MAX5*MAX6 * →(COUNT<7)/ΔL1
[34] →L0
[35] CK1:MAX*MAX1*([G2[1]:2)) * →(MAX1=([G2[1]:2)))/CH1 * MAX2*MAX1-1 * →ΔL1
[36] CH1:MAX2*MAX1 * →ΔL1
[37] CK2:MAX*MAX1*([G2[1]:3)) * →(MAX1=([G2[1]:3)))/CH2
[38] →((MAX1-(G2[1]:3))>0.4)/CH3 * MAX2*MAX1 * MAX3*MAX1-1 * →ΔL1
[39] CH2:MAX2*MAX3*MAX1 * →ΔL1
[40] CH3:MAX2*MAX3*MAX1-1 * →ΔL1
[41] CK3:MAX*MAX1*([G2[1]:4)) * →(MAX1=([G2[1]:4)))/CH4
[42] →(((MAX1-(G2[1]:4))=0.75),((MAX1-(G2[1]:4))=0.5))/K1,K2 * MAX2*MAX1 * MAX3*MAX4*MAX2-1 * →ΔL1
[43] K1:MAX4*MAX3*MAX2*MAX1-1 * →ΔL1
[44] K2:MAX3*MAX2*MAX1 * MAX4*MAX1-1 * →ΔL1
[45] CH4:MAX4*MAX3*MAX2*MAX1 * →ΔL1
[46] CK4:TEM*G2[1]:5 * →((((TEM)-TEM)=0.2),((((TEM)-TEM)=0.4),((((TEM)-TEM)=0.6),((((TEM)-TEM)=0.8)))/Δ1,Δ2,Δ3,Δ4
[47] MAX*MAX1*MAX2*MAX3*MAX4*MAX5*TEM * →ΔL1
[48] Δ1:MAX*MAX1*MAX2*MAX3*MAX4*TEM * MAX5*TEM * →ΔL1
[49] Δ2:MAX*MAX1*MAX2*MAX3*TEM * MAX4*MAX5*TEM * →ΔL1
[50] Δ3:MAX*MAX1*MAX2*TEM * MAX3*MAX4*MAX5*TEM * →ΔL1
[51] Δ4:MAX*MAX1*TEM * MAX2*MAX3*MAX4*MAX5*TEM * →ΔL1
[52] CK5:TEM*G2[1]:6 * →((((TEM)-TEM)<0),((((TEM)-TEM)=0.5))/A,B
[53] →((((TEM)-TEM)<0.5)^(((TEM)-TEM)<0.2),((((TEM)-TEM)>0.5)^(((TEM)-TEM)>0.7)))/C,D
[54] →((((TEM)-TEM)<0.5),(((TEM)-TEM)>0.5))/LΔ1,LΔ2
[55] A:MAX*MAX1*MAX2*MAX3*MAX4*MAX5*MAX6*TEM * →ΔL1
[56] B:MAX*MAX1*MAX2*MAX3*TEM * MAX4*MAX5*MAX6*TEM * →ΔL1
[57] C:MAX*MAX1*MAX2*MAX3*MAX4*MAX5*TEM * MAX6*TEM * →ΔL1
[58] D:MAX*MAX1*TEM * MAX2*MAX3*MAX4*MAX5*MAX6*TEM * →ΔL1
[59] LΔ1:MAX*MAX1*MAX2*MAX3*MAX4*TEM * MAX5*MAX6*TEM * →ΔL1
[60] LΔ2:MAX*MAX1*MAX2*TEM * MAX3*MAX4*MAX5*MAX6*TEM * →ΔL1
[61] L0:[FUNITIE [FNUMS

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      V CHNG B1
[1]  A←B1
[2]  IN←1
[3]  AA←B1[IN;].[1]  [TCNL
[4]  NXT:IN←IN+1
[5]  AA←AA.[1]  B1[IN;].[1]  [TCNL
[6]  -(IN<A[1])/NXT
      V

```

Function name: CHNG

input: A variable in matrix form which this function will change into a vector so that it can be submitted to the high speed printer.
output: a vector of whatever length it is needed to be, the variable name is AA.

SUBROUTINES: none

VARIABLES: AA

```

▽ M3-REMOVE MC
[1] QR←oMC
[2] QM←,MC
[3] M2←(QM='(')v(QM=')')v(QM='-'')
[4] QM[M2/1oQM]←' '
[5] M3←QRoQM
▽

```

Function name: REMOVE

input: A matrix that has hyphens, or parenthesis in its contents which are to be removed.

output: a matrix without hyphens, or parenthesis.

SUBROUTINES: none

VARIABLES: none

REFERENCES

1. First Annual Report, Geothermal Energy Research, Development and Demonstration Program, Energy Research and Development Administration, ERDA 77-9, April, 1977.
2. United States Geological Survey Circular 726, 1975.
3. Birsic, R.J., The Geothermal Steam Story or a Hot Tip from Mother Earth, Published by R.J. Birsic, June 1974.
4. Reistad, G.M., Analysis of Potential Non-Electric Applications of Geothermal Energy and their Place in the National Economy, Lawrence Livermore Laboratory, UCRL 51747, February 1973.
5. Status Report: Geothermal Program Definition Project, (Part II: Geothermal Energy Development Status) Jet Propulsion Laboratory, April 1975.
6. Sacarto, D.M., State Policies for Geothermal Development, National Conference of State Legislatures, November 1976.
7. Johnson, L.R., Simmons, G., and Peterson, J., Energy Supply and Environmental Impacts- Unconventional Energy Sources, Study Module III - B, Northwest Energy Policy Project, 1977.
8. U.S. ERDA, A Bibliography , Geothermal Resources, Exploration, and Exploitation, July 1976.
9. U.S. DOE, Legal and Institutional Impediments to Geothermal Energy Resource Development: A Bibliography, January 1978.
10. Hiatt, W.E., Jr., Unconventional Energy Sources, In Balmer et al., Northwest Energy Policy Project, 1977
11. Balmer, D.G., Mattersdorf, G.H., Kelley, K.R., and Foote, J.H., Institutional Constraints and opportunities, Report on Tasks 4-7, Study Module V-B, Northwest Energy Policy Project, 1977.
12. Brewer, W.A., and Lee, K.N., Institutional Constraints and opportunities, Report on Tasks 1-3, Study Module V-A, Northwest Energy Policy Project, 1977.
13. Schuller, C.R., Schilling, A.H., Cole, R.J., and Simon, G.D., Legal, Institutional and Political Problems in Producing Electric Power from Geothermal Resources in California, Battelle Human Affairs Research Center, Richland, Washington, August 1976.

14. Raschen, R., and Cook, W.S., Exploration and Development of Geothermal Resources, Conservation Division, Office of the Area Geothermal Supervisor, U.S. Geological Survey, Menlo Park, California, 1976.
15. Vollintine, L., and Weres, O., Public Opinion Concerning Geothermal Development in Lake County, California, Lawrence Berkeley Laboratories, March 1976.
16. Vollintine, L., and Weres, O., Public Opinion in Cobb Valley concerning Geothermal Development in Lake County, California, Lawrence Berkeley Laboratories, June 1976.
17. U.S. DOE, Solar, Geothermal, Electric and Storage Systems Program-Summary Document for Fiscal Year Year 1979, March 1978.
18. Institutional Barriers Panel, First Report to Interagency Geothermal Coordinating Council, July 1976.
19. Institutional Barriers Panel, Second Report to IGCC, December 1976.
20. Institutional Barriers Panel, Draft Report of Minutes of Meeting of April 5, 1977, May 1977.
21. U.S. DOI Memorandum of Understanding for Geothermal Program, June 15, 1976.
22. Streamlining Taskforce of Interagency Geothermal Coordinating Council, Program and Objectives of the Interagency Geothermal Streamlining Task Force, June 1978.
23. Davidson, R., Geothermal Energy Prospectus in the Western States, Special Report to the Governors, Western Governors Regional Energy Policy Office, May 1976.
24. Harric, R.C., Technical Status Report of the Geothermal Policy Project, National Conference of State Legislatures, March 1978.
25. Arizona Team of the Southwest Regional Geothermal Development Operations Research Project, Final Report, July 1978.
26. Colorado Team of the Southwest Regional Geothermal Development Operations Research Project, Final Report, July 1978.
27. Nevada State Team of the Southwest Regional Geothermal Development Operations Research Project, Final Report, July 1978.
28. New Mexico Team of tje Southwest Regional Geothermal Development Operations Research Project, Final Report, July 1978.
29. Utah State Team of the Southwest Regional Geothermal Development Operations Research Project, Final Report, July 1978.

30. Mount, T.C., Chapman, L.D., and Tyrrell, T.J., Electricity Demand in the United States: An Econometric Analysis, Oak Ridge National Laboratories, Oak Ridge, 1973.
31. Taylor, L.C., The Demand for Electricity: A Survey, The Bell Journal of Economics, 6:1, 74-110.
32. Johnston, J., Econometric Methods, McGraw Hill Book Co., N.Y., 1972.
33. Anderson, K.P., Sales and Load Growth of Participating Companies, Arizona Nuclear Power Project, 1974-1978, National Economic Research Association, New York, 1976.
34. Edison Electric Institute., Report on Economic Growth in the Future., New York, N.Y., 1976.
35. Barnes, B.B., Contributions of Emerging Technologies-Geothermal Energy, Federal Energy Administration, February 1977.
36. Chiang, C.W., and Hardy, Brain., Geothermal Space Heating for Low-Income Houses at Edgemont, S.D., Geothermal Resources Council Annual Meeting, (May 1977).
37. Reistad, G.M., Potential for Non-Electrical Applications of Geothermal Energy and their Place in the National Economy, Proceedings of Second United Nations Symposium on the Development and Use of Geothermal Resources, Vol 3, San Francisco, Calif., May 20-29, 1975, pp 2127.
38. Kunze, J.F., and Richardson, A.S., National Program Definition study for the Non-Electrical Utilization of Geothermal Energy, Idaho Falls, Idaho: Aerojet Nuclear Company, Idaho National Engineering Laboratory, June 1975.
39. Lineau, Paul J., OIT Adds a New Building to its Geothermal Heating System, Geo-Heat Utilization Center Quarterly Bulletin, Vol. 1, No.2 , October 1975.
40. Lineau, Paul J., Geoheat Utilization Center Established at Oregon Institute of Technology, Geo-Heat Utilization Center Quarterly Bulletin, Vol. 1, No. 1, May 1975.
41. Lund, J.W., The Utilization and Economics of Low Temperature Geothermal Water for Spapc Heating, Eleventh Intersociety Energy Conversion Engineering Conference Proceedings, 12 September 1976.

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APPENDIX 1

SUMMARY OF GEOTHERMAL ALGORITHM - ELECTRIC USES (GIRORA-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.¹ 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 to a producer from a geothermal field for which electricity production is planned. This model can easily be modified to fit any type of energy production from a geothermal field.

The basic equation is of the simple form for discounting cash flows:

$$\text{Investment} = \sum_{t=1}^T (\text{Net Income}_t) (1 + R)^{-t} \quad (1.1)$$

where Net Income = (Total Revenues) - (Total Operating Cost) - (Taxes)

Total Revenues = (Price) (Quantity Output)

Total Operating Cost = A Percentage of Investment

R: Rate-of-Return

t: Each year, $t = 1, 2, \dots, T$.

T: Expected life span of the Investment

However, this rather fundamental notion is modified somewhat in GIRORA-Electric due to the fact that some investments are made throughout the life of the project and thus must also be discounted to the present for proper evaluation. This yields the equation,

$$\sum_{t=1}^T (\text{Investment}_t) (1 + R)^{-t} = \sum_{t=1}^T (\text{Net Income}_t) (1 + R)^{-t} \quad (1.2)$$

¹For a discussion of this principal, see Fred R. Glahe Macroeconomics (New York: Harcourt, Brace, Jovanich, Inc., 1973), pp. 91-95

which reduces to

$$\sum_{t=1}^T (\text{Investment}_t) (1 + R)^{-t} = 0 \quad (1.3)$$

If we set $(1 + R)^{-1} = b$, then

$$\sum_{t=1}^T (\text{Investment}_t - \text{Net Income}_t) b^t = 0 \quad (1.4)$$

Equation (1.4) is a polynomial with T roots. Assuming a monotonic function there will be one real (non-imaginary) root (b) which permits a solution for the equation. This root can be found iteratively by Newton's technique.² Fortunately, GIRORA-Electric has generated only monotonic functions.

GIRORA-Electric simulates all investment, revenue, and cost flows for a specified resource site, and inputs the flows to equation (1.3) and solves for R.

Investment, revenue and cost flows are divided into two sectors, a geothermal developer sector, and an electric utility sector. The geothermal developer's revenues are operating costs as perceived by the electric utility. The electric utility demand for geothermal fluid (or steam) is derived from the demand for electricity. Once a quantity of electricity has been specified, given resource characteristics, the quantity of fluid or steam is automatically specified. The price of the geothermal energy is the highest price consistent with the competitive price of electricity and the electric utility's regulated rate-of-return (both which are assumed to be known). The description of GIRORA-Electric begins with a description of the Electric Utility Sector.

Electric Utility Sector

The model first identifies the principal components of cost to the electric utility for each year (t) of electricity production: capital costs (CC_t),

²For a description of the mathematical technique involved, see C. C. T. Baker, Dictionary of Mathematics, (New York City, Hart Publishing Co., 1966), p. 206.

operating costs (OMC_t), income taxes (ITX_t), property taxes (PTX_t), and energy costs (ENC_t).

Capital costs are a function the investment (K) required for a specified level of capacity in kilowatts (CAP).

$$K = (CAP) (CAPC) \quad (1.5)$$

CAPC: capacity cost in dollars per KW; an input parameter

Capital costs are also a function of the regulated return to equity (ER), the bond rate (BR), the debt to equity ratio, and depreciation ($DEPR_t$).

$$E = (EK) (K) (ER), \text{ (equity costs),} \quad (1.6)$$

$$D = (DK) (K) (BR), \text{ (debt costs),} \quad (1.7)$$

$$DEPR_t = (DEP_t) (K), \text{ (depreciation),} \quad (1.8)$$

and therefore

$$CC_t = E + D + DEPR_t \quad (1.9)$$

where, EK: equity share of capital; an input parameter,

DK: debt share of capital; an input parameter

$$(EK = 1-DK)$$

DEP_t : depreciation rate in year t;

$$DEP_t = (T + 1 - t) / \sum_{t=1}^T t, \quad (1.10)$$

where T is the length of time for electricity production. The model provides for a fast write-off option.

Operating costs are a function of total investment and escalate through time.

$$OMC_t = (OC_t) (K) \quad (1.11)$$

$$OC_t = (OCB) (1 + \dot{OC})^t \quad (1.12)$$

OC_t : operating percent of investment in year t; input variable

OCB: base rate; input variable,

$\dot{OC}$: escalation rate; input variable

Likewise, property taxes are a function of investment.

$$PTX = (PTP) (K). \quad (1.13)$$

PTP: property tax rate; input variable

Before income taxes are calculated, total revenues must be known. They are, of course, a function of the price of electricity (PE_t) and the quantity of electricity (QE), which is a function of plant capacity. PE_t is specified as an exogenous busbar price of electricity which is determined by the market and escalates over time.

$$PE_t = (PB) (1 + \dot{P})^t \quad (1.14)$$

PB: Base busbar price of electricity; input variable.

$\dot{P}$: escalation factor; input variable

$$QE = (CAP) (8760) (LF) (1-UF) \quad (1.15)$$

LF: Plant factor; an input variable,

UF: Plant use of power; an input variable.

Income taxes and energy costs must be determined simultaneously, because the price of the geothermal energy (PHW_t) is an element of both and moreover, PHW_t is the output of the utility sector for the model. The quantity of geothermal energy is determined by electricity plant requirements.

$$QHW = (CAP) (8760) (LF) \quad (1.16)$$

$$ENC_t = (PHW_t) (QHW) \quad (1.17)$$

$$ITX_t = \{TXRT\} \{[(PE_t) (QE)] - [OMC_t] - [PTX] - [ENC_t] - [D] - [DEPR_t]\} - \{[CRRT] [K_{t=1,t=2,t=3}]\} \quad (1.18)$$

TXRT: income tax rate; input variable

CRRT; investment tax credit rate; input variable

Therefore,

$$PHW_t = \frac{(TXRT) (DEPR_t) + (CRRT) (K_{t=1,t=2,t=3}) - (CC_t)}{(QHW) (1-TXRT)} + \frac{(PE_t) (QE) - (OMC_t) - (PTX)}{(QHW)} \quad (1.19)$$

The price of energy in year (t) from (15) and the quantity of energy from (12), that is, ENC_t (equation 1.17), become total revenue for the geothermal energy producer.

Geothermal Energy Producer Sector

We will recall equation (1.17) ENC_t for the producer, REV_j , or total revenues.

$$REV_j = ENC_t \quad (1.20)$$

First, a discussion of the time period involved is necessary. The producer's time horizon is different from that of the electric utility. The years t are elements of T, while the years j are elements of J. $J - T = PPY$, the "pre-production years." PPY is composed of two periods. The exploration period (EXP) and the development period (DVP), and thus $EXP + DVP = PPY$. Thus, the determinative direction is $EXP + DVP + T = J$. EXP is the period during which only exploratory wells are drilled. The development period begins with the drilling of the first production well.

The producer's activity is modeled somewhat differently from the utilities because the output of the simulation is a rate of return on the producer's equity. Thus, the first order of business is to determine what the level of the investment is in each year of the project. The producer's investment (PNV_j) is a share of the total investment in year J (PPK_j).

$$PNV_j = (EPK)(PPK_j) \quad (1.21)$$

$$PPK_j = (LNV_j) + (DNV_j) + (IDC_j) + (OPNV_j) \quad (1.22)$$

EPK: Equity portion of capital; an input variable,

LNV_j: Leasing investment in year j, in \$,

DNV_j: Drilling investment in year j, in \$,

IDC_j: Interest cost during construction in year j, in \$,

OPNV_j: Other producer investments in year j, in \$,

Total investment by the producer, cumulative to year j is

$$PK_j = \sum_{i=0}^j PKK_i \quad (1.23)$$

We will first describe the calculation of each element of PKK_j , beginning with DNV_j .

$$DNV_j = \left[\left(\frac{NPW_j}{PSS} \right) (ADDP) (CPFP) \right] + \left[\left(\frac{NIW_j}{ISS} \right) (ADDI) (CPFI) \right] \quad (1.24)$$

NPW_j : New producing wells in year j.

PSS : Production Well Success ratio,

$CPFP$: Cost per foot, producing wells,

NIW_j : New injection wells in year j,

ISS : Injection well success ratio (= 1 usually),

$ADDI$: Average depth of injection wells,

$CPFI$: Cost per foot of injection wells.

The calculation of the elements of DNV_j is shown below.

$$NPW_j = RPW_j - RPW_{j-1} \quad (1.25)$$

RPW_j : required producing wells, $RPW_j = 0$ when $j < EXP + 1$.

$$RPW_j = \frac{RFR_{CAP}}{FR} \quad (1.26)$$

FR : Flowrate in lb/hr per producing well,

RFR_{CAP} : required flowrate for rated capacity in lb/hr.³
(CAP is stated here in MW, not KW, and is net of UF.)

$$RFR_{50} = 1374.912e^{-0.01379 (TEMP)} \quad (1.27a)$$

$$RFR_{100} = 2667.012e^{-0.01372 (TEMP)} \quad (1.27b)$$

³ Bechtel Corporation, Advanced Design and Economic Considerations for Commercial Geothermal Power Plants at Heber and Niland, California. SAN-1124-2, San Francisco, California, 1977.

$$RFR_{150} = 3959.226 e^{-0.013655 (TEMP)} \quad (1.27c)$$

$$RFR_{200} = 5251.44 e^{-0.01359 (TEMP)} \quad (1.27d)$$

Temperature decline is estimated, and resulting need for increased flow rate, thus producing wells, is modeled in the following way:

$$Temp = \frac{T_0}{360} [358.344 e^{-0.00144 (Time)}], \text{ for CAP} = 50MW \quad (1.28a)$$

$$Temp = \frac{T_0}{360} [357.474 e^{-0.00233 (Time)}], \text{ for CAP} = 100 MW \quad (1.28b)$$

$$Temp = \frac{T_0}{360} [357.12 e^{-0.00322 (Time)}], \text{ for CAP} = 150 MW \quad (1.28c)$$

$$Temp = \frac{T_0}{360} [357.769 e^{-0.00411 (Time)}], \text{ for CAP} = 200MW \quad (1.28d)$$

T_0 : downhole temperature of brine in °F, an input variable.

$$NIW_j = RIW_j - RIW_{j-1} \quad (1.29)$$

RIW_j : required injection wells in year j .

$$RIW_j = RPW_j (PIR)^{-1} \quad (1.30)$$

PIR : required ratio of producing wells to injection wells, in year j , an input variable.

After initiation of power generation, NPW_j and NIW_j will generally take on a value of 0 or 1, but are arbitrarily allocated during DVP.

The remaining elements of PKK_j are discussed below:

$$LNV_j = [(DPAC)(ACPW)(NPW_j)] + [(DPAC)(ACIW)(NIW_j)] \quad (1.31)$$

$DPAC$: dollars per acre leasing cost; input variable,

$ACPW$: acres per producing well; input variable,

$ACIW$: acres per injection well; input variable.

$$OPNV_j = EXPN_n + PIPN_j + ONV_j \quad (1.32)$$

$EXPN_j$: exploration investments, year j ,

PIP_j: piping investments, year j,

ONV_j: other investments, year j.

$$\text{EXPN}_j = f(\text{EXPN}) \quad (1.33)$$

$$\text{EXPN} = (\text{EXD})(\text{CAP}) \quad (1.34)$$

EXD: dollars per unit of capacity (electric needed for exploration, on average; input variable.

$$j > \text{EXP}, \text{EXPN}_j = 0$$

EXPN: total exploration investment in \$

(Note: $\text{EXPN} = \sum_{j=0}^{\text{EXP}} \text{EXPN}_j$, where the distribution function is chosen arbitrarily)

$$\text{PIP}_j = (\text{PIP})(\text{DNV}_j) \quad (1.35)$$

PIP: average percentage of drilling investment required for piping and similar field developments.

$$\text{ONV}_j = (\text{OPE}_j)(\text{DNV}_j) \quad (1.36)$$

$$\text{OPE}_j = (\text{OPEB})(1+\text{OP})^j \quad (1.37)$$

Equations (1.37) and (1.38) calculate estimate additional investments in field development which are related to drilling expenses.

$$\text{IDC}_j = [\text{BR}] [\text{DPK}] \left[\sum_{i=0}^j \text{LNV}_i + \sum_{i=0}^j \text{DNV}_i + \sum_{i=0}^j \text{OPNV}_i \right] \quad (1.38)$$

$$\text{IDC}_j = 0 \text{ for } j > \text{PPY}.$$

DPK: debt portion of capital; $\text{DPK} = 1 - \text{EPK}$.

Thus, total revenues and all elements of investment have been calculated. What remain are uncanceled elements of cost. OMCP_j are operating and other current outlays.

$$\text{OMCP}_j = [(\text{OCP}_j)(\text{PK}_j)] + [(\text{BR})(\text{PK}_j)(\text{DPK})] + [\text{PTXP}_j] \quad (1.39)$$

$$OCP_j = (OCPB)(1+OCP)^j \quad (1.40)$$

OCP_j : operating percentage of investment outlay,

$OCPB$: base percentage; input variable,

OCP : escalation factor.

$PTXP_j$: property taxes.

$$PTXP_j = (PTPP)(PK_j) \quad (1.41)$$

$PTPP$: property tax rate; input variable.

Income taxes are as follows:

$$ITXP_j = \{TXRT\} \{[(REV_j)(1-\lambda)(1-Z)] - OMCP_j - [(Y)(DNVD_j)]\} \\ - \{[CRRT][(1-Y) \sum_{i=j-2}^j DNVD_i]\} \quad (1.42)$$

$$DNVD_j = \sum_{i=1}^j DNVD_i (DEPRP_{j-i+1}) \quad (1.43)$$

$$DEPRP_j = (D + 1 - j) / \sum_{j=1}^D j \quad (1.44)$$

D : period chosen for depreciation; input variable

λ : royalty rate, input variable,

Y : percentage tangible investment, input variable,

Z : depletion allowance, input variable,

$DNVD_j$: depreciation allowance in year j , \$

$DEPRP_j$: depreciation rate in year j . Program contains fast write-off option.

Finally, the model solves for R , the rate of return to equity for the geothermal energy producer from the J th degree polynomial given by

$$\sum_{j=1}^J \{[(REV_j)(1-\lambda) - (OMCP_j) - (ITXP_j)]\} e^{-Rj} = 0 \quad (1.45)$$

The R thus solved is one criterion for ranking geothermal resource sites and for comparing the outcomes of policy variable changes.

APPENDIX 2

A DISTRICT SPACE HEATING MODEL - GIRORA: NONELECTRIC

To find the commercial feasibility of a geothermal resource for district heating, an internal rate of return model is developed, which is labeled as GIRORA-NONELECTRIC.

GIRORA NON-ELECTRIC is a simple but powerful simulation model which evaluates the economic potential of low temperature hydrothermal geothermal resources for district space heating. The model also provides a means for measuring the estimated economic impacts of variations in a number of policy variables and site specific geophysical variables. In composite, these findings present an empirical collage which proves richly productive in evaluating the potential of low temperature geothermal energy.

GIRORA NON-ELECTRIC will be considered in detail below. The primary output of the model is an estimated measure of profitability for a geothermal producer developing a given geothermal resource site. On this basis, an ordinal ranking of low temperature sites in Region 4 can be compiled with respect to expected profitability. Such a ranking provides a best guess listing, ceteris paribus, of which sites might be expected to come "on line" and in what order they will be developed.

While a number of analytical models similar to the model described herein are being developed, each of the current generation is dependent upon the original GEOCITY model developed by Bloomster, et. al., at Battelle Pacific Northwest Laboratories¹. Unfortunately for most analysts interested in broad regional study, GEOCITY may be too elegant. "GEOCITY is an offshoot of the GEOCOST program. . .," a highly technical and extremely detailed

¹Bloomster, C. H., Fassbender, L. L. and McDonald, C. L. Geothermal Energy Potential for District and Process Heating Applications in the U.S. An Economic Analysis. Battelle Pacific Northwest Laboratories, Richland, Washington, August 1977.

simulation model which describes the development of high temperature resources for generating electricity². As a result, GEOCITY might be more appropriately described as an engineering description of a district heating model than as a financial feasibility model.

For a broader research thrust with which little proprietary data or detailed district heating plans are available, many properties of GEOCITY are redundant. Given the objectives of the present analysis, therefore, a simpler more functional model is necessary. Accordingly, Geothermal Internal Rate of Return Algorithm (GIRORA) has been developed.

From an analytical perspective, GIRORA NON-ELECTRIC is a discounted cash flow model which simulates required investments, revenues, and operating outlays for each year of the investment life of a geothermal anomaly. The model iterates for the internal rate of return which equates the sums of investment costs incurred with net revenues, discounted to the present. In simple terms, the model calculates R (internal rate of return) from

$$\sum_{t=1}^T \text{Investments}_t (1+R)^{-t} = \sum_{t=1}^T \text{Net Revenues}_t (1+R)^{-t} \quad (2.1)$$

T: Each year of the period, $t=1, \dots, T$

Simulating the life of an investment through T years results in a T-th order polynomial which is solved iteratively by Newton's method of approximation for a unique real root, R. This root is a measure of the expected profitability of an investment. Ceteris Paribus, the greater the present value of all net revenues or the lowest cost of all investments throughout the productive life of a resource, the higher is R, and vice versa.

² Bloomster, C. H., Huber, H. D. and Walter, R. A. User Manual for GEOCOST: A Computer Model for Geothermal Cost Analysis; Vols. 1 & 2, Battelle Pacific Northwest Laboratories, Richland, Washington, 1975-1976.

The heart of the simulation model is an expanded version of equation (2.1).

$$\sum_{t=1}^T \text{INV}(1+R)^{-t} = \sum_{t=1}^T (\text{REV}_t - \text{TC}_t - \text{TX}_t) (1+R)^{-t} \quad (2.2)$$

INV: Equity Investment by project developers

REV_t: Total revenues in year t.

TC_t: Variable costs in year t.

TX_t: Taxes in year t.

R: Discount rate of internal rate of return.

t: Each year of project, t=1,...T.

The remainder of the model identifies explicitly each element of equation (2.2). Beginning on the left side of the equation and working to the right,

$$\text{INV} = (\text{EK}) (\text{TNV}) \quad (2.3)$$

EK: Equity portion of capital.

TNV: Total Investment.

Equation (2.3) indicates that the return to risk capital is of primary concern, since the return on debt capital will be specified by a bond rate.

Total investment costs include drilling investment, leasing costs, plant investment, and interest paid during construction. During the early years of a geothermal resource investment, i.e. during the period of reservoir exploration and development and plant construction, investment cost is the sum of all of the four components above. Thereafter, during the actual operation of the space heating system, total investment is the sum of drilling, leasing, and interest expenses. Thus,

$$\text{TNV}_t = \text{DNV}_t + \text{LNV}_t + \text{IDC}_t + \text{PLV}_t, \quad t = \text{EXP} + \text{DVP} + \text{CON} \quad (2.4a)$$

$$\text{TNV}_t = \text{DNV}_t + \text{LNV}_t + \text{IDC}_t, \quad t \neq \text{EXP} + \text{DVP} + \text{CON} \quad (2.4b)$$

DNV_t = Drilling investment costs in year t, \$

LNV_t = Leasing investment cost in year t, \$

PLV = Plant investment cost for transmission and distribution system, \$

IDC_t = Interest during construction in year t, \$

EXP = Exploration period in years, input variable

DVP = Development period in years, input variable

CON = Plant construction period in years, input variable

Each of the four components of the capital investment is estimated individually. The first is the drilling investment. Drilling investment is a function of the number of geothermal production and injection wells required, the average depth of production and injection wells, and the cost per unit depth of production and injection wells.

$$DNV_t = \left(\frac{NPW_t}{PSS} \right) (ADDP) (CPFF) + \left(\frac{NIW_t}{ISS} \right) (ADDI) (CPFI) \quad (2.5)$$

NPW_t = New production wells to be drilled in year t

PSS = Production well success ratio; input variable,

ADDP = Average depth of production well in feet; input variable,

CPFF = Drilling cost per foot of production well, \$, input variable,

NIW_t = New injection wells to be drilled in year t,

ISS = Injection well success ratio; input variable,

ADDI = Average depth of injection well in feet; input variable,

CPFI = Drilling cost per foot of injection well, \$, input variable.

The number of production wells required is dependent upon the amount of hot water required to meet the space heating system demand and the flow rate of each production well.

$$RPW = HWLBH/FR \quad (2.6)$$

RPW = Required number of production wells to be drilled,

HWLBH = Hot water required to meet system demand, lbs/hr,

FR = Flow rate of the production well, lbs/hr; input variable.

In return, the amount of hot water that is required to meet the demand of the space heating system is jointly dependent upon the estimated peak heat demand (PHD) of the user and the usable heat (TD) from the available water. In the case of the former, the hot water required is assumed to be 75 percent of the amount necessary to supply peak heat demand, with the remaining 25 percent supplied by conventionally fueled backup units. Thus³

$$HWLBH = 0.75 [PHD/TD] \quad (2.7)$$

When estimating peak heat demand, the user mix or the percent of the population residing in single family dwelling units versus multiple family dwelling units is specified. In addition, the non-residential demand is assumed to be 50 percent of residential demand.

$$PHD = 1.5 [2.016 (\Omega) + 0.914 (1-\Omega)] [POP/3] [DEGD] \quad (2.8)$$

DEGD = Heating degree days (°F) of the community

POP = Population of the community; input

Ω = User mix ($0.0 < \Omega < 1.0$)

TD = Usable temperature from the available hot water

As the hot water is transported from the resource site to the demand site, there will be a decline in temperature of hot water proportional to the distance. In addition, the usable temperature also depends on the downhole temperature of the hot water at the source.⁴

³ E. F. Wehlage, The Basics of Applied Geothermal Engineering, Geothermal Information Services, California, 1976.

⁴ E G & G Idaho Inc., The Potential for Utilizing Geothermal Energy in Reconstructed Sugar City, Idaho, TREE-116, January 1977.

$$TD = -75.41 + 0.7142 (TEMP - DIST) \quad (2.9)$$

TEMP = Downhole temperature of hot water at source, °F;
input variable,

DIST = Distance from resource to the population center,
miles; input variable.

Neither the temperature nor the flow rate is assumed to decline through time. Accordingly, once the production and injection wells are drilled at the beginning of the project, they are assumed adequate to support the estimated demand throughout the project life.

$$NPW_t = RPW \quad t=1 \quad (2.10a)$$

$$NPW_t = 0 \quad t>1 \quad (2.10b)$$

$$NIW_t = NPW_t / PIR \quad (2.11)$$

PIR = Necessary production well to injection well ratio;
input variable.

The second component of investment expenditures is the leasing investment. Leasing investment is a joint function of the acreage required for production and injection wells and the leasing cost per acre.

$$LNV_t = (DPAC) (ACPW) (NPW_t) + (DPAC) (ACIW) (NIW_t) \quad (2.12)$$

DPAC = Leasing cost, \$ per acre; input variable,

ACPW = Required acreage per production well; input
variable,

ACIW = Required acreage per injection well; input
variable.

The third component of investment cost necessary for the development of a low temperature geothermal resource is the plant investment cost. Plant investment consists of two components. The first is transmission investment, the costs incurred in transporting geothermal hot water from the supply site to the point of demand. The second component is distribution investment, which consists of costs incurred in distributing geothermal water to individual demand units.

$$PLV = TRNV + DINV$$

(2-13)

TRNV = Transmission costs, \$

DINV = Distribution costs, \$

Each of these two investment expenses is individually explained below.

The transmission cost is a dual function of the transmission line pipe diameter (which is itself directly related to the amount of hot water to be transported) and the distance from the geothermal resource to the population center. This cost includes the expense of schedule 10 international pipe, fittings and valves, 2.5" insulation, tin shield, labor and trenching, modified expansion loop and miscellaneous costs associated with transmission pipe installation^{5,6}. More specifically,

$$TRNV = 7.2474 + 2.699 (TPD) \times 5280 \times DIST \quad (2.14)$$

$$TPD = \text{Transmission line pipe diameter, inches} \quad (2.15)$$

$$TPD = 6.6 + 4.04 \times HWLBH \times 10^{-6}$$

The transmission line pipe diameter is in each case adjusted to the next highest integer.

The distribution investment is a function of the peak heat demand.⁶

$$DINV = 0.75 (115,000 \times PHD/3.413) \quad (2.16)$$

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

⁵ C. L. McDonald and C. H. Bloomster, The Geocity Model: Description and Application, Battelle Pacific Northwest Laboratories, Richland, Washington, June 1977.

⁶ S. S. Einarsson, Geothermal Space Heating and Cooling, Second U. N. Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 1975.

$$IDC_t = [BR] \left[\sum_{j=1}^t (DNV_j + LNV_j) \right] [DK], \quad (2.17a)$$

$$t = EXP + DVP,$$

$$IDC_t = [BR] \left[\sum_{j=1}^t (DNV_j + LNV_j + PLV_j) \right] [DK], \quad (2.17b)$$

$$t = EXP + DVP + CON,$$

$$IDC_t = 0, \quad t > EXP + DVP + CON \quad (2.17c)$$

where

The sum of the present values of all of these four investment costs, including drilling, leasing, plant investment and interest during construction is equated to the sum of the net revenues earned. Net revenue is defined as gross revenue (REV) less variable expenses (TC) and taxes (TX). Taking each of these items in order,

$$REV_t = (AHD) (8760) P (1 + i)^t (1 - \lambda) \quad (2.18)$$

AHD = Average heat demand of the population center,
in million Btu/hr

P = Price of alternate fuel (natural gas),
\$ per million Btu equivalent; input variable,

i = rate of growth of alternate fuel price; input variable,

λ = Royalty rate; input variable

$$AHD = (PHD) (LF) \quad (2.19)$$

PHD = Peak heat demand of the population center in
million Btu/hr

LF = Load factor; input variable

Gross revenue is directly related to the average heat demand placed upon the system. In theory, the demand for space heating is extremely variable, both as a diurnal and on an annual basis. As mentioned above, the space heating system is assumed to have installed capacity sufficient to fulfill 75 percent of estimated peak heat demand; the remaining demand is assumed to be supplied by an appropriate backup system. Over a period

of a year, the space heating system will function at a certain percent of its peak capacity, and this element is defined as the load factor.

Having thus calculated gross revenues, net revenues are gross revenues less operating costs and taxes. Property taxes are assumed proportional to the plant investment. In the case of total cost,

$$TC_t = [OCE_t + (BR) (DK) + DEPRD_t] \times \left[\sum_{j=1}^t (TNV_j - IDC_j) \right],$$

$$t = EXP + DVP \quad (2.20a)$$

$$TC_t = [OCP_t + (BR) (DK) + DEPRD_t] \times \left[\sum_{j=1}^t (TNV_j - IDC_j) \right]$$

$$+ PTX_t, \quad t = EXP + DVP + 1, EXP + DVP + 2, \dots, T \quad (2.20b)$$

OCE_t = Percent of drilling costs which constitutes operating expenses

OCP_t = Percent of drilling and plant costs which constitutes operating expenses

PTX_t = Property taxes during year T

$$PTX_t = [PTXR_t] [PLV] \quad (2.21)$$

$PTXR_t$ = Property tax rate

$$OCE_t = C(1 + \dot{C})^t \quad (2.22)$$

$$OCP_t = PC(1 + \dot{PC})^t \quad (2.23)$$

C = Base year percentage; input variable,

$\dot{C}$ = Rate of increase of C over time; input variable

PC = Base year percentage; input variable

$\dot{PC}$ = Rate of increase of PC over time; input variable

$DEPRD_t$ = Depreciation for drilling investment in year t

$$DEPRD_t = (D + 1 - t) / \sum_{j=1}^D j \quad (2.24)$$

D = period of depreciation for drilling and leasing (Input)

Finally, income taxes are computed

$$TX_t = \{TXRT\} \{[REV_t (1 - Z)] - [TC_t - (BR \cdot DK + DEPRD_t)]\} \quad (2.25)$$

$$\begin{aligned} & \left(\sum_{j=1}^t TNV_t - IDC_t \right) \\ & - [Y - (DEPRD_t) \sum_{j=1}^t LNV_j] + DNVD_t + DEPRN_t \cdot PLV \\ & - \{[CRRT] [(1 - Y) \sum_{j=1}^t LNV_j + PLV]\} \end{aligned}$$

TXRT = Tax rate (Input)

Z = Depletion allowance (Input)

Y = Percentage tangible investment (Input)

DNVD_t = A dollar amount for depreciation of drilling investment in year t

DLPRN = Depreciation for plant investment in year t

CRRT = Investment tax credit rate (Input)

$$DNVD_t = \sum_{j=1}^t DNV \cdot DEPRD_{t-j+1} \quad (2.26)$$

$$DEPRN_t = 0, \quad t \leq PPY \quad (2.27a)$$

$$= (N + PPY + 1 - t) / \sum_{j=1}^N, \quad t > PPY \quad (2.27b)$$

N = Depreciation period for plant; input variable

All of the appropriate terms in equation (2.2) are now known, except for R. Any variables which have not been identified are manual inputs to the simulation model. Equation (2.2) is a polynomial of order T, and it is solved iteratively for a value of R.

APPENDIX 3

THE GEOTHERMAL RPPM DATABASE

The Regional Program Progress Monitor (RPPM) Database was created for the Regional Operations Research Program for Development of Geothermal Energy in the Southwest United States, ERDA Contract No. EG-77-S043992.

The Database has been implemented on the IBM System/360 at the New Mexico State University (NMSU) Computer Center. The APL language has been used in file definition, update, retrieval and formatting. Use of APL as the host language permits interactive access to the Database from core team offices throughout the NMSU campus.

The Database contains no classified or proprietary data. Since the Database is designed to meet Project needs, it is likely to be modified in the future as Project requirements change. This report describes the Database as of May 5, 1978. The status of the Database at any time may be determined by contacting the Core Team at NMSU.

This report was prepared by John Nance, Roy Heath and Pat O'Dea of the Physical Science Laboratory, New Mexico State University.

DATABASE STRUCTURE

The RPPM Database consists of three relations: SITE, CITY and COUNTY. The SITE relation contains data on approximately 350 geothermal locations in the five state Southwest Region. The data has been collected from a variety of sources. A source code has been provided for each data item, where source might be of importance. A description of sources and source codes may be found in Table 4.

The CITY relation contains data on approximately 1000 U. S. cities in or near the Southwest Region. The population data was compiled from the 1970 Report of the Bureau of the Census. It includes all incorporated places with a population greater than 500 persons and all unincorporated places with a population greater than 1500 persons. The London Times Atlas was the primary source for latitude and longitude.

The COUNTY relation contains approximately 450 counties in or near the Southwest Region.

DOMAIN NUMBER	DOMAIN	UNITS	FIELD SIZE
* 1	**Site ID	-	4
2	Site Name	-	20
* 3	County Code	-	3
* 4	Latitude	Degrees North	2
* 5	Latitude	Minutes North	2
* 6	Longitude	Degrees West	3
* 7	Longitude	Minutes West	2
8	Township	-	4
9	Range	-	4
10	Section	-	2
*11	Reservoir Volume	cubic kilometers	6.2
12	Source of Reservoir Volume	-	2
*13	Subsurface Temperature	degrees Celsius	3
14	Source of Subsurface Temp	-	2
*15	Surface Temperature	degrees Celsius	3
16	Source of Surface Temp	-	2
*17	Estimated Temp (Swanberg)	degrees Celsius	3
*18	Measured Temp (Swanberg)	degrees Celsius	3
*19	Thermal Gradient	degrees Celsius/km	3
20	Source of Thermal Gradient	-	2
*21	Dissolved Solids	parts per thousand	3
22	Source of Dissolved Solids	-	2
*23	Flowrate	liters per second	3
24	Source of Flowrate	-	2

Table 1. Contents of the SITE File (Relation)

DOMAIN NUMBER	DOMAIN	UNITS	FIELD SIZE
* 1	**City ID	-	5
* 2	Latitude	Degrees North	2
* 3	Latitude	Minutes North	2
* 4	Longitude	Degrees West	3
* 5	Longitude	Minutes West	2
* 6	Population	-	6
7	County Name	-	12
8	City Name	-	25

Table 2. Contents of the CITY File (Relation)

*Indicates a valid qualifying domain

**Indicates primary key

DOMAIN NUMBER	DOMAIN	UNITS	FIELD SIZE
* 1	**County ID	-	4
2	County Name	-	12

Table 3. Contents of the COUNTY File (Relation)

*Indicates a valid qualifying domain

**Indicates primary key

SOURCE CODE	SOURCE
1	U. S. Geological Survey, Circular 726
2	Dr. C. Swanberg, or NMSU Dept. of Earth Sciences
3	MITRE
4	Arizona State Team
5	Colorado State Team
6	Nevada State Team
7	New Mexico State Team
8	Utah State Team
9	U. S. Dept. of Energy
10	NOAA
11	New Mexico Energy Institute
12	GEO THERM Database
13	W. K. Summers, or New Mexico Bureau of Mines and Mineral Resources
14	U. S. Bureau of the Census Report for 1970
15	U. S. Bureau of the Census Update 1976
16	London Times Atlas
17	U. S. Geological Survey - Waring
18	Stone & Mizell, or New Mexico Bureau of Mines and Mineral Resources

Table 4. Source Codes used in the RPPM Database

DATABASE ACCESS

The RPPM Database may be accessed through terminals communicating with the System/360 at the NMSU Computer Center. Access requires approval of the Geothermal Operations Research Project Director, and use of a private APL workspace. Access from a public workspace is not permitted.

Presently, users are permitted to retrieve data, but not modify it. Update operations may be performed only by the Database Administrator.

DATA RETRIEVAL

The APL routines necessary for data retrieval are found in the workspace 310733401 RPPM. After signing on to a private APL workspace, execute the following command.

```
)LOAD 310733401 RPPM
```

A description of commands follows.

OPEN 'relation name'

The OPEN command must be executed before any retrievals are attempted. Only one relation may be "open" at once. Valid relation names are SITE, CITY, and COUNTY. Refer to the preceding section, DATABASE STRUCTURE (Tables 1, 2 and 3), for a detailed description of each relation.

arg1 GET arg2

The GET command actually retrieves data from the Database. It may be executed only after an OPEN command has been issued. It accesses only the currently "open" relation.

Arg1 is a numerical list of domains being retrieved. It may include any domain number or combination of domain numbers.

Arg2 is a four element numeric vector. Element one is the number of the qualifying domain (the domain over which the search is to occur). Only those domains which contain numeric data can be searched, and are indicated in the section DATABASE STRUCTURE. Elements three and four, respectively, provide the lower and upper limits of the search. Element two restricts the search by state as follows:

4	Arizona
5	Colorado
6	Nevada
7	New Mexico
8	Utah
0	no restriction

Retrieval examples using GET:

```
1 2 13 GET 13 0 100 200
```

This command retrieves the Site ID (domain 1), Site Name (domain 2), and Subsurface Temperature (domain 13) for each site in all states (because element 2 of arg2 = 0) whose Subsurface Temperature (element 1 of arg2 = 13) is greater than or equal to 100 and less than or equal to 200 (elements 3 and 4 of arg2).

```
1 2 11 GET 11 7 2.26 1000
```

This command retrieves Site ID (domain 1), Site Name (domain 2), and Reservoir Volume (domain 11) for each site in New Mexico (element 2 of arg2 = 7) whose Reservoir Volume (element 1 of arg2 = 11) is greater than or equal to 2.26 and less than or equal to 1000 (elements 3 and 4 of arg2).

```
15 GET 3 6 601 601
```

This command retrieves the Surface Temperature (domain 15) of each site in Nevada whose County Code (element 1 of arg2) is equal to 601.

To store the results of a retrieval for future processing, the syntax of the GET command may be altered as follows:

```
X← arg1 GET arg2
```

where X is a variable name provided by the user.

CLOSE

Each "open" relation must be "closed" with the CLOSE command before another may be "opened". It is not necessary to specify the name of the relation to be "closed".

<u>ARIZONA</u>					<u>TOWN</u>		
<u>ID</u>	<u>SITE NAME</u>	<u>COUNTY</u>	<u>LAT</u>	<u>LONG</u>	<u>SHIP</u>	<u>RANGE</u>	<u>SEC</u>
4017	AGUA CALIENTE	407	33 0	113 18			
4018	ARTESIAN H W	405	32 43	109 43			
4026	ARTESIA AREA	405	32 41	109 42			
4022	BARNGAN MTN	414	33 7	113 25			
4024	BOWIE AREA	402	32 19	109 29			
4016	BUCKHORN AREA	407	33 25	111 42			
4032	CASA GRANDE	411	32 53	111 45	6S	6E	
4012	CASTLE H S	413	33 59	112 22			
4008	CAT TANK	405	32 44	109 23			
4002	CLIFTON HOT SPRINGS	406	33 4	109 18			
4007	COFFERS H S	408	34 42	113 35			
4006	COOLIDGE H S	404	33 10	110 32			
4013	COOLIDGE AREA	411	32 54	111 34			
4031	COOLIDGE	411	33 02	111 35	5S	8E	
4005	EAGLE CREEK H S	402	33 3	109 26			
4029	ELOY	411	32 45	111 35	10S	8E	
4030	FLORENCE	411	33 05	111 18	4S	10E	
4004	GILLARD HS	406	32 58	109 21			
4015	HOOKEES H S	402	32 20	110 14			
4011	INDIAN H S	405	33 0	109 54			
4009	JAVELINA PEAK	405	32 31	109 26			
4020	LUCATS SPA	405	32 45	109 45			
4033	MAMMOTH	411	32 42	110 35	9S	7E	
4025	MOBIL AREA	407	33 12	112 22			
4019	MT GRAHAM	405	32 52	109 45			
4021	PALOMAS MTS	414	33 0	113 31			
4034	PAPAGO FARMS	410	31 47	112 19	19S	1E	
4028	PHOENIX TEMPE	407	33 24	111 56	1N	4E	
4001	POWER RANCH AREAS	407	33 17	111 41			
4014	RADIUM SPRINGS	414	32 44	114 4			
4010	SAFFORD AREA	405	32 51	109 34			
4023	THEBA	407	32 56	112 45			
4027	TOM NIECE WARM SPR	405	33 4	109 59			
4003	VERDE HOT SPRINGS	413	34 22	111 43			
4035	WIKIEUP	408	34 39	113 39	15N	3W	

TABLE 5. GEOTHERMAL SITE LOCATIONS.

COLORADO

ID	SITE NAME	COUNTY	LAT	LONG	TOWN SHIP	RANGE	SEC
5047	ANTELOPE BIRDSIE	540	37 45	107 2	40N	2W	1
5005	BRANDS RANCH ARTESIA	529	40 42	106 32	9N	81W	31
5025	BROWN CANYON THERM A	508	38 39	106 4	51N	8E	23
5029	CANON CITY HOT SPRIN	522	38 26	105 16	18S	70W	31
5050	CEBOLLA HOT SPRINGS	526	38 16	107 6	46N	2W	4
5016	CEMENT CREEK WS	526	38 50	106 50	14S	84W	18
5021	CHALK CR MT PRINCETN	508	38 44	106 10	15S	78W	19
5022	CHALK CREEK WRIGHT H	508	38 44	106 10	15S	79W	24
5023	CHALK CREEK HORTENSE	508	38 44	106 10	15S	79W	24
5024	CHALK CREEK WOOLMING	508	38 43	106 11	15S	79W	24
5033	CLARK ARTESIAN WELL	551	38 15	104 37	21S	65W	1
5014	COLONEL CHIEN HOT WE	515	38 52	107 38	14S	92W	14
5015	CONUNDRUM HOT SPRING	549	39 1	106 53	12S	85W	16
5020	COTTONWOOD CREEK JUM	508	38 49	106 13	14S	79W	21
5002	CRAIG WARM WATER WEL	541	40 30	107 33	6N	91W	1
5039	DEXTER MCINTYRE	511	37 18	105 48	35N	11E	8
5032	DON K RANCH ARTESIAN	522	38 10	105 1	22S	68W	5
5010	DOTSERO WARM SPRINGS	519	39 38	107 6	5S	87W	12
5054	DUNTON GEYSR PARADIS	517	37 46	108 6	41N	11W	32
5041	DUTCH CROWLY STINKNG	504	37 2	106 48	32N	2E	18
5008	ELDORADO	507	39 56	105 16	1S	71W	25
5043	EOFF ARTESIAN WELL	504	37 11	107 0	34N	1W	7
5031	FLORENCE ARTESIAN WE	522	38 25	105 3	19S	68W	7
5030	FREMONT NATATORIUM	522	38 28	105 12	18S	40W	26
5061	FULL N WIDER WARM SP	555	38 18	105 59			
5011	GLENWOOD HOT SPRINGS	523	39 33	107 19	6S	89W	9
5019	HARTSELL HOT SPRINGS	547	39 1	105 48	12S	75W	8

TABLE 5. GEOTHERMAL SITE LOCATIONS.

COLORADO

ID	SITE NAME	COUNTY	LAT	LONG	TOWN SHIP	RANGE	SEC
5007	HAYSTACK BUTTE WW	507	40 6	105 14	2N	70W	33
5006	HOT SULPHUR SPRINGS	525	40 5	106 7	1N	78W	3
5009	IDAHO HOT SPRINGS	510	39 44	105 31	4S	73W	1
5001	JUNIPER	541	40 28	107 57	6N	94W	16
5053	LEMON HOT SPRING	557	38 01	108 3	44N	11W	34
5034	MINERAL HOT SPRINGS	555	38 10	105 55	45N	9E	12
5051	ORVIS HOT SPRING	546	38 8	107 44	45N	8W	22
5052	OURAY HOT SPRINGS	546	38 1	107 40	44N	7W	31
5044	PAGOSA SPRINGS	504	37 16	107 1	35N	2W	13
5013	PENNY AVALANCHE HS	549	39 14	107 13	10S	88W	4
5058	PINKERTON	534	37 27	107 48	37N	9W	25
5026	PONCHA HOT SPRINGS	508	38 30	106 5	49N	8E	15
5045	RAINBOW HOT SPRING	540	37 31	106 57	38N	1W	9
5017	RANGER WARM SPRING	526	38 49	106 52	14S	85W	22
5018	RHODES WARM SPRING	547	39 10	106 4	10S	78W	24
5057	RICO	517	37 42	108 2	40N	11W	
5003	ROUT ES	554	40 34	106 51	7N	84W	18
5037	SAND DUNES SWIMMING	502	37 47	105 51	41N	10E	27
5036	SEAWS WARM SPRING	555	37 45	106 19	41N	6E	33
5012	SOUTH CANYON HOT SPR	523	39 33	107 24	6S	90W	2
5038	SPLASHLAND HOT WATER	502	37 29	105 51	38N	10E	34
5004	STEAMBOAT SPRINGS	554	40 29	106 50	6N	84W	17
5059	TRIPP AND TRIMBLE WS	534	37 23	107 51	36N	9W	10
5035	VALLEY VIEW HOT SPRI	555	38 12	105 49	46N	10E	36
5046	WAGON WHEEL GAP HS	540	37 41	106 50	41N	1E	35
5027	WELLSVILLE SWISSVALE	508	38 29	105 55	49N	10E	18
5049	WUANITA HOT SPRINGS	526	38 31	106 31	49N	4E	11

TABLE 5. GEOTHERMAL SITE LOCATIONS.

<u>NEVADA</u>					<u>TOWN</u>		
<u>ID</u>	<u>SITE NAME</u>	<u>COUNTY</u>	<u>LAT</u>	<u>LONG</u>	<u>SHIP</u>	<u>RANGE</u>	<u>SEC</u>
6063	ALKALI HOT SPRING	0	37 50	117 20			
6064	ASH SPRINGS	0	37 28	115 11			
6016	BALTAZOR HS	0	41 55	118 43			
6040	BARTHOLOMAE	0	39 24	116 21			
6065	BENNETT SPRINGS	0	37 47	114 32			
6001	BEOWAVE H S	0	40 34	116 35			
6066	BIG LOCKES SPRING	0	38 33	115 46			
6067	BIG SPRING	0	36 23	116 17			
6068	BIG SPRINGS	0	40 58	114 31			
6022	BLACK ROCK DESERT	0	40 57	118 58			
6069	BLUE EAGLE SPRINGS	0	38 34	115 32			
6070	BOILING SPRING	0	40 16	119 23			
6071	BORAX SPRING	0	39 20	118 38			
6059	BOWERS H S	0	39 14	119 56			
6058	BO6 H S	0	41 56	118 48			
6002	BRADY HOT SP	0	39 47	119 0			
6072	BROOKS SPRING	0	40 50	117 18			
6073	BRUFFEYS HOT SPRINGS	0	40 13	116 4			
6031	BUFFALO VALLEY H S	0	40 22	117 20			
6036	BUTTE SPR	0	40 46	119 7			
6074	BUTTERFIELD SPRINGS	0	38 27	115 1			
6075	CAIN SPRINGS	0	41 15	118 56			
6076	CALIENTE HOT SPRING	0	37 37	114 31			
6077	CARSON HOT SPRINGS	0	39 12	119 45			
6078	CHARNOCK BIG BLUE	0	38 57	117 3			
6030	CHERRY CR H S	0	39 52	114 56			
6079	CHIMNEY SPRINGS	0	38 28	115 47			
6080	COLLAR AND ELBOW SPR	0	40 5	114 39			
6081	CRYSTAL POOL	0	36 25	116 19			
6082	CRYSTAL SPRINGS	0	37 32	115 14			
6025	DARROUGHS HS	0	38 49	117 11			
6083	DELMUES SPRING	0	37 52	114 19			
6084	DEVILS HOLE	0	36 26	116 17			
6056	DIANA PUNCH BOWL	0	39 2	116 40			
6023	DIXIE VALLEY HS	0	39 48	118 4			
6024	DOUBLE HS	0	41 3	119 3			
6026	DYKE H S	0	41 34	118 34			
6044	ELKO HS	0	40 49	115 47			
6085	EMIGRANT SPRINGS	0	38 37	115 3			
6086	FAIRBANKS SPRING	0	36 30	116 21			
6015	FERNLEY HS	0	39 35	119 8			

TABLE 5. GEOTHERMAL SITE LOCATIONS.

<u>NEVADA</u>					<u>TOWN</u>	
<u>ID</u>	<u>SITE NAME</u>	<u>COUNTY</u>	<u>LAT</u>	<u>LONG</u>	<u>SHIP</u>	<u>RANGE SEC</u>
6087	FISH SPRINGS	0	40 6	119 53		
6088	FLAG SPRINGS	0	38 25	115 1		
6033	FLY RANCH	0	40 52	119 21		
6089	FLYNN RANCH SPRINGS	0	40 5	116 2		
6090	GAMBLES HOLE	0	41 53	114 7		
6091	GEYSER RANCH SPRINGS	0	38 41	114 37		
6092	GEYSER RANCH SPRINGS	0	38 40	114 38		
6093	GEYSER RANCH SPRINGS	0	38 39	114 38		
6013	GREAT BOILING H S	0	40 40	119 22		
6035	E S NEAR TREBO	0	40 46	119 7		
6094	HAY CORRAL SPRING	0	38 33	115 46		
6095	HICKS HOT SPRINGS	0	36 58	116 43		
6096	HIKO SPRING	0	37 36	115 13		
6097	HORSESHOE RANCH SPRI	0	40 36	116 28		
6098	HOT CREEK SPRING	0	38 23	115 9		
6099	HOT CREEK SPRINGS	0	41 34	115 11		
6100	HOT HOLE ELKO HOT S	0	40 49	115 46		
6032	HOT POT BLOSSOM	0	40 55	117 7		
6008	HOT SULPHUR SP	0	41 28	116 9		
6009	HOT SP NEAR WELLS	0	41 11	114 59		
6010	HOT SP RANCH	0	40 46	117 30		
6027	HOT SULPHUR SP	0	41 9	114 59		
6038	HOT SPR POINT	0	40 24	116 31		
6101	HOT SPRING	0	37 46	117 38		
6102	HOT SPRING	0	38 31	116 22		
6103	HOT SPRINGS	0	39 56	116 41		
6104	HOT SPRINGS	0	39 33	116 22		
6105	HOT SPRINGS	0	40 46	116 2		
6106	HOT SPRINGS	0	40 40	116 50		
6107	HOT SPRINGS	0	40 19	116 3		
6108	HOT SPRING	0	40 19	116 26		
6109	HOT SPRINGS	0	40 12	117 7		
6110	HOT SPRING	0	41 59	114 23		
6111	HOT SPRINGS	0	41 53	115 38		
6112	HOT SPRINGS	0	41 39	115 46		
6113	HOT SPRINGS	0	41 16	115 18		
6029	HOWARD HS	0	41 43	118 30		
6114	HUFFAKER SPRINGS	0	39 25	119 46		
6042	HYDER H S	0	40 1	117 44		
6115	INDIAN SPRINGS	0	36 34	115 40		

TABLE 5. GEOTHERMAL SITE LOCATIONS.

<u>NEVADA</u>					<u>TOWN</u>		
<u>ID</u>	<u>SITE NAME</u>	<u>COUNTY</u>	<u>LAT</u>	<u>LONG</u>	<u>SHIP</u>	<u>RANGE</u>	<u>SEC</u>
6116	IZZENHOOD RANCH SPRI	0	40 55	116 54			
6117	JACK RABBIT SPRING	0	36 23	116 17			
6007	JERSEY VALLEY HS	0	40 11	117 29			
6118	JOHN SALVIS HOT SPRI	0	39 53	114 54			
6119	KATE SPRING	0	38 33	115 32			
6006	KYLE H S	0	40 24	117 53			
6120	LACKAWANNA SPRINGS	0	39 17	114 52			
6121	LAWTON HOT SPRINGS	0	39 31	119 54			
6014	LEACH HS	0	40 36	117 39			
6011	LEE H S	0	39 13	118 43			
6122	LONGSTREET SPRING	0	36 28	116 20			
6049	LOWER RANCH	0	40 3	117 35			
6123	MACFARLAND HOT SPRIN	0	41 3	118 43			
6124	MANSE SPRINGS	0	36 9	115 54			
6125	MCCOY SPRINGS	0	40 5	117 36			
6126	MCGILL SPRING	0	39 25	114 47			
6034	MINERAL SAN JACINTO	0	41 47	114 43			
6050	MONTE NEVA HS	0	39 38	114 48			
6127	MOON RIVER SPRING	0	38 21	115 11			
6128	MOORES RANCH SPRINGS	0	39 49	115 37			
6129	MOORMAN SPRING	0	38 36	115 8			
6130	MOUND SPRINGS	0	40 19	117 4			
6131	MUD SPRINGS	0	39 38	118 11			
6132	MUD SPRINGS	0	40 39	119 23			
6133	MUDDY SPRING	0	36 43	114 43			
6039	NEAR GOLCONDA	0	40 58	117 30			
6051	NEAR CARLIN	0	40 42	116 8			
6053	NEAR RUBY MARSH	0	40 14	115 25			
6021	NEEDLE ROCKS	0	40 9	119 40			
6055	NEVADA H S	0	38 54	119 25			
6061	NILE SPR	0	41 56	114 5			
6134	PANACA SPRING	0	37 48	114 23			
6135	PEARL HOT SPRINGS	0	37 49	117 29			
6012	PINTO H S	0	41 21	118 47			
6136	POINT OF ROCKS SPRIN	0	36 24	116 16			
6060	POTTS RANCH H S	0	39 5	116 41			
6137	PRESTON SPRINGS	0	38 55	115 5			
6138	RIZZI RANCH HOT SPRI	0	41 47	115 55			
6139	ROGERS SPRING	0	36 29	116 19			
6004	SAN EMIDIO	0	40 24	117 25			

TABLE 5. GEOTHERMAL SITE LOCATIONS.

<u>NEVADA</u>						<u>TOWN</u>		
<u>ID</u>	<u>SITE NAME</u>	<u>COUNTY</u>	<u>LAT</u>	<u>LONG</u>		<u>SHIP</u>	<u>RANGE</u>	<u>SEC</u>
6140	SHIPLEY HOT SPRING	0	39 57	116 4				
6141	SIRI RANCH SPRING	0	39 59	116 3				
6019	SMITH CREEK VALLEY	0	39 21	117 33				
6017	SODA LAKE	0	39 34	118 49				
6046	SODA SP	0	38 21	118 7				
6057	SOLDIER MEADOWS	0	41 22	119 13				
6043	SOU H S	0	40 5	117 44				
6037	SPENCER H S	0	39 19	116 51				
6142	SPRINGS	0	40 57	114 45				
6143	SPRING	0	40 11	116 48				
6144	SPRING	0	40 59	117 46				
6145	SPRING	0	40 52	117 56				
6146	SPRINGS HOT	0	41 25	114 41				
6147	SPRING HOT	0	41 23	114 10				
6148	SPRING	0	41 42	118 18				
6149	SPRING	0	41 32	118 34				
6062	SSE PATSVILLE	0	41 5	115 55				
6003	STEAMBOAT SP	0	39 23	119 45				
6018	STILLWATER	0	39 31	118 33				
6150	STORM SPRING	0	38 24	115 51				
6005	SULPHUR HS	0	40 35	115 17				
6151	SULPHUR SPRING	0	39 50	116 4				
6045	THE HOT SPR	0	41 25	117 23				
6152	TWIN SPRINGS	0	41 35	119 52				
6153	UPPER WARM SPRING	0	38 32	116 28				
6047	VALLEY OF THE MOON	0	40 14	117 6				
6020	WABUSKA HS	0	39 10	119 11				
6154	WALL SPRING	0	40 41	119 36				
6054	WALLEYS (GENOA) H S	0	38 59	119 50				
6052	WALTI HS	0	39 54	116 35				
6041	WARM SPR	0	38 11	116 23				
6155	WARM SPRINGS	0	36 43	114 43				
6156	WARM SPRINGS	0	40 45	115 2				
6157	WARM SPRINGS	0	41 45	118 50				
6158	WEDELL HOT SPRINGS	0	38 55	118 12				
6028	WELL NEAR GERLACH	0	40 39	119 21				
6159	WEST SPRING	0	41 44	118 55				
6048	WILD HORSE RES	0	41 40	115 48				
6160	WILLIAMS HOT SPRINGS	0	38 57	115 14				
6161	WILSON HOT SPRING	0	38 46	119 10				

TABLE 5. GEOTHERMAL SITE LOCATIONS.

NEW MEXICO

ID	SITE NAME	COUNTY	LAT	LONG	TOWN SHIP RANGE SEC
7044	ALEMAN	727	0 0	0 0	15S 2W
7018	BERINO - MESQUITE	707	32 9	106 40	
7049	CARNE	716	0 0	0 0	24S 7W
7029	CLIFF AREA	709	32 53	108 35	
7027	CLOSSON	732	35 15	108 19	
7040	CROCKER	727	0 0	0 0	11S 1E
7033	CROWNPOINT AREA	717	35 42	108 8	
7030	DERRY WARM SPRING	727	32 48	107 17	
7021	E SAN AUGUSTIN PLAIN	728	34 41	107 33	
7023	FAYWOOD HS	709	32 33	108 0	
7041	FREIBORN CANYON	702	0 0	0 0	7S 21W
7047	GALLINAS CREEK	725	0 0	0 0	17N 15E
7046	GARTON WELL	717	0 0	0 0	18S 8E
7010	GILA HS-BELOW BRIDGE	709	33 10	108 13	
7011	GILA HS-MIDDLE FORK	702	33 14	108 14	
7013	GILA HS-DOC CAMPBELL	702	33 12	108 13	
7025	GILA HS-UPR MDL FRK	702	33 17	108 17	
7035	GUADALUPE SP	723	35 36	107 8	
7048	HATCHET MOUNTAIN	712	0 0	0 0	32S 16W
7036	HOT WELL	723	35 45	106 40	
7038	HUECO-S TULAROSA BAS	719	32 3	106 10	
7004	KILBOURNE HOLE	707	31 58	106 57	
7017	LAS ALTURAS	707	32 16	106 42	
7042	LAS PALOMAS	707	0 0	0 0	14S 5W
7002	LIGHTNING DOCK	712	32 8	108 50	
7003	LWR SAN FRANCISCO HS	702	33 15	108 53	
7014	MAMBY'S HS	729	36 32	105 41	
7007	MC CAULEY SP (JEMEZ)	723	35 47	106 41	
7045	MCKINLEY WEST	717	35 50	108 30	18N 16W
7019	MIMBRES HS	709	32 45	107 50	
7012	MONTEZUMA HS	725	35 39	105 17	
7050	NEWMAN SO PAC RR	719	0 0	0 0	26S 8E
7034	NORTHEAST OF PREWITT	717	35 26	107 53	
7009	OJO CALIENTE	721	36 18	106 3	
7028	PLAYAS VALLEY	712	31 50	108 37	
7020	PONCE DE LEON	729	36 19	105 36	
7008	RADIUM SPRINGS	707	32 30	106 56	
7043	RINCON EAST	707	0 0	0 0	19S 2W
7005	SAN ANTONIO HS (JEME	723	35 47	106 41	
7039	SAN JUAN BASIN	724	0 0	0 0	24N 18W
7037	SAN YSIDRO	723	35 32	106 50	
7031	SEDILLO SPRING	728	34 2	106 56	
7006	SPENCE SP (JEMEZ)	723	35 47	106 41	
7024	T OR C	727	33 8	107 15	
7032	TOHATCHI AREA	717	35 55	108 35	
7015	TURKEY CREEK	709	33 7	108 29	
7022	UPR SAN FRANCISCO HS	702	33 50	108 48	
7001	VALLES CALDERA	723	35 53	106 32	
7026	W MESA-BLACK MNTN	707	32 8	106 52	
7016	WHITE SANDS	707	32 20	106 25	

TABLE 5. GEOTHERMAL SITE LOCATIONS. 3-13

<u>UTAH</u>						
ID	SITE NAME	COUNTY	LAT	LONG	TOWN SHIP RANGE SEC	
8007	ABRAHAM HS	812	39 37	112 43	14S 8W	10
8015	BECKS HS	818	40 47	111 56	1N 1W	14
8044	BIG WS	823	40 52	112 36	1S 7W	8
8033	BLUE WS	802	41 50	112 24	13N 5W	29
8025	CASTILLA HS	825	40 3	111 32	9S 4E	18
8037	COMO HS	815	41 5	111 40	4N 3E	31
8002	COVE FORT-SULPHURDAL	814	38 36	112 33	25S 6W	
8021	CRATER HS	825	40 28	111 53	5S 1W	25
8006	CRYSTAL HS	818	40 30	111 55	4S 1W	11
8016	CRYSTAL H.S.	802	41 40	112 5	11N 2W	24
8041	DIAMOND FORK WS	825	40 5	111 22	8S 5E	14
8030	FISH SPRINGS	812	39 52	113 25	11S 14W	23
8031	GANDY	814	39 27	113 58	15S 19W	31
8042	GOSHEN WS	825	39 57	111 51	10S 1E	8
8038	GRANTSVILLE	823	40 38	112 31	2S 6W	16
8026	HATTON HS	814	38 51	112 30	22S 6W	35
8013	HOOVER HS	829	41 9	112 12	5N 3W	27
8036	JOHNSONS WS	821	38 36	112 15	25S 3W	27
8004	JOSEPH HS	821	38 38	112 11	25S 4W	23
8022	LAVERKIN HS	827	37 13	113 16	41S 13W	25
8028	LINCOLN POINT WS	825	40 1	111 50	8S 1E	3
8012	MEADOW HS	814	38 50	112 31	22S 6W	26
8018	MIDWAY HS	826	40 31	111 28	3S 4E	26
8009	MONROE(COOPER) HS	821	38 31	112 12	25S 3W	10
8032	MORGANS WS	823	40 24	112 25	5S 5W	9
8010	OGDEN HS	829	41 14	111 58	6N 1W	23
8027	RADIUM(DOTSON) HS	801	38 13	112 55	30S 9W	
8005	RED HILL HS	821	38 38	112 6	25S 3W	11
8040	RICHFIELD WS	821	38 45	112 5	23S 3W	26
8001	ROOSEVELT HS	801	38 30	112 49	26S 9W	34
8039	RUSSELS WS	823	40 22	112 27	5S 5W	17
8019	SARATOGA HS	825	40 28	111 53	5S 1W	25
8029	SPLIT MOUNTAIN WS	824	40 27	109 15	4S 24E	16
8043	STERLING SPR	820	39 12	111 32	19S 2E	4
8011	STINKING SPR	803	41 35	112 14	10N 3W	10
8003	THERMO HS	801	38 11	113 12	30S 9W	21
8020	UDDY HS	802	41 51	112 9	13N 3W	23
8024	UNNAMED HS	802	41 50	114 7	11N 19W	11
8014	UTAH HS	829	41 24	112 2	7N 2W	14
8023	VEYO HS	827	37 19	113 42	40S 16W	7
8034	WARM SPR	802	41 48	113 35	12N 15W	19
8035	WARM SPR-UTAH LAKE	825	40 14	111 46	7S 1E	5
8008	WASATCH HS	818	40 45	111 55	1N 1W	25
8017	WILSON HS	812	39 55	113 26	10S 14W	33

TABLE 5. GEOTHERMAL SITE LOCATIONS.

		ARIZONA					
		-----TEMPERATURE IN DEGREES CELSIUS-----					
SITE ID	SITE NAME	SUBSUR- FACE	SOU- RCE	SURFACE RCE	SOU- RCE	CS EST	CS MEAS
4017	AGUA CALIENTE	0		0		0	46
4018	ARTESIAN H W	0		0		0	44
4026	ARTESIA AREA	0		0		0	33
4022	BARNGAN MTN	0		0		0	39
4024	BOWIE AREA	0		0		0	36
4016	BUCKHORN AREA	0		0		0	49
4032	CASA GRANDE	24	4	0		0	0
4012	CASTLE H S	0		0		105	0
4008	CAT TANK	0		0		115	0
4002	CLIFTON HOT SPRINGS	0		0		160	0
4007	COFFERS H S	0		0		120	0
4006	COOLIDGE H S	0		0		120	0
4013	COOLIDGE AREA	0		0		0	61
4031	COOLIDGE	42	4	0		0	0
4005	EAGLE CREEK H S	0		0		130	0
4029	ELOY	27	4	0		0	0
4030	FLORENCE	28	4	0		0	0
4004	GILLARD HS	0		0		140	0
4015	HOOKEERS H S	0		0		0	50
4011	INDIAN H S	0		0		105	0
4009	JAVELINA PEAK	0		0		110	0
4020	LUCATS SPA	0		0		0	42
4033	MAMMOTH	32	4	0		0	0
4025	MOBIL AREA	0		0		0	35
4019	MT GRAHAM	0		0		0	44
4021	PALOMAS MTS	0		0		0	42
4034	PAPAGO FARMS	31	4	0		0	0
4028	PHOENIX TEMPE	34	4	0		0	0
4001	POWER RANCH AREAS	0		0		184	0
4014	RADIUM SPRINGS	0		0		0	53
4010	SAFFORD AREA	0		0		110	0
4023	THEBA	0		0		0	38
4027	TOM NIECE WARM SPR	0		0		0	32
4003	VERDE HOT SPRINGS	0		0		150	0
4035	WIKIEUP	22	4	0		0	0

TABLE 6. GEOTHERMAL SITE TEMPERATURES.

<u>COLORADO</u>							
-----TEMPERATURE IN DEGREES CELSIUS-----							
SITE ID	SITE NAME	SUBSUR- FACE	SOU- RCE	SURFACE	SOU- RCE	CS EST	CS MEAS
5047	ANTELOPE BIRDSIE	44	5	32	5	0	32
5005	BRANDS RANCH ARTESIA	49	5	0	5	0	42
5025	BROWN CANYON THERML A	100	5	25	5	0	25
5029	CANON CITY HOT SPRIN	50	5	40	5	0	40
5050	CEBOLLA HOT SPRINGS	60	5	39	5	135	0
5016	CEMENT CREEK WS	45	5	0	5	0	26
5021	CHALK CR MT PRINCETN	200	5	50	5	120	0
5022	CHALK CREEK WRIGHT H	170	5	69	5	0	0
5023	CHALK CREEK HORTENSE	170	5	82	5	0	0
5024	CHALK CREEK WOOLMING	170	5	39	5	0	0
5033	CLARK ARTESIAN WELL	40	5	25	5	0	25
5014	COLONEL CHINN HOT WE	51	5	42	5	80	0
5015	CONUNDRUM HOT SPRING	45	5	35	5	0	38
5020	COTTONWOOD CREEK JUM	170	5	52	5	105	0
5002	CRAIG WARM WATER WEL	55	5	39	5	90	0
5039	DEXTER MCINTYRE	35	5	20	5	0	20
5032	DON K RANCH ARTESIAN	45	5	28	5	110	0
5010	DOTSERO WARM SPRINGS	39	5	32	5	0	32
5054	DUNTON GEYSR PARADIS	50	5	42	5	0	44
5041	DUTCH CROWLY STINKNG	65	5	27	5	0	70
5008	ELDORADO	35	5	25	5	0	26
5043	EOFF ARTESIAN WELL	50	5	39	5	0	39
5031	FLORENCE ARTESIAN WE	42	5	28	5	0	28
5030	FREMONT NATATORIUM	43	5	35	5	0	36
5061	FULL N WIDER WARM SP	0	0	0	0	0	18
5011	GLENWOOD HOT SPRINGS	65	5	33	5	130	0
5019	HARTSELL HOT SPRINGS	70	5	48	5	105	0

TABLE 6. GEOTHERMAL SITE TEMPERATURES.

		COLORADO					
		-----TEMPERATURE IN DEGREES CELSIUS-----					
SITE ID	SITE NAME	SUBSUR- FACE	SOU- RCE	SURFACE SOU- RCE	CS EST	CS MEAS	
5007	HAYSTACK BUTTE WWW	40	5	28	5	0	28
5006	HOT SULPHUR SPRINGS	75	5	42	5	95	0
5009	IDAHO HOT SPRINGS	80	5	33	5	120	0
5001	JUNIPER	63	5	35	5	0	38
5053	LEMON HOT SPRING	43	5	32	5	140	0
5034	MINERAL HOT SPRINGS	70	5	60	5	105	0
5051	ORVIS HOT SPRING	75	5	52	5	105	0
5052	OURAY HOT SPRINGS	80	5	59	5	0	69
5044	PAGOSA SPRINGS	80	5	46	5	140	0
5013	PENNY AVALANCHE HS	75	5	43	5	150	0
5058	PINKERTON	50	5	29	5	100	0
5026	PONCHA HOT SPRINGS	145	5	55	5	140	0
5045	RAINBOW HOT SPRING	45	5	40	5	0	40
5017	RANGER WARM SPRING	45	5	26	5	0	27
5018	RHODES WARM SPRING	35	5	0	5	0	25
5057	RICO	63	5	39	5	140	0
5003	ROUT HS	138	5	57	5	145	0
5037	SAND DUNES SWIMMING	75	5	44	5	160	0
5036	SHAWS WARM SPRING	45	5	30	5	130	0
5012	SOUTH CANYON HOT SPR	75	5	47	5	105	0
5038	SPLASHLAND HOT WATER	75	5	40	5	160	0
5004	STEAMBOAT SPRINGS	70	5	29	5	120	0
5059	TRIPP AND TRIMBLE WS	58	5	40	5	110	0
5035	VALLEY VIEW HOT SPRI	50	5	34	5	0	37
5046	WAGON WHEEL GAP HS	115	5	52	5	140	0
5027	WELLSVILLE SWISSVALE	40	5	30	5	0	33
5049	WUANITA HOT SPRINGS	135	5	78	5	160	0

TABLE 6. GEOTHERMAL SITE TEMPERATURES.

		<u>NEVADA</u>				
		-----TEMPERATURE IN DEGREES CELSIUS-----				
SITE ID	SITE NAME	SUBSUR- FACE	SOU- RCE	SURFACE RCE	CS EST	CS MEAS
6063	ALKALI HOT SPRING	0		59	10	0
6064	ASH SPRINGS	0		36	10	0
6016	BALTAZOR HS	0		0		170
6040	BARTHOLOMAE	0		0		125
6065	BENNETT SPRINGS	0		21	10	0
6001	BEOWAVE H S	0		0		240
6066	BIG LOCKES SPRING	0		37	10	0
6067	BIG SPRING	0		28	10	0
6068	BIG SPRINGS	0		22	10	0
6022	BLACK ROCK DESERT	0		0		150
6069	BLUE EAGLE SPRINGS	0		27	10	0
6070	BOILING SPRING	0		86	10	0
6071	BORAX SPRING	0		81	10	0
6059	BOWERS H S	0		0		0
6058	BO6 H S	0		0		46
6002	BRADY HOT SP	0		0		54
6072	BROOKS SPRING	0		34	10	0
6073	BRUFFEYS HOT SPRINGS	0		66	10	0
6031	BUFFALO VALLEY H S	0		0		0
6036	BUTTE SPR	0		0		130
6074	BUTTERFIELD SPRINGS	0		23	10	0
6075	CAIN SPRINGS	0		23	10	0
6076	CALIENTE HOT SPRING	0		53	10	0
6077	CARSON HOT SPRINGS	0		48	10	0
6078	CHARNOCK BIG BLUE	0		26	10	0
6030	CHERRY CR H S	0		0		0
6079	CHIMNEY SPRINGS	0		71	10	130
6080	COLLAR AND ELBOW SPR	0		33	10	0
6081	CRYSTAL POOL	0		32	10	0
6082	CRYSTAL SPRINGS	0		32	10	0
6025	DARROUGHES HS	0		0		0
6083	DELMUES SPRING	0		21	10	140
6084	DEVILS HOLE	0		33	10	0
6056	DIANA PUNCH BOWL	0		0		0
6023	DIXIE VALLEY HS	0		0		59
6024	DOUBLE HS	0		0		150
6026	DYKE H S	0		0		145
6044	ELKO HS	0		0		140
6085	EMIGRANT SPRINGS	0		21	10	115
6086	FAIRBANKS SPRING	0		27	10	0
6015	FERNLEY HS	0		0		0
						170

TABLE 6. GEOTHERMAL SITE TEMPERATURES.

		NEVADA					
		-----TEMPERATURE IN DEGREES CELSIUS-----					
SITE ID	SITE NAME	SUBSUR- FACE	SOU- RCE	SURFACE RCE	SOU- RCE	CS EST	CS MEAS
6087	FISH SPRINGS	0		22	10	0	0
6088	FLAG SPRINGS	0		23	10	0	0
6033	FLY RANCH	0		0		130	0
6089	FLYNN RANCH SPRINGS	0		25	10	0	0
6090	GAMBLES HOLE	0		43	10	0	0
6091	GEYSER RANCH SPRINGS	0		21	10	0	0
6092	GEYSER RANCH SPRINGS	0		21	10	0	0
6093	GEYSER RANCH SPRINGS	0		21	10	0	0
6013	GREAT BOILING H S	0		0		170	0
6035	H S NEAR TREBO	0		0		130	0
6094	HAY CORRAL SPRING	0		37	10	0	0
6095	HICKS HOT SPRINGS	0		43	10	0	0
6096	HIKO SPRING	0		32	10	0	0
6097	HORSESHOE RANCH SPRI	0		57	10	0	0
6098	HOT CREEK SPRING	0		33	10	0	0
6099	HOT CREEK SPRINGS	0		67	10	0	0
6100	HOT HOLE ELKO HOT S	0		33	10	0	0
6032	HOT POT BLOSSOM	0		0		130	0
6008	HOT SULPHUR SP	0		0		180	0
6009	HOT SP NEAR WELLS	0		0		180	0
6010	HOT SP RANCH	0		0		180	0
6027	HOT SULPEUR SP	0		0		140	0
6038	HOT SPR POINT	0		0		125	0
6101	HOT SPRING	0		71	10	0	0
6102	HOT SPRING	0		82	10	0	0
6103	HOT SPRINGS	0		82	10	0	0
6104	HOT SPRINGS	0		40	10	0	0
6105	HOT SPRINGS	0		36	10	0	0
6106	HOT SPRINGS	0		55	10	0	0
6107	HOT SPRINGS	0		26	10	0	0
6108	HOT SPRING	0		85	10	0	0
6109	HOT SPRINGS	0		53	10	0	0
6110	HOT SPRING	0		30	10	0	0
6111	HOT SPRINGS	0		39	10	0	0
6112	HOT SPRINGS	0		54	10	0	0
6113	HOT SPRINGS	0		49	10	0	0
6029	HOWARD HS	0		0		130	0
6114	HUFFAKER SPRINGS	0		34	10	0	0
6042	HYDER H S	0		0		120	0
6115	INDIAN SPRINGS	0		25	10	0	0

TABLE 6. GEOTHERMAL SITE TEMPERATURES.

		NEVADA					
		-----TEMPERATURE IN DEGREES CELSIUS-----					
SITE ID	SITE NAME	SUBSUR- FACE	SOU- RCE	SURFACE RCE	SOU- RCE	CS EST	CS MEAS
6116	IZZENHOOD RANCH SPRI	0		28	10	0	0
6117	JACK RABBIT SPRING	0		27	10	0	0
6007	JERSEY VALLEY HS	0		0		185	0
6118	JOHN SALVIS HOT SPRI	0		65	10	0	0
6119	KATE SPRING	0		22	10	0	0
6006	KYLE H S	0		0		190	0
6120	LACKAWANNA SPRINGS	0		34	10	0	0
6121	LAWTON HOT SPRINGS	0		33	10	0	0
6014	LEACH HS	0		0		170	0
6011	LEE H S	0		0		175	0
6122	LONGSTREET SPRING	0		27	10	0	0
6049	LOWER RANCH	0		0		100	0
6123	MACFARLAND HOT SPRIN	0		76	10	0	0
6124	MANSE SPRINGS	0		23	10	0	0
6125	MCCOY SPRINGS	0		48	10	0	0
6126	MCGILL SPRING	0		28	10	0	0
6034	MINERAL SAN JACINTO	0		0		130	0
6050	MONTE NEVA HS	0		0		0	79
6127	MOON RIVER SPRING	0		33	10	0	0
6128	MOORES RANCH SPRINGS	0		21	10	0	0
6129	MOORMAN SPRING	0		37	10	0	0
6130	MOUND SPRINGS	0		43	10	0	0
6131	MUD SPRINGS	0		21	10	0	0
6132	MUD SPRINGS	0		75	10	0	0
6133	MUDDY SPRING	0		32	10	0	0
6039	NEAR GOLCONDA	0		0		125	0
6051	NEAR CARLIN	0		0		0	79
6053	NEAR RUBY MARSH	0		0		0	65
6021	NEEDLE ROCKS	0		0		150	0
6055	NEVADA H S	0		0		0	61
6061	NILE SPR	0		0		0	43
6134	PANACA SPRING	0		31	10	0	0
6135	PEARL HOT SPRINGS	0		43	10	0	0
6012	PINTO H S	0		0		175	0
6136	POINT OF ROCKS SPRIN	0		33	10	0	0
6060	POTTS RANCH H S	0		0		0	45
6137	PRESTON SPRINGS	0		22	10	0	0
6138	RIZZI RANCH HOT SPRI	0		43	10	0	0
6139	ROGERS SPRING	0		28	10	0	0
6004	SAN EMIDIO	0		0		200	0

TABLE 6. GEOTHERMAL SITE TEMPERATURES.

		<u>NEVADA</u>					
		-----TEMPERATURE IN DEGREES CELSIUS-----					
SITE ID	SITE NAME	SUBSUR- FACE	SOU- RCE	SURFACE SOU- RCE	CS EST	CS MEAS	
6140	SHIPLEY HOT SPRING	0		41	10	0	0
6141	SIRI RANCH SPRING	0		30	10	0	0
6019	SMITH CREEK VALLEY	0		0		160	0
6017	SODA LAKE	0		0		165	0
6046	SODA SP	0		0		105	0
6057	SOLDIER MEADOWS	0		0	0		54
6043	SOU H S	0		0	115		0
6037	SPENCER H S	0		0	125		0
6142	SPRINGS	0		29	10	0	0
6143	SPRING	0		38	10	0	0
6144	SPRING	0		33	10	0	0
6145	SPRING	0		27	10	0	0
6146	SPRINGS HOT	0		58	10	0	0
6147	SPRING HOT	0		45	10	0	0
6148	SPRING	0		26	10	0	0
6149	SPRING	0		39	10	0	0
6062	SSE PATSVILLE	0		0		0	41
6003	STEAMBOAT SP	0		0		210	0
6018	STILLWATER	0		0		165	0
6150	STORM SPRING	0		29	10	0	0
6005	SULPHUR HS	0		0		190	0
6151	SULPEUR SPRING	0		23	10	0	0
6045	THE HOT SPR	0		0		110	0
6152	TWIN SPRINGS	0		21	10	0	0
6153	UPPER WARM SPRING	0		33	10	0	0
6047	VALLEY OF THE MOON	0		0		100	0
6020	WABUSKA HS	0		0		155	0
6154	WALL SPRING	0		28	10	0	0
6054	WALLEYS (GENOA) H S	0		0		0	61
6052	WALTI HS	0		0		0	72
6041	WARM SPR	0		0		120	0
6155	WARM SPRINGS	0		32	10	0	0
6156	WARM SPRINGS	0		18	10	0	0
6157	WARM SPRINGS	0		44	10	0	0
6158	WEDELL HOT SPRINGS	0		62	10	0	0
6028	WELL NEAR GERLACH	0		0		135	0
6159	WEST SPRING	0		42	10	0	0
6048	WILD HORSE RES	0		0		100	0
6160	WILLIAMS HOT SPRINGS	0		53	10	0	0
6161	WILSON HOT SPRING	0		84	10	0	0

TABLE 6. GEOTHERMAL SITE TEMPERATURES.

		NEW MEXICO				
		-----TEMPERATURE IN DEGREES CELSIUS-----				
SITE ID	SITE NAME	SUBSUR- FACE	SOU- RCE	SURFACE SOU- RCE	CS EST	CS MEAS
7044	ALEMAN	110	7	0	0	0
7018	BERINO - MESQUITE	0		0	120	0
7049	CARNE	30	7	0	0	0
7029	CLIFF AREA	0		0	0	31
7027	CLOSSON	0		0	0	61
7040	CROCKER	0		30	7	0
7033	CROWNPOINT AREA	0		0	0	37
7030	DERRY WARM SPRING	0		0	90	0
7021	E SAN AUGUSTIN PLAIN	0		0	0	35
7023	FAYWOOD HS	0		0	0	54
7041	FREIBORN CANYON	0		30	7	0
7047	GALLINAS CREEK	0		50	7	0
7046	GARTON WELL	0		30	7	0
7010	GILA HS-BELOW BRIDGE	0		0	0	44
7011	GILA HS-MIDDLE FORK	0		0	0	65
7013	GILA HS-DOC CAMPBELL	0		0	0	66
7025	GILA HS-UPR MDL FRK	0		0	0	36
7035	GUADALUPE SP	0		0	120	0
7048	HATCHET MOUNTAIN	160	7	0	0	0
7036	HOT WELL	0		0	100	0
7038	HUECO-S TULAROSA BAS	0		0	0	71
7004	KILBOURNE HOLE	0		0	155	0
7017	LAS ALTURAS	0		0	120	0
7042	LAS PALOMAS	0		30	7	0
7002	LIGHTNING DOCK	0		0	170	0
7003	LWR SAN FRANCISCO HS	0		0	150	0
7014	MAMBY'S HS	0		0	120	0
7007	MC CAULEY SP (JEMEZ)	0		0	0	32
7045	MCKINLEY WEST	0		60	7	0
7019	MIMERES HS	0		0	0	58
7012	MONTEZUMA HS	0		0	130	0
7050	NEWMAN SO PAC RR	0		60	7	0
7034	NORTHEAST OF PREWITT	0		0	0	46
7009	OJO CALIENTE	0		0	130	0
7028	PLAYAS VALLEY	0		0	0	28
7020	PONCE DE LEON	0		0	105	0
7008	RADIUM SPRINGS	0		0	130	0
7043	RINCON EAST	0		50	7	0
7005	SAN ANTONIO HS (JEME)	0		0	0	56
7039	SAN JUAN BASIN	0		0	0	0
7037	SAN YSIDRO	0		0	80	0
7031	SEDILLO SPRING	0		0	0	34
7006	SPENCE SP (JEMEZ)	0		0	0	42
7024	T OR C	0		0	100	0
7032	TOHATCHI AREA	0		0	0	39
7015	TURKEY CREEK	0		0	0	74
7022	UPR SAN FRANCISCO HS	0		0	0	37
7001	VALLES CALDERA	0		0	240	0
7026	W MESA-BLACK MNTN	0		0	95	0
7016	WHITE SANDS	0	3-22	0	120	0

TABLE 6. GEOTHERMAL SITE TEMPERATURES.

		UTAH				
		-----TEMPERATURE IN DEGREES CELSIUS-----				
SITE ID	SITE NAME	SUBSUR- FACE	SOU- RCE	SURFACE SOU- RCE	CS EST	CS MEAS
8007	ABRAHAM HS	0		0	125	0
8015	BECKS HS	0		0	90	0
8044	BIG WS	0		0	0	18
8033	BLUE WS	0		0	0	27
8025	CASTILLA HS	0		0	0	40
8037	COMO HS	0		0	0	25
8002	COVE FORT-SULPHURDAL	0		0	200	0
8021	CRATER HS	0		0	0	43
8006	CRYSTAL ES	0		0	135	0
8016	CRYSTAL H.S.	0		0	90	0
8041	DIAMOND FORK WS	0		0	0	20
8030	FISH SPRINGS	0		0	0	28
8031	GANDY	0		0	0	27
8042	GOSHEN WS	0		0	0	20
8038	GRANTSVILLE	0		0	0	24
8026	HATTON HS	0		0	0	38
8013	HOOVER HS	0		0	105	0
8036	JOHNSONS WS	0		0	0	25
8004	JOSEPH HS	0		0	140	0
8022	LAVERKIN HS	0		0	0	42
8028	LINCOLN POINT WS	0		0	0	32
8012	MEADOW HS	0		0	105	0
8018	MIDWAY HS	0		0	0	45
8009	MONROE(COOPER) HS	0		0	120	0
8032	MORGANS WS	0		0	0	27
8010	OGDEN HS	0		0	110	0
8027	RADIUM(DOTSON) HS	0		0	0	33
8005	RED HILL HS	0		0	135	0
8040	RICHFIELD WS	0		0	0	22
8001	ROOSEVELT HS	0		0	250	0
8039	RUSSELS WS	0		0	0	22
8019	SARATOGA HS	0		0	0	44
8029	SPLIT MOUNTAIN WS	0		0	0	30
8043	STERLING SPR	0		0	0	19
8011	STINKING SPR	0		0	110	0
8003	THERMO HS	0		0	185	0
8020	UDDY HS	0		0	0	43
8024	UNNAMED HS	0		0	0	42
8014	UTAH HS	0		0	95	0
8023	VEYO HS	0		0	0	42
8034	WARM SPR	0		0	0	27
8035	WARM SPR-UTAH LAKE	0		0	0	25
8008	WASATCH HS	0		0	120	0
8017	WILSON HS	0		0	0	61

TABLE 6. GEOTHERMAL SITE TEMPERATURES.

SITE ID	SITE NAME	ARIZONA			SOU- RCE	DISS SLDS PPT	SOU- RCE	FLOW RATE L/SEC	SOU- RCE
		RSVR VOLUME CU KM	SOU RCE	THERM GRAD C/KM					
4017	AGUA CALIENTE	2.25	1	0					
4018	ARTESIAN H W	2.25	1	0					
4026	ARTESIA AREA	2.25	1	0					
4022	BARNGAN MTN	2.25	1	0					
4024	BOWIE AREA	2.25	1	0					
4016	BUCKHORN AREA	2.25	1	234	4				
4032	CASA GRANDE	2.25	1	260	4				
4012	CASTLE H S	2.25	1	0					
4008	CAT TANK	2.25	1	0					
4002	CLIFTON HOT SPRINGS	2.25	1	0					
4007	COFFERS H S	2.25	1	0					
4006	COOLIDGE H S	2.25	1	0					
4013	COOLIDGE AREA	2.25	1	0					
4031	COOLIDGE	2.25	1	514	4				
4005	EAGLE CREEK H S	2.25	1	0					
4029	ELOY	2.25	1	108	4				
4030	FLORENCE	2.25	1	479	4				
4004	GILLARD HS	2.25	1	0					
4015	HOOKERS H S	2.25	1	0					
4011	INDIAN H S	2.25	1	0					
4009	JAVELINA PEAK	2.25	1	0					
4020	LUCATS SPA	2.25	1	0					
4033	MAMMOTH	2.25	1	536	4				
4025	MOBIL AREA	2.25	1	0					
4019	MT GRAHAM	2.25	1	0					
4021	PALOMAS MTS	2.25	1	0					
4034	PAPAGO FARMS	2.25	1	208	4				
4028	PHOENIX TEMPE	2.25	1	0					
4001	POWER RANCH AREAS	2.50	1	0					
4014	RADIUM SPRINGS	2.25	1	0					
4010	SAFFORD AREA	2.25	1	0					
4023	THEBA	2.25	1	0					
4027	TOM NIECE WARM SPR	2.25	1	0					
4003	VERDE HOT SPRINGS	2.25	1	0					
4035	WIKIEUP	2.25	1	0					

TABLE 7. RESERVOIR VOLUME, THERMAL GRADIENT, DISSOLVED SOLIDS
AND FLOW RATE

SITE ID	SITE NAME	<u>COLORADO</u>						FLOW RATE L/SEC	SOU- RCE
		RSVR	SOU	THRM	SOU-	DISS	SOU-		
		VOLUME CU KM	RCE	GRAD °C/KM	RCE	SLDS PPT	RCE		
5047	ANTELOPE BIRDSIE	.94	5						
5005	BRANDS RANCH ARTESIA	.06	5						
5025	BROWN CANYON THRL A	3.82	5						
5029	CANON CITY HOT SPRIN	.04	5						
5050	CEBOLLA HOT SPRINGS	.73	5						
5016	CEMENT CREEK WS	.13	5						
5021	CHALK CR MT PRINCETN	2.48	5						
5022	CHALK CREEK WRIGHT H	2.25	1						
5023	CHALK CREEK HORTENSE	2.25	1						
5024	CHALK CREEK WOOLMING	2.25	1						
5033	CLARK ARTESIAN WELL	.17	5						
5014	COLONEL CHINN HOT WE	.24	5						
5015	CONUNDRUM HOT SPRING	.18	5						
5020	COTTONWOOD CREEK JUM	1.09	5						
5002	CRAIG WARM WATER WEL	.51	5						
5039	DEXTER MCINTYRE	.95	5						
5032	DON K RANCH ARTESIAN	.59	5						
5010	DOTSERO WARM SPRINGS	.17	5						
5054	DUNTON GEYSR PARADIS	.37	5						
5041	DUTCH CROWLY STINKNG	.24	5						
5008	ELDORADO	.28	5						
5043	EOFF ARTESIAN WELL	2.25	1						
5031	FLORENCE ARTESIAN WE	.16	5						
5030	FREMONT NATATORIUM	.17	5						
5061	FULL N WIDER WARM SP	2.25	1						
5011	GLENWOOD HOT SPRINGS	.26	5						
5019	HARTSELL HOT SPRINGS	.34	5						

TABLE 7. RESERVOIR VOLUME, THERMAL GRADIENT, DISSOLVED SOLIDS
AND FLOW RATE

SITE ID	SITE NAME	COLORADO		SOU- GRAD RCE ° C/KM	SOU- RCE	DISS SLDS RCE PPT	FLOW RATE L/SEC	SOU- RCE
		RSVR VOLUME CU KM						
5007	HAYSTACK BUTTE WW	.36		5				
5006	HOT SULPHUR SPRINGS	.64		5				
5009	IDAHO HOT SPRINGS	.88		5				
5001	JUNIPER	.16		5				
5053	LEMON HOT SPRING	.27		5				
5034	MINERAL HOT SPRINGS	7.89		5				
5051	ORVIS HOT SPRING	.22		5				
5052	CURAY HOT SPRINGS	1.63		5				
5044	PAGOSA SPRINGS	.34		5				
5013	PENNY AVALANCHE HS	1.27		5				
5058	PINKERTON	.14		5				
5026	PONCHA HOT SPRINGS	1.73		5				
5045	RAINBOW HOT SPRING	.78		5				
5017	RANGER WARM SPRING	.13		5				
5018	RHODES WARM SPRING	1.21		5				
5057	RICO	1.37		5				
5003	ROUT HS	.39		5				
5037	SAND DUNES SWIMMING	.59		5				
5036	SHAWS WARM SPRING	.25		5				
5012	SOUTH CANYON HOT SPR	.08		5				
5038	SPLASHLAND HOT WATER	.59		5				
5004	STEAMBOAT SPRINGS	.10		5				
5059	TRIPP AND TRIMBLE WS	.39		5				
5035	VALLEY VIEW HOT SPRI	.83		5				
5046	WAGON WHEEL GAP HS	1.67		5				
5027	WELLSVILLE SWISSVALE	.18		5				
5049	WUANITA HOT SPRINGS	.22		5				

TABLE 7. RESERVOIR VOLUME, THERMAL GRADIENT, DISSOLVED SOLIDS
AND FLOW RATE

SITE ID	SITE NAME	NEVADA		THERM GRAD °C/KM	SOU- RCE	DISS SLDS PPT	SOU- RCE	FLOW RATE L/SEC	SOU- RCE
		RSVR VOLUME CU KM							
6063	ALKALI HOT SPRING	2.25	1						
6064	ASH SPRINGS	2.25	1						
6016	BALTAZOR HS	3.00	1						
6040	BARTHOLOMAE	2.25	1						
6065	BENNETT SPRINGS	2.25	1						
6001	BEOWAVE H S	42.00	1						
6056	BIG LOCKES SPRING	2.25	1						
6067	BIG SPRING	2.25	1						
6068	BIG SPRINGS	2.25	1						
6022	BLACK ROCK DESERT	2.25	1						
6069	BLUE EAGLE SPRINGS	2.25	1						
6070	BOILING SPRING	2.25	1						
6071	BORAX SPRING	2.25	1						
6059	BOWERS H S	2.25	1						
6058	BO6 H S	4.00	1						
6002	BRADY HOT SP	30.00	1						
6072	BROOKS SPRING	2.25	1						
6073	BRUFFEYS HOT SPRINGS	2.25	1						
6031	BUFFALO VALLEY H S	10.00	1						
6036	BUTTE SPR	2.25	1						
6074	BUTTERFIELD SPRINGS	2.25	1						
6075	CAIN SPRINGS	2.25	1						
6076	CALIENTE HOT SPRING	2.25	1						
6077	CARSON HOT SPRINGS	2.25	1						
6078	CHARNOCK BIG BLUE	2.25	1						
6030	CHERRY CR H S	2.25	1						
6079	CHIMNEY SPRINGS	2.25	1						
6080	COLLAR AND ELBOW SPR	2.25	1						
6081	CRYSTAL POOL	2.25	1						
6082	CRYSTAL SPRINGS	2.25	1						
6025	DARROUGHS HS	2.25	1						
6083	DELMUES SPRING	2.25	1						
6084	DEVILS HOLE	2.25	1						
6056	DIANA PUNCH BOWL	2.25	1						
6023	DIXIE VALLEY HS	3.00	1						
6024	DOUBLE HS	20.00	1						
6026	DYKE H S	2.25	1						
6044	ELKO HS	3.00	1						
6085	EMIGRANT SPRINGS	2.25	1						
6086	FAIRBANKS SPRING	2.25	1						
6015	FERNLEY HS	2.25	1						

TABLE 7. RESERVOIR VOLUME, THERMAL GRADIENT, DISSOLVED SOLIDS
AND FLOW RATE

SITE ID	SITE NAME	NEVADA		THERM GRAD °C/KM	SOU- RCE	DISS SLDS PPT	SOU- RCE	FLOW RATE L/SEC	SOU- RCE
		RSVR VOLUME CU KM							
6087	FISH SPRINGS	2.25	1						
6088	FLAG SPRINGS	2.25	1						
6033	FLY RANCH	16.00	1						
6089	FLYNN RANCH SPRINGS	2.25	1						
6090	GAMBLES HOLE	2.25	1						
6091	GEYSER RANCH SPRINGS	2.25	1						
6092	GEYSER RANCH SPRINGS	2.25	1						
6093	GEYSER RANCH SPRINGS	2.25	1						
6013	GREAT BOILING H S	25.00	1						
6035	H S NEAR TREBO	2.25	1						
6094	HAY CORRAL SPRING	2.25	1						
6095	HICKS HOT SPRINGS	2.25	1						
6096	HIKO SPRING	2.25	1						
6097	HORSESHOE RANCH SPRI	2.25	1						
6098	HOT CREEK SPRING	2.25	1						
6099	HOT CREEK SPRINGS	2.25	1						
6100	HOT HOLE ELKO HOT S	2.25	1						
6032	HOT POT BLOSSOM	2.25	1						
6008	HOT SULPHUR SP	2.25	1						
6009	HOT SP NEAR WELLS	2.25	1						
6010	HOT SP RANCH	2.25	1						
6027	HOT SULPHUR SP	2.25	1						
6038	HOT SPR POINT	7.50	1						
6101	HOT SPRING	2.25	1						
6102	HOT SPRING	2.25	1						
6103	HOT SPRINGS	2.25	1						
6104	HOT SPRINGS	2.25	1						
6105	HOT SPRINGS	2.25	1						
6106	HOT SPRINGS	2.25	1						
6107	HOT SPRINGS	2.25	1						
6108	HOT SPRING	2.25	1						
6109	HOT SPRINGS	2.25	1						
6110	HOT SPRING	2.25	1						
6111	HOT SPRINGS	2.25	1						
6112	HOT SPRINGS	2.25	1						
6113	HOT SPRINGS	2.25	1						
6029	HOWARD HS	2.25	1						
6114	HUFFAKER SPRINGS	2.25	1						
6042	HYDER H S	2.25	1						
6115	INDIAN SPRINGS	2.25	1						

TABLE 7. RESERVOIR VOLUME, THERMAL GRADIENT, DISSOLVED SOLIDS
AND FLOW RATE

SITE ID	SITE NAME	NEVADA		THERM GRAD °C/KM	SOU- RCE	DISS SLDS PPT	SOU- RCE	FLOW RATE L/SEC	SOU- RCE
		RSVR VOLUME CU KM							
6116	IZZENHOOD RANCH SPRI	2.25	1						
6117	JACK RABBIT SPRING	2.25	1						
6007	JERSEY VALLEY HS	2.25	1						
6118	JOHN SALVIS HOT SPRI	2.25	1						
6119	KATE SPRING	2.25	1						
6006	KYLE H S	2.25	1						
6120	LACKAWANNA SPRINGS	2.25	1						
6121	LAWTON HOT SPRINGS	2.25	1						
6014	LEACH HS	10.00	1						
6011	LEE H S	2.25	1						
6122	LONGSTREET SPRING	2.25	1						
6049	LOWER RANCH	2.25	1						
6123	MACFARLAND HOT SPRIN	2.25	1						
6124	MANSE SPRINGS	2.25	1						
6125	MCCOY SPRINGS	2.25	1						
6126	MCGILL SPRING	2.25	1						
6034	MINERAL SAN JACINTO	2.25	1						
6050	MONTE NEVA HS	2.25	1						
6127	MOON RIVER SPRING	2.25	1						
6128	MOORES RANCH SPRINGS	2.25	1						
6129	MOORMAN SPRING	2.25	1						
6130	MOUND SPRINGS	2.25	1						
6131	MUD SPRINGS	2.25	1						
6132	MUD SPRINGS	2.25	1						
6133	MUDDY SPRING	2.25	1						
6039	NEAR GOLCONDA	2.25	1						
6051	NEAR CARLIN	2.25	1						
6053	NEAR RUBY MARSH	2.25	1						
6021	NEEDLE ROCKS	3.00	1						
6055	NEVADA H S	2.25	1						
6061	NILE SPR	2.25	1						
6134	PANACA SPRING	2.25	1						
6135	PEARL HOT SPRINGS	2.25	1						
6012	PINTO H S	7.50	1						
6136	POINT OF ROCKS SPRIN	2.25	1						
6060	POTTS RANCH H S	2.25	1						
6137	PRESTON SPRINGS	2.25	1						
6138	RIZZI RANCH HOT SPRI	2.25	1						
6139	ROGERS SPRING	2.25	1						
6004	SAN EMIDIO	2.25	1						

TABLE 7. RESERVOIR VOLUME, THERMAL GRADIENT, DISSOLVED SOLIDS
AND FLOW RATE

SITE ID	SITE NAME	NEVADA		THRM GRAD °/KM	SOU- RCE	DISS SLDS PPT	SOU- RCE	FLOW RATE L/SEC	SOU- RCE
		RSVR VOLUME CU KM							
6140	SHIPLEY HOT SPRING	2.25	1						
6141	SIRI RANCH SPRING	2.25	1						
6019	SMITH CREEK VALLEY	2.25	1						
6017	SODA LAKE	12.50	1						
6046	SODA SP	2.25	1						
6057	SOLDIER MEADOWS	12.00	1						
6043	SOU H S	2.25	1						
6037	SPENCER H S	2.25	1						
6142	SPRINGS	2.25	1						
6143	SPRING	2.25	1						
6144	SPRING	2.25	1						
6145	SPRING	2.25	1						
6146	SPRINGS HOT	2.25	1						
6147	SPRING HOT	2.25	1						
6148	SPRING	2.25	1						
6149	SPRING	2.25	1						
6062	SSE PATSVILLE	2.25	1						
6003	STEAMBOAT SP	16.00	1						
6018	STILLWATER	25.00	1						
6150	STORM SPRING	2.25	1						
6005	SULPHUR HS	10.00	1						
6151	SULPHUR SPRING	2.25	1						
6045	THE HOT SPR	2.25	1						
6152	TWIN SPRINGS	2.25	1						
6153	UPPER WARM SPRING	2.25	1						
6047	VALLEY OF THE MOON	2.25	1						
6020	WABUSKA HS	2.25	1						
6154	WALL SPRING	2.25	1						
6054	WALLEYS (GENOA) H S	2.25	1						
6052	WALTI HS	3.00	1						
6041	WARM SPR	2.25	1						
6155	WARM SPRINGS	2.25	1						
6156	WARM SPRINGS	2.25	1						
6157	WARM SPRINGS	2.25	1						
6158	WEDELL HOT SPRINGS	2.25	1						
6028	WELL NEAR GERLACH	2.25	1						
6159	WEST SPRING	2.25	1						
6048	WILD HORSE RES	2.25	1						
6160	WILLIAMS HOT SPRINGS	2.25	1						
6161	WILSON HOT SPRING	2.25	1						

TABLE 7. RESERVOIR VOLUME, THERMAL GRADIENT, DISSOLVED SOLIDS
AND FLOW RATE

SITE ID	SITE NAME	<u>NEW MEXICO</u>		SOU- RCE	THERM GRAD C/KM	DISS SLDS PPT	SOU- RCE	FLOW RATE L/SEC	SOU- RCE
		RSVR	SOU						
		VOLUME CU KM	RCE						
7044	ALEMAN	2.25	1						
7018	BERINO - MESQUITE	2.25	1						
7049	CARNE	2.25	1						
7029	CLIFF AREA	2.25	1						
7027	CLOSSON	2.25	1						
7040	CROCKER	2.25	1						
7033	CROWNPOINT AREA	2.25	1						
7030	DERRY WARM SPRING	2.25	1						
7021	E SAN AUGUSTIN PLAIN	2.25	1						
7023	FAYWOOD HS	2.25	1						
7041	FREIBORN CANYON	2.25	1						
7047	GALLINAS CREEK	2.25	1						
7046	GARTON WELL	2.25	1						
7010	GILA HS-BELOW BRIDGE	2.25	1						
7011	GILA HS-MIDDLE FORK	2.25	1						
7013	GILA HS-DOC CAMPBELL	2.25	1						
7025	GILA HS-UPR MDL FRK	2.25	1						
7035	GUADALUPE SP	2.25	1						
7048	HATCHET MOUNTAIN	2.25	1						
7036	HOT WELL	2.25	1						
7038	HUECO-S TULAROSA BAS	2.25	1						
7004	KILBOURNE HOLE	2.25	1						
7017	LAS ALTURAS	2.25	1						
7042	LAS PALOMAS	2.25	1						
7002	LIGHTNING DOCK	2.25	1						
7003	LWR SAN FRANCISCO HS	2.25	1						
7014	MAMBY'S HS	2.25	1						
7007	MC CAULEY SP (JEMEZ)	2.25	1						
7045	MCKINLEY WEST	2.25	1						
7019	MIMBRES HS	2.25	1						
7012	MONTEZUMA ES	2.25	1						
7050	NEWMAN SO PAC RR	2.25	1						
7034	NORTHEAST OF PREWITT	2.25	1						
7009	OJO CALIENTE	2.25	1						
7028	PLAYAS VALLEY	2.25	1						
7020	PONCE DE LEON	2.25	1						
7008	RADIUM SPRINGS	2.25	1						
7043	RINCON EAST	2.25	1						
7005	SAN ANTONIO HS (JEME	2.25	1						
7039	SAN JUAN BASIN	2.25	1						
7037	SAN YSIDRO	2.25	1						
7031	SEDILLO SPRING	2.25	1						
7006	SPENCE SP (JEMEZ)	2.25	1						
7024	T OR C	2.25	1						
7032	TOHATCHI AREA	2.25	1						
7015	TURKEY CREEK	2.25	1						
7022	UPR SAN FRANCISCO HS	2.25	1						
7001	VALLES CALDERA	130.00	1						
7026	W MESA-BLACK MNTN	2.25	1						
7016	WHITE SANDS	2.25	1						

TABLE 7. RESERVOIR VOLUME, THERMAL GRADIENT, DISSOLVED SOLIDS
AND FLOW RATE

SITE ID	SITE NAME	UTAH		THERM GRAD °/KM	SOU- RCE	DISS SLDS PPT	SOU- RCE	FLOW RATE L/SEC	SOU- RCE
		RSVR VOLUME CU KM							
8007	ABRAHAM HS	2.25	1						
8015	BECKS HS	2.25	1						
8044	BIG WS	2.25	1						
8033	BLUE WS	2.25	1						
8025	CASTILLA HS	2.25	1						
8037	COMO HS	2.25	1						
8002	COVE FORT-SULPHURDAL	22.50	1						
8021	CRATER HS	2.25	1						
8006	CRYSTAL HS	2.25	1						
8016	CRYSTAL H.S.	2.25	1						
8041	DIAMOND FORK WS	2.25	1						
8030	FISH SPRINGS	2.25	1						
8031	GANDY	2.25	1						
8042	GOSHEN WS	2.25	1						
8038	GRANTSVILLE	2.25	1						
8026	HATTON HS	2.25	1						
8013	HOOVER HS	2.25	1						
8036	JOHNSONS WS	2.25	1						
8004	JOSEPH HS	2.25	1						
8022	LAVERKIN HS	2.25	1						
8028	LINCOLN POINT WS	2.25	1						
8012	MEADOW HS	2.25	1						
8018	MIDWAY HS	2.25	1						
8009	MONROE(COOPER) HS	2.25	1						
8032	MORGANS WS	2.25	1						
8010	OGDEN HS	2.25	1						
8027	RADIUM(DOTSON) HS	2.25	1						
8005	RED HILL HS	2.25	1						
8040	RICHFIELD WS	2.25	1						
8001	ROOSEVELT HS	8.00	1						
8039	RUSSELS WS	2.25	1						
8019	SARATOGA HS	2.25	1						
8029	SPLIT MOUNTAIN WS	2.25	1						
8043	STERLING SPR	2.25	1						
8011	STINKING SPR	2.25	1						
8003	THERMO HS	2.25	1						
8020	UDDY HS	2.25	1						
8024	UNNAMED HS	2.25	1						
8014	UTAH HS	2.25	1						
8023	VEYO HS	2.25	1						
8034	WARM SPR	2.25	1						
8035	WARM SPR-UTAH LAKE	2.25	1						
8008	WASATCH HS	2.25	1						
8017	WILSON HS	2.25	1						

TABLE 7. RESERVOIR VOLUME, THERMAL GRADIENT, DISSOLVED SOLIDS
AND FLOW RATE

<u>ARIZONA</u>						
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG	
04001	AJO	PIMA	5881	32 24	112	51
04002	APACHE JUNCTION	PINAL	2390	33 26	111	32
04003	AVONDALE	MARICOPA	6304	33 28	112	22
04004	BAGDAD	YAUAPAI	2079	38 16	113	12
04005	BENSON	COCHISE	2839	31 58	110	19
04006	BISBEE	COCHISE	8328	31 27	109	55
04007	BUCKEYE	MARICOPA	2599	33 25	112	34
04008	BYLAS	GRAHAM	1125	33 04	110	11
04009	CASA GRANDE	PINAL	10536	32 52	111	46
04010	CASHION	MARICOPA	2705	33 22	112	28
04011	CENTRAL HEIGHTS	GILA	2289	00 00	000	00
04012	CHANDLER	MARICOPA	13763	33 19	111	49
04013	CLARKDALE	YAUAPAI	892	34 49	112	03
04014	CLAYPOOL	GILA	2245	33 25	110	52
04015	CLIFTON	GREENLEE	5087	33 04	109	17
04016	COOLIDGE	PINAL	4651	32 58	111	30
04017	COTTONWOOD	YAUAPAI	2815	34 45	112	00
04018	DOUGLAS	COCHISE	12462	31 21	109	34
04019	DUHCAN	GREENLEE	773	32 43	109	06
04020	EAGER	APACHE	1279	34 79	109	19
04021	EL MIRAGE	MARICOPA	3258	33 39	112	21
04022	ELOY	PINAL	5381	32 45	111	33
04023	FLAGSTAFF	COCONINO	26117	35 12	111	38
04024	FLORENCE	PINAL	2173	33 02	111	22
04025	FREDONIA	COCONINO	798	36 57	112	31
04025	FT HUACHUCA	COCHISE	6659	31 34	110	24
04027	GILA BEND	MARICOPA	1795	32 56	112	42
04028	GILBERT	MARICOPA	1971	33 22	111	46
04029	GLENDALE	MARICOPA	36228	33 34	112	10
04030	GLOBE	GILA	7333	33 23	110	48
04031	GOODYEAR	MARICOPA	2140	33 29	112	23
04032	GRAND CANYON	COCONINO	1011	36 04	112	07
04033	HAYDEN	GILA	1283	33 01	110	48
04034	HOLBROOK	NAVAJO	4759	34 54	110	11
04035	HUACHUCA	COCHISE	1233	31 34	110	21
04036	KEARNEY	PINAL	2829	33 00	110	55
04037	KINGMAN	MOHAVE	7312	35 12	114	02
04038	LITCHFIELD PARK	MARICOPA	1664	33 32	112	20
04039	LUKE AFB	MARICOPA	5047	33 34	112	27
04040	MAMMOTH	PINAL	1953	32 43	110	40
04041	MESA	MARICOPA	62853	33 25	115	50
04042	MIAMI	GILA	3394	33 24	110	54
04043	NOGALES	SANTA CRUZ	8946	31 20	110	56

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

		<u>ARIZONA</u>				
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG	
04044	PAGE	COCONINO	1439	36 57	111	28
04045	PARADISE VALLEY	MARICOPA	7155	33 40	111	55
04046	PARKER	YUMA	1948	34 09	114	18
04047	PATAGONIA	SANTA CRUZ	630	31 33	110	46
04048	PAYSON	GILA	1490	34 16	111	20
04049	PEORIA	MARICOPA	4792	33 38	112	13
04050	PHOENIX	MARICOPA	581562	33 30	112	03
04051	PIMA	GRAHAM	1184	32 53	109	50
04052	PLANTSITE	GREENLEE	1077	33 02	109	18
04053	PRESCOTT	YAVAPAI	13030	34 34	112	28
04054	SAFFORD	GRAHAM	5333	32 50	109	43
04056	SAN CARLOS	GILA	2542	33 22	110	29
04057	SAN MANUEL	PINAL	4332	32 28	110	40
04058	SCOTTSDALE	MARICOPA	67823	33 31	111	53
04059	SEDONA	COCONINO	2022	34 53	111	45
04060	SHOWHOW	NAVAJO	2285	34 16	110	03
04061	SIERRA VISTA	COCHISE	6689	31 36	110	18
04062	SNOWFLAKE	NAVAJO	1833	34 32	110	05
04063	SOMERTON	YUMA	2225	32 35	114	44
04064	SOUTH TUCSON	PIMA	6220	32 14	110	57
04065	SPRINGERVILLE	APACHE	1038	34 09	109	18
04055	ST JOHNS	APACHE	1320	34 30	109	24
04066	STARGO	GREENLEE	1194	33 06	109	23
04067	SUN CITY	MARICOPA	13670	33 37	112	13
04068	SUPERIOR	PINAL	4975	33 18	116	06
04069	SURPRISE	MARICOPA	2427	33 41	112	23
04070	TAYLOR	NAVAJO	888	34 29	110	05
04071	TEMPE	MARICOPA	62907	33 25	111	55
04072	THATCHER	GRAHAM	2320	32 50	109	46
04073	TOLLESON	MARICOPA	3881	33 29	112	15
04074	TOMBSTONE	COCHISE	1241	31 44	110	04
04075	TUCSON	PIMA	262933	32 15	110	57
04076	WEST YUMA	YUMA	5552	32 40	114	39
04077	WICKENBURG	MARICOPA	2698	33 59	112	44
04078	WILCOX	COCHISE	2568	32 16	109	50
04079	WILLIAMS	COCONINO	2386	35 16	112	10
04080	WILLIAMS AFB	MARICOPA	3443	33 19	111	45
04081	WINKELMAN	GILA	974	33 00	110	48
04082	WINSLOW	NAVAJO	8066	35 01	110	43
04083	YOUNGTOWN	MARICOPA	1886	33 39	112	14
04084	YUMA	YUMA	29007	32 40	114	39
04085	YUMA PROVING GROUND	YUMA	1349	32 43	114	24
04086	YUMA STATION	YUMA	3460	00 00	000	00

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

CITY ID	CITY NAME	COLORADO			
		COUNTY NAME	POPULATION	LAT	LONG
05001	AGUILAR	LAS ANIMAS	699	37 25	104 40
05002	AKRON	WASHINGTON	1775	40 09	103 13
05003	ALAMOSA	ALMOSA	6985	37 28	105 54
05004	ALAMOSA EAST	ALAMOSA	1040	37 28	105 54
05005	ANTONITO	CONEJOS	1113	37 04	106 01
05006	APPLEWOOD	JEFFERSON	8214	00 00	000 00
05007	ARVADA	JEFFERSON	46814	39 47	105 07
05008	ASPEN	PITKIN	2404	39 12	106 49
05009	AULT	WELD	841	40 35	104 44
05010	AURORA	ARAPAHOE	74974	39 45	104 50
05011	AUSTIN	DELTA	1163	38 47	107 57
05012	BENNETT	ADAMS	613	39 45	104 25
05013	BERTHAUD	LARIMER	1446	40 19	105 05
05014	BOULDER	BOULDER	66870	40 02	105 16
05015	BOW MAR	ARAPAHOE	945	39 38	105 03
05016	BRECKENRIDGE	SUMMIT	548	39 29	106 03
05017	BRIGHTON	ADAMS	8309	39 59	104 50
05018	BROOMFIELD	BOULDER	7261	39 50	105 07
05019	BRUSH	MORGAN	3377	40 15	103 36
05020	BUENA VISTA	CHAFFEE	1962	38 44	106 10
05021	BURLINGTON	KIT CARSON	2828	39 17	102 17
05022	CANON CITY	FREMONT	9206	38 27	105 14
05023	CARBONDALE	GARFIELD	726	39 23	107 13
05024	CASTLE ROCK	DOUGLAS	1531	39 23	104 53
05025	CEDAREDGE	DELTA	581	38 44	107 55
05026	CENTER	RIO GRANDE	1470	37 45	106 07
05027	CHERRY HILLS VLG	ARAPAHOE	4605	39 38	104 51
05028	CHEYENNE WELLS	CHEYENNE	982	38 48	102 30
05029	COLORADO SPRINGS	EL PASO	135000	38 50	104 50
05030	COMMERCE CITY	ADAMS	17407	39 50	104 55
05031	CORTEZ	MONTEZUMA	6032	37 22	108 36
05032	CRAIG	MOFFAT	4205	40 30	107 33
05033	CREEDE	MINERAL	653	37 52	106 56
05034	DEL NORTE	RIO GRANDE	1569	37 40	106 22
05035	DELTA	DELTA	3694	38 42	108 04
05036	DENVER	DENVER	514000	39 45	105 00
05037	DERBY	ADAMS	10206	00 00	000 00
05038	DOLORES	MONTEZUMA	820	37 28	108 30
05039	DOVE CREEK	DOLORES	619	37 46	108 55
05040	DURANGO	LA PLATA	10333	37 16	107 53

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

<u>COLORADO</u>					
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG
05041	EADS	KIOWA	795	38 28	102 48
05042	EAGEL	EAGLE	790	39 39	106 50
05043	EAST CANON	FREMONT	1805	38 27	105 14
05044	EATON	WELD	1389	40 32	104 43
05045	EDGEWATER	JEFFERSON	4866	39 45	105 04
05046	ENGLEWOOD	ARAPAHOE	33695	39 39	105 00
05047	ERIE	BOULDER	1090	40 03	105 04
05048	ESTES PARK	LARIMER	1616	40 24	105 32
05049	EVANS	WELD	2570	39 35	105 39
05050	EVERGREEN	JEFFERSON	2321	39 38	105 20
05051	FEDERAL HEIGHTS	ADAMS	1502	39 52	105 01
05052	FIRESTONE	WELD	570	40 05	104 55
05053	FLAGLER	KIT CARSON	615	39 17	103 05
05054	FLORENCE	FREMONT	2846	38 23	105 07
05060	FOUNTAIN	EL PASO	3515	38 40	104 44
05061	FOWLER	OTERO	1241	38 07	104 03
05062	FREDERICK	WELD	696	40 05	104 55
05063	FRUITA	MESA	1822	39 08	108 44
05055	FT CARSON	EL PASO	19399	38 45	104 50
05056	FT COLLINS	LARIMER	43337	40 35	105 05
05057	FT COLLINS WEST	LARIMER	1693	40 35	105 05
05058	FT LUPTON	WELD	2489	40 04	104 49
05059	FT MORGAN	MORGAN	7594	40 14	103 48
05064	GEORGETOWN	CLEAR CREEK	542	39 42	105 45
05065	GLENDALE	ARAPAHOE	765	39 43	104 56
05066	GLENWOOD SPRINGS	GARFIELD	4106	39 33	107 21
05067	GOLDEN	JEFFERSON	9817	39 45	105 15
05068	GRANADA	PROWERS	551	38 03	102 20
05069	GRANBY	GRAND	554	40 05	105 56
05070	GRAND JUNCTION	MESA	20170	39 04	108 33
05071	GREELEY	WELD	38902	40 26	104 43
05072	GREENWOOD VILLAGE	ARAPAHOE	2578	00 00	000 00
05073	GUNNISON	GUNNISON	4613	38 33	106 55
05074	HAYTUN	PHILLIPS	899	40 38	102 37
05075	HAYDEN	ROUTT	763	40 31	107 17
05076	HOLLY	PROWERS	993	38 04	102 09
05077	HOLYOKE	PHILLIPS	1640	40 34	102 20
05078	HOTCHKISS	DELTA	507	38 47	107 42
05079	HUDSON	WELD	518	40 04	104 37
05080	HUGO	LINCOLN	759	39 07	103 27

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

		<u>COLORADO</u>				
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG	
05081	IDAHO SPRINGS	CLEAR CREEK	2003	39 44	105 31	
05082	IGNACIO	LA PLATA	613	37 06	107 38	
05083	JOHNSTOWN	WELD	1191	40 20	104 50	
05084	JULESBURG	SEDGWICK	1578	40 59	102 16	
05085	KREMMLING	GRAND	764	40 03	106 24	
05087	LA JARA	CONEJOS	768	37 17	105 58	
05088	LA JUNTA	OTERO	7938	37 59	103 34	
05091	LA SALLE	WELD	1227	40 21	104 43	
05093	LA VETA	HUERFANO	589	37 30	105 01	
05086	LAFAYETTE	BOULDER	3498	39 59	105 06	
05089	LAKEWOOD	JEFFERSON	92787	39 44	105 11	
05090	LAMAR	PROWERS	7797	38 04	102 37	
05092	LAS ANIMAS	BENT	3148	38 03	103 14	
05094	LEADVILLE	LAKE	4314	39 14	106 18	
05095	LEADVILLE NORTH	LAKE	1717	39 14	106 18	
05096	LIMON	LINCOLN	1814	39 16	103 40	
05097	LINCOLN PARK	FREMONT	2984	38 24	105 12	
05098	LITTLETON SE	ARAPAHOE	22899	39 36	105 02	
05099	LITTLETON	ARAPAHOE	26466	39 36	105 02	
05100	LONGMONT	BOULDER	23209	40 11	105 06	
05101	LOUISVILLE	BOULDER	2409	39 58	105 09	
05102	LOVELAND	LARIMER	16220	40 24	105 06	
05103	LYONS	BOULDER	958	40 14	105 17	
05104	MANASSA	CONEJOS	814	37 11	105 56	
05105	MANCOS	MONTEZUMA	709	37 21	108 19	
05106	MANITOU SPRINGS	EL PASO	4278	38 51	104 55	
05107	MEEKER	RIO BLANCO	1597	40 03	107 56	
05108	MILLIKEN	WELD	702	40 21	104 53	
05109	MINTURN	EAGLE	706	39 35	106 24	
05110	MONTE VISTA	RIO GRANDE	3909	37 34	106 11	
05111	MONTROSE	MONTROSE	6496	38 29	107 53	
05112	MOUNTAIN VIEW	JEFFERSON	706	00 00	000 00	
05113	NATURITA	MONTROSE	820	38 12	108 36	
05114	NORTH GLENN	ADAMS	27937	39 53	104 59	
05115	NORTH LA JUNTA	OTERO	1249	38 01	103 38	
05116	NUCLA	MONTROSE	949	38 17	108 33	
05117	OLATHE	MONTROSE	756	38 33	107 57	
05118	ORCHARD CITY	MESA	5824	38 50	107 58	
05119	ORDWAY	CROWLEY	1017	38 13	103 47	

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

CITY ID	CITY NAME	COLORADO			
		COUNTY NAME	POPULATION	LAT	LONG
05120	OTIS	WASHINGTON	521	40 09	102 58
05121	OURAY	OURAY	741	38 02	107 40
05122	PAGOSA SPRINGS	ARCHULETA	1360	37 16	107 01
05123	PALISADE	MESA	874	39 05	108 23
05124	PALMER LAKE	EL PASO	947	39 07	104 56
05125	PAONIA	DELTA	1161	38 52	107 35
05126	PLATTEVILLE	WELD	683	40 13	104 50
05127	PUEBLO	PUEBLO	97453	38 17	104 38
05128	RANGELY	RIO BLANCO	1591	40 04	108 48
05129	RED CLIFF	EAGLE	621	39 31	106 22
05130	RIFLE	GARFIELD	2150	39 32	107 47
05131	ROCKY FORD	OTERO	4859	38 03	103 44
05132	SAGUACHE	SAGUACHE	642	38 05	106 10
05133	SALIDA	CHAFFEE	4355	38 33	106 01
05135	SAN LUIS	COSTILLA	781	37 03	105 25
05134	SANFORD	CONEJOS	638	37 16	105 55
05136	SECURITY-WIDEFIELD	EL PASO	15297	38 42	104 44
05137	SHERIDAN	ARAPAHOE	4787	39 39	105 02
05138	SHERRELWOOD	ADAMS	18868	00 00	000 00
05139	SILVERTON	SAN JUAN	797	37 48	107 40
05140	SPRINGFIELD	BACA	1660	37 26	102 36
05141	STEAMBOAT SPRINGS	ROUTT	2340	40 28	106 51
05142	STERLING	LOGAN	10636	40 37	103 13
05143	STRATTON MEADOWS	EL PASO	6223	00 00	000 00
05144	STRATTON	KIT CARSON	790	39 18	102 36
05145	TELLURIDE	SAN MIGUEL	553	37 57	107 48
05146	THORNTON	ADAMS	13326	39 57	105 00
05147	TRINIDAD	LAS ANIMAS	9901	37 11	104 31
05158	URAY	YUMA	1953	40 05	102 14
05148	WALDEN	JACKSON	907	40 43	106 19
05149	WALSENBURG	HUERFANO	4329	37 36	104 48
05150	WALSH	BACA	989	37 24	102 17
05151	WELBY	ADAMS	6875	39 50	104 58
05152	WELLINGTON	LARIMER	691	40 42	105 01
05153	WESTMINSTER	ADAMS	19432	39 49	105 05
05154	WESTMINSTER EAST	ADAMS	7576	39 49	105 05
05155	WHEAT RIDGE	JEFFERSON	29795	39 47	105 13
05156	WINDSOR	WELD	1564	40 28	104 53
05157	WOODLAND PARK	TELLER	1022	39 00	105 04

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

		<u>NEVADA</u>			
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG
06001	BABBETT	MINERAL	1579	38 32	118 38
06002	BATTLE MOUNTAIN	LANDER	1856	40 41	117 07
06003	BOULDER CITY	CLARK	5223	39 59	114 51
06004	CALIENTE	LINCOLN	916	37 36	114 31
06005	CARLIN	ELKO	1313	40 44	116 06
06006	CARSON CITY	ORMSBY	15468	39 10	119 46
06007	EAST ELY	WHITE PINE	1992	39 17	114 52
06008	EAST LAS VEGAS	CLARK	6501	36 04	115 03
06009	ELKO CITY	ELKO	7621	40 50	115 46
06010	ELY	WHITE PINE	4175	39 15	114 53
06011	FALLON	CHURCHILL	2959	39 29	118 47
06012	FALLON STATION	CHURCHILL	1045	39 25	118 44
06013	GABBS	NYE	874	38 44	118 07
06014	GARDNERVILLE-MINDEN	DOUGLAS	1320	38 57	119 45
06015	HAWTHORNE	MINERAL	3539	38 31	118 37
06016	HENDERSON	CLARK	16395	36 01	115 00
06017	LAS VEGAS	CLARK	125787	36 10	115 10
06018	LOVELOCK	PERSHING	1571	40 12	118 28
06019	MC GILL	WHITE PINE	2164	39 24	114 47
06020	NELLIS AFB	CLARK	6449	36 15	115 03
06021	NORTH LAS VEGAS	CLARK	36216	36 15	115 07
06022	PARADISE	CLARK	24477	00 00	000 00
06023	RENOE	WASHOE	72863	39 32	119 49
06024	SPARKS	WASHOE	24187	39 34	119 46
06026	SUN VALLEY	WASHOE	2414	00 00	000 00
06025	SUNRISE MANOR	CLARK	10886	00 00	000 00
06027	TONOPAH	NYE	1716	38 05	117 15
06028	VEGAS CREEK	CLARK	8970	00 00	000 00
06029	WELLS	ELKO	1081	41 08	114 58
06030	WINCHESTER	CLARK	13981	00 00	000 00
06031	WINNEMUCCA	HUMBOLDT	3587	40 58	117 45
06032	YERRINGTON	LYON	2010	39 00	119 10

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

CITY ID	CITY NAME	NEW MEXICO			
		COUNTY NAME	POPULATION	LAT	LONG
07001	ALAMOGORDO	OTERO	23035	32 54	105 57
07002	ALBUQUERQUE	BERNALILLO	243751	35 05	106 38
07003	ANTHONY	DONA ANA	1728	32 00	106 36
07004	ARTESIA	EDDY	10315	32 51	104 24
07005	AZTEC	SAN JUAN	3354	36 49	108 59
07006	BAYARD	GRANT	2908	32 47	108 07
07007	BELEN	VALENCIA	4823	34 39	106 48
07008	BERNALILLO	SANDOVAL	2016	35 18	106 34
07009	BLOOMFIELD	SAN JUAN	1574	36 43	107 59
07010	CANNON	CURRY	5461	34 14	103 15
07011	CARLSBAD	EDDY	21297	32 25	104 14
07012	CARRIZOZO	LINCOLN	1123	33 39	105 54
07013	CENTRAL	GRANT	1864	32 47	108 09
07014	CHAMA	RIO ARriba	899	36 54	106 36
07015	CIMARRON	COLFAX	927	36 30	104 55
07016	CLAYTON	UNION	2931	36 27	103 12
07017	CLOUDCROFT	OTERO	525	32 58	105 46
07018	CLOVIS	CURRY	28495	34 14	103 13
07019	DEMING	LUNA	8343	32 17	107 46
07020	DEXTER	CHAVES	746	33 11	104 22
07021	ESPAÑOLA	RIO ARriba	4528	35 59	106 05
07022	ESTANCIA	TORRENCE	721	34 45	106 04
07023	EUNICE	LEA	2641	32 26	103 09
07024	FARMINGTON	SAN JUAN	21979	36 43	108 12
07025	FT SUMNER	DE BACA	1615	34 27	104 16
07026	GALLUP	MC KINLEY	14596	35 35	108 46
07027	GRANTS	VALENCIA	8768	35 10	107 51
07028	HAGERMAN	CHAVES	953	33 06	104 20
07029	HATCH	DONA ANA	867	32 39	107 10
07030	HOBBS	LEA	26025	32 42	103 08
07031	HOLLOMAN	OTERO	8001	32 51	105 57
07032	HURLEY	GRANT	1796	32 41	108 07
07033	ISLETA PUEBLO	BERNALILLO	1080	34 55	106 43
07034	JAL	LEA	2602	32 05	103 12
07035	JEMEZ PUEBLO	SANDOVAL	1197	35 37	106 44
07036	LA MESILLA	DONA ANA	1713	32 17	106 48
07037	LAS CRUCES	DONA ANA	37857	32 18	106 47
07038	LAS VEGAS	SAN MIGUEL	7528	35 36	105 15
07039	LAS VEGAS WEST	SAN MIGUEL	6307	35 36	105 15
07040	LORDSBURG	HIDALGO	3429	32 22	108 43
07041	LOS ALAMOS	LOS ALAMOS	11310	35 52	106 19

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

CITY ID	CITY NAME	NEW MEXICO COUNTY NAME	POPULATION	LAT	LONG
07042	LOS LUNAS	VALENCIA	973	34 48	106 46
07043	LOS RANCHOS DE ALBQ	BERNALILLO	1900	35 08	106 38
07044	LOVING	EDDY	1192	32 17	104 06
07045	LOVINGTON	LEA	8915	32 58	103 21
07046	MAGDALENA	SOCORRO	652	34 06	107 14
07047	MEADOW VISTA	DONA ANA	1402	00 00	000 00
07048	MELROSE	CURRY	636	34 26	103 38
07049	MILAN	VALENCIA	2185	35 11	108 48
07050	MORIARTY	TORRENCE	758	34 59	106 03
07051	MOUNTAINAIR	TORRENCE	1022	34 32	106 16
07052	NORTH VALLEY	BERNALILLO	10366	35 05	106 38
07053	PECOS	SAN MIGUEL	598	35 34	105 41
07054	PORTALES	ROOSEVELT	10554	34 12	103 20
07055	QUESTA	TAOS	1095	36 43	105 36
07056	RATON	COLFAX	6962	36 54	104 27
07057	ROSWELL	CHAVES	33908	33 24	104 33
07058	RUIDOSO	LINCOLN	2216	33 20	105 42
07059	RUIDOSO DOWNS	LINCOLN	702	33 20	105 39
07061	SAN FELIPE PUEBLO	SANDOVAL	1187	35 26	106 27
07060	SANDIA	BERNALILLO	6867	35 08	106 19
07062	SANTA FE	SANTA FE	41167	35 41	105 57
07063	SANTA ROSA	GUADALUPE	2485	34 56	104 42
07064	SANTO DOMINGO PUEBLO	SANDOVAL	1662	35 35	106 28
07065	SILVER CITY	GRANT	7751	32 47	108 16
07066	SOCORRO	SOCORRO	4687	34 04	106 55
07067	SOUTH VALLEY	BERNALILLO	29389	35 05	106 38
07068	SPRINGER	COLFAX	1574	36 22	104 36
07069	TAOS	TAOS	2475	36 24	105 35
07070	TAOS PUEBLO	TAOS	1030	36 26	105 34
07071	TATUM	LEA	982	33 16	103 18
07072	TEXICO	CURRY	772	34 14	103 05
07073	TRUTH OR CONSEQUENCES	SIERRA	4656	33 08	107 16
07074	TUCUMCARI	QUAY	7189	35 11	103 44
07075	TULAROSA	OTERO	2851	33 04	106 02
07076	UNIV PK-TORTUGAS	DONA ANA	4165	32 18	106 47
07077	VAUGHN	GUADALUPE	867	34 35	105 14
07078	WAGON MOUND	MORA	630	36 01	104 44
07079	WHITE ROCK	LOS ALAMOS	3861	35 48	106 16
07080	WHITE SANDS	DONA ANA	4167	32 47	106 04
07081	ZUNI PUEBLO	MC KINLEY	3958	35 05	108 52

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

		<u>UTAH</u>				
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG	
08001	ALPINE	UTAH	1047	40 29	111	47
08002	AMERICAN FORK	UTAH	7713	40 24	111	48
08003	BEAVER	BEAVER	1453	38 18	112	38
08004	BLANDING	SAN JUAN	2250	37 37	109	29
08005	BOUNTIFUL	DAVIS	27853	40 54	111	54
08006	BRIGHAM CITY	BOX ELDER	14007	41 30	112	02
08007	CASTLE DALE	EMERY	541	39 12	111	00
08008	CEDAR CITY	IRON	8946	37 40	113	04
08009	CENTERVILLE	DAVIS	3268	40 56	111	54
08010	CLEARFIELD	DAVIS	13316	41 07	112	03
08011	CLINTON	DAVIS	1768	41 14	112	08
08012	COALVILLE	SUMMIT	864	40 55	111	25
08013	COTTONWOOD HEIGHTS	SALT LAKE	8431	40 38	111	49
08014	DELTA	MILLARD	1610	39 22	112	35
08015	DRAGERTON	CARBON	1614	39 32	110	25
08016	DUCHESNE	DUCHESNE	1094	40 10	110	24
08017	DUGWAY	TOOELE	2357	40 15	112	50
08018	EAST LAYTON	DAVIS	763	40 56	111	59
08019	EAST MILLCREEK	SALT LAKE	26579	40 41	111	49
08020	ENTERPRISE	WASHINGTON	844	37 43	113	43
08021	EPHRAIM	SANPETE	2127	39 21	111	35
08022	ESCALANTE	GARFIELD	638	37 47	111	35
08023	EUREKA	JUAB	753	39 57	112	09
08024	FAIRVIEW	SANPETE	696	39 38	111	27
08025	FARMINGTON	DAVIS	2526	40 50	111	55
08026	FERRON	EMERY	663	39 00	111	04
08027	FILLMORE	MILLARD	1411	38 58	112	20
08028	FRIUT HEIGHTS	DAVIS	800	00 00	000	00
08029	GARLAND	BOX ELDER	1187	41 45	112	10
08030	GRANGER-HUNTER	SALT LAKE	9029	40 41	111	58
08031	GRANITE PARK	SALT LAKE	9573	40 07	113	16
08032	GRANTSVILLE	TOOELE	2931	40 36	112	29
08033	GREEN RIVER	EMERY	1033	38 55	109	55
08034	GUNNISON	SANPETE	1073	39 09	111	50
08035	HARRISVILLE	WEBER	603	00 00	000	00
08036	HEBER CITY	WASATCH	3245	40 32	111	22
08037	HELPER	CARBON	1964	39 40	110	51
08038	HOLLADAY	SALT LAKE	23014	40 40	111	50
08039	HONEYVILLE	BOX ELDER	640	41 32	112	02
08040	HUNTINGTON	EMERY	857	39 19	110	58
08041	HUNTSVILLE	WEBER	553	41 15	111	45
08042	HURRICANE	WASHINGTON	1408	37 10	113	16

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

CITY ID	CITY NAME	UTAH			
		COUNTY NAME	POPULATION	LAT	LONG
08043	HYDE PARK	CACHE	1025	41 50	111 50
08044	HYRUM	CACHE	2340	41 39	111 50
08045	KAMAS	SUMMIT	806	40 40	111 16
08046	KANAB	KANE	1381	37 03	112 32
08047	KAYSVILLE	DAVIS	6192	41 03	111 56
08048	KEARNS	SALT LAKE	17071	40 43	112 02
08049	LAYTON	DAVIS	13603	40 56	111 59
08050	LEHI	UTAH	4659	40 25	111 51
08051	LEWISTON	CACHE	1244	41 57	111 53
08052	LINDON	UTAH	1644	40 20	111 45
08053	LOGAN	CACHE	22333	41 45	111 50
08057	MABLETON	UTAH	1980	40 10	111 35
08054	MAESER	UINTAH	1248	40 27	109 38
08055	MAGNA	SALT LAKE	5509	40 43	112 06
08056	MANTI	SANPETE	1803	39 16	111 38
08058	MIDVALE	SALT LAKE	7840	40 37	111 55
08059	MIDWAY	WASATCH	804	40 32	111 25
08060	MILFORD	BEAVER	1304	38 22	113 00
08061	MOAB	GRAND	4793	38 35	109 34
08062	MONROE	SEVIER	918	38 38	112 06
08063	MONTICELLO	SAN JUAN	1431	37 53	109 22
08064	MORGAN CITY	MORGAN	1586	41 02	111 40
08065	MORONI	SANPETE	894	39 33	111 35
08066	MOUNT OLYMPUS	SALT LAKE	5909	00 00	000 00
08067	MOUNT PLEASANT	SANPETE	1516	39 33	111 29
08068	MURRAY	SALT LAKE	21206	40 40	111 53
08069	NEPHI	JUAB	2699	39 43	111 50
08070	NORTH LOGAN	CACHE	1405	41 46	111 50
08071	NORTH OGDEN	WEBER	5257	41 19	111 59
08072	NORTH SALT LAKE	DAVIS	2143	40 47	111 55
08073	OGDEN	WEBER	69478	41 14	111 59
08074	ONAQUI	TOOELE	541	00 00	000 00
08075	ORANGEVILLE	EMERY	511	39 15	110 55
08076	OREM	UTAH	25729	40 20	111 45
08077	PANGUITCH	GARFIELD	1318	37 49	112 27
08078	PARK CITY	SUMMIT	1193	40 39	111 30
08079	PAROWAN	IRON	1423	37 50	112 50
08080	PAYSON	UTAH	4501	40 04	111 45
08081	PERRY	BOX ELDER	909	41 30	112 01
08082	PLAIN CITY	WEBER	1543	41 19	112 06
08083	PLEASANT GROVE	UTAH	5327	40 23	111 45

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE AND LONGITUDE

CITY ID	CITY NAME	UTAH			
		COUNTY NAME	POPULATION	LAT	LONG
08084	PLEASANT VIEW	WEBER	2028	41 18	112 00
08085	PRICE	CARBON	6218	39 35	110 49
08086	PROVIDENCE	CACHE	1608	41 43	111 48
08087	PROVO	UTAH	53131	40 15	111 40
08088	RANDOLPH	RICH	500	41 41	111 10
08089	RICHFIELD	SEVIER	4471	38 45	112 05
08090	RICHMOND	CACHE	1000	41 57	111 49
08091	RIVERDALE CITY	WEBER	3704	00 00	000 00
08092	RIVER HEIGHTS	CACHE	1008	00 00	000 00
08093	RIVERTON	SALT LAKE	2320	40 32	111 56
08094	ROOSEVELT	DUCHESNE	2005	40 18	110 00
08095	ROY	WEBER	14356	41 07	112 01
08097	SALIM	UTAH	1081	40 04	111 40
08098	SALINA	SEVIER	1494	38 57	111 52
08099	SALT LAKE CITY	SALT LAKE	175885	40 45	111 55
08100	SANDY	SALT LAKE	6438	40 37	111 53
08101	SANTAQUIN	UTAH	1236	39 57	111 42
08102	SMITHFIELD	CACHE	3342	41 50	111 50
08103	SOUTH JORDAN	SALT LAKE	2942	40 32	111 55
08104	SOUTH OGDEN	WEBER	9991	41 12	111 59
08105	SOUTH SALT LAKE1	SALT LAKE	7810	40 42	111 55
08106	SOUTH WEBER	DAVIS	1073	00 00	000 00
08107	SPANISH FORK CITY	UTAH	7284	40 07	111 39
08108	SPRINGVILLE	UTAH	8790	40 10	111 36
08096	ST GEORGE	WASHINGTON	7097	37 06	113 35
08109	SUNSET	DAVIS	6268	00 00	000 00
08110	SYRACUSE	DAVIS	1843	41 05	112 08
08111	TOOELE	TOOELE	12539	40 32	112 18
08112	TREMONTON	BOX ELDER	2794	41 43	112 10
08113	VERNAL	UINTAH	3908	40 26	109 32
08114	WASHINGTON	WASHINGTON	750	37 08	113 30
08115	WASHINGTON TERRACE	WEBER	7241	41 10	111 58
08116	WELLINGTON	CARBON	922	39 33	110 45
08117	WELLSVILLE	CACHE	1267	41 39	111 56
08118	WENDOVER	TOOELE	781	40 45	114 02
08119	WEST BOUNTIFUL	DAVIS	1246	40 50	111 55
08120	WEST JORDAN	SALT LAKE	4221	40 32	111 57
08121	WEST POINT	DAVIS	1020	41 00	112 03
08122	WHITE	SALT LAKE	6402	00 00	000 00
08123	WILLARD	BOX ELDER	1045	41 25	112 03
08124	WOODS GROSS	DAVIS	3124	40 54	111 55

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE AND LONGITUDE

		<u>CALIFORNIA</u>				
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG	
09063	ADELANTO	SANTA BARBAR	2115	34 34	117	25
09180	ALPINE	SAN DIEGO	1570	32 46	116	42
09010	ALTA HILL	NEVADA	1185	0 0	0	0
09001	ALTURAS	MODOC	2799	41 30	120	34
09223	ANDERSON	SHASTA	5492	40 28	122	18
09061	ANGELS CAMP	CALARERAS	1710	38 05	120	33
09066	APPLE VALLEY	SANTA BARBAR	6702	0 0	0	0
09141	ARBUCKLE	COLUSA	1037	39 02	122	04
09146	ARVIN	KERN	5090	35 11	118	50
09170	ATWATER	MERCED	11640	37 20	120	37
09047	AUBURN	PLACER	6570	38 53	121	04
09218	AUGUST SCHOOL AREA	SAN JOAQUINE	6293	0 0	0	0
09148	BAKERSFIELD	KERN	69515	35 20	118	52
09043	BANNING	RIVERSIDE	12034	33 56	116	52
09069	BARSTOW	SANTA BARBAR	17442	34 55	117	01
09287	BEALE EAST	YUBA	7029	39 02	121	27
09288	BEALE WEST	YUBA	2325	39 02	121	28
09044	BEAUMONT	RIVERSIDE	5484	33 56	117	00
09070	BIG BEAR	SANTA BARBAR	5268	34 15	116	53
09130	BIGGS	BUTTE	1115	39 27	121	44
09013	BISHOP	INYO	3498	37 20	118	24
09075	BLOOMINGTON	SANTA BARBAR	3059	0 0	0	0
09037	BLYTHE	RIVERSIDE	7047	33 38	114	35
09038	BLYTHEE	RIVERSIDE	1252	33 38	114	25
09226	BONNYVIEW	SHASTA	4882	0 0	0	0
09151	BORON	KERN	1999	35 05	117	39
09048	BOWMAN AUBURN	PLACER	2089	38 55	121	04
09099	BRAWLEY	IMPERIAL	13746	32 59	115	30
09225	BURNEY	SHASTA	2190	40 55	121	40
09149	BUTTONWILLO	KERN	1193	35 24	119	29
09045	CABAZON	RIVERSIDE	598	33 50	116	47
09100	CALEXICO	IMPERIAL	10625	32 39	115	28
09152	CALIFORNIA CITY	KERN	1309	37 53	122	27
09101	CALIPATRIA	IMPERIAL	1824	33 09	115	30
09111	CALWA	FRESNO	5191	36 41	119	43
09204	CARDIFF-BY-THE-SEA	SAN DIEGO	5724	33 00	117	18
09181	CARLSBAD	SAN DIEGO	14944	33 09	117	20
09171	CASTLE	MERCED	1903	37 20	120	37
09015	CATHEDRAL CITY	RIVERSIDE	3640	33 45	116	27
09229	CENTRAL VALLEY	SHASTA	2361	40 42	122	24
09241	CERES	STANISLAUS	6029	37 36	120	58
09046	CHERRY VALLEY	RIVERSIDE	3165	0 0	0	0
09004	CHESTER	PLUMAS	1531	40 20	121	14
09131	CHICO	BUTTE	19580	39 46	121	50
09132	CHICO NORTH	BUTTE	6656	39 46	121	50
09133	CHICO WEST	BUTTE	4787	39 46	121	50
09153	CHINA LAKE	KERN	11105	35 45	117	36
09071	CHINO	SANTA BARBAR	20411	35 55	117	37
09109	CHOWCHILLA	MADERA	4349	37 07	120	14

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

<u>CALIFORNIA</u>						
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG	
09183	CHULA VISTA	SAN DIEGO	67901	32 36	117	05
09112	CLOVIS	FRESNO	13856	36 47	119	43
09020	COACHELLA	RIVERSIDE	8353	33 40	116	10
09113	COALINGA	FRESNO	6161	36 08	120	22
09041	COLFAX	PLACER	798	39 07	120	56
09072	COLTON	SANTA BARBAR	19974	34 05	117	20
09143	COLUSA	COLUSA	3842	39 11	122	00
09262	CORNING	TEHAMA	3573	39 56	122	12
09022	CORONA	RIVERSIDE	27519	33 52	117	34
09185	CORONADO	SAN DIEGO	20910	32 40	117	10
09224	COTTONWOOD	SHASTA	1288	40 24	122	18
09067	CREST FOREST	SANTA BARBAR	3509	0 0	0	0
09065	CUCAMONGA	SANTA BARBAR	3064	0 0	0	0
09074	CUCAMONGA	SANTA BARBAR	2732	0 0	0	0
09271	CUTLER	TULARE	2503	36 30	119	17
09205	DEL MAR	SAN DIEGO	3956	32 57	117	15
09150	DELANO	KERN	14559	35 45	119	16
09175	DELHI	MERCED	2063	37 22	120	45
09254	DENAIR	STANISLAUS	1128	37 25	120	54
09024	DESERT HOT SPRING	RIVERSIDE	2738	33 58	116	30
09264	DINUBA	TULARE	7917	36 31	119	26
09231	DORRIS	SISKIYOU	840	41 57	121	55
09173	DOS PALOS	MERCED	2496	36 59	120	39
09232	DUNSMUIR	SISKIYOU	2214	41 12	122	18
09019	EAGLE MOUNTAIN	RIVERSIDE	2454	33 48	115	30
09265	EARLIMART	TULARE	3080	35 52	119	18
09274	EAST POTERVILE	TULARE	4042	0 0	0	0
09129	EASTON	FRESNO	1065	36 35	119	45
09154	EDWARDS	KERN	10331	34 55	117	54
09187	EL CAJON	SAN DIEGO	52273	32 48	116	58
09102	ELCENTRO	IMPERIAL	19272	32 47	115	33
09026	ELSINORE	RIVERSIDE	3530	33 40	117	19
09245	EMPIRE	STANISLAUS	2016	0 0	0	0
09206	ENCINITAS	SAN DIEGO	5375	33 04	117	17
09227	ENTERPRISE	SHASTA	11486	0 0	0	0
09211	ESCALON	SAN JOAQUINE	2366	37 43	121	00
09189	ESCONDIDO	SAN DIEGO	36792	33 07	117	05
09233	ETNA	SISKIYOU	667	41 28	122	54
09267	EXETER	TULARE	4475	36 17	119	09
09190	FALLBROOK	SAN DIEGO	6945	33 23	117	15
09268	FARMERSVILLE	TULARE	3456	36 17	119	10
09114	FIREBAUGH	FRESNO	2517	36 51	120	30
09076	FONTANA	SANTA BARBAR	20673	34 03	117	23
09164	FORD CITY	KERN	3503	35 05	119	30
09234	FORT JONES	SISKIYOU	515	41 37	122	51
09115	FOWLER	FRESNO	2239	36 38	119	41
09165	FRAZIER PARK	KERN	1167	34 51	119	00
09116	FRESNO	FRESNO	165972	36 41	119	47
09087	FT IRWIN	SANTA BARBAR	2991	0 0	0	0

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

		<u>CALIFORNIA</u>				
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG	
09219	GARDEN ACRES	SAN JOAQUINE	7870	0 0	0 0	
09064	GEORGE AFB	SANTA BARBAR	7404	34 30	117 18	
09031	GLEN AVON	RIVERSIDE	5759	0 0	0 0	
09285	GOSHEN	TULARE	1324	36 20	119 26	
09073	GRAND TERRACE	SANTA BARBAR	5901	0 0	0 0	
09011	GRASS VALLEY	NEVADA	5149	39 13	121 04	
09005	GREENVILLE	PLUMAS	1073	40 09	120 57	
09160	GREENACRES	KERN	2116	35 26	119 03	
09135	GRIDLEY	BUTTE	3534	39 24	121 42	
09174	GUSTINE	MERCED	2793	37 14	121 00	
09028	HEMET	RIVERSIDE	12252	33 45	116 58	
09029	HEMET EAST	RIVERSIDE	8598	33 45	116 55	
09077	HESPERIA	SANTA BARBAR	4592	34 25	117 19	
09078	HIGHLAND	SANTA BARBAR	12669	34 08	117 11	
09103	HOLTVILLE	IMPERIAL	3496	32 47	115 22	
09023	HOMEGARDENS	RIVERSIDE	5116	0 0	0 0	
09039	HOMELAND	RIVERSIDE	1187	0 0	0 0	
09244	HUGHSON	STANISLAUS	2144	37 35	120 53	
09117	HURON	FRESNO	1525	36 14	120 05	
09104	IMPERIAL	IMPERIAL	3094	32 51	115 33	
09191	IMPERIAL BEACH	SAN DIEGO	20244	32 51	115 33	
09016	INDIAN WELLS	RIVERSIDE	760	33 45	116 19	
09021	INDIO	RIVERSIDE	14459	33 44	116 14	
09057	IONE	AMADOR	2369	38 20	120 55	
09269	IVANHOE	TULARE	1595	36 20	119 15	
09058	JACKSON	AMADOR	1924	38 19	120 49	
09093	JOSHUA TREE	SANTA BARBAR	1211	34 09	116 20	
09118	KERMAN	FRESNO	2667	36 42	120 04	
09242	KEYES	STANISLAUS	1875	37 31	120 52	
09119	KINSSBURG	FRESNO	3843	36 29	119 31	
09194	LA MESA	SAN DIEGO	39178	32 45	117 00	
09027	LAKELAND VILLAGE	RIVERSIDE	1724	33 32	117 30	
09192	LAKESIDE	SAN DIEGO	11991	32 51	116 55	
09147	LAMONT	KERN	7007	35 15	118 56	
09214	LATHROP	SAN JOAQUINE	2137	0 0	0 0	
09120	LATON	FRESNO	1071	36 25	119 42	
09195	LEMON GROVE	SAN DIEGO	19690	32 45	116 58	
09080	LENWOOD	SANTA BARBAR	3834	34 52	117 05	
09054	LINCOLN	PLACER	3176	38 53	121 18	
09220	LINCOLN	SAN JOAQUINE	6772	38 53	121 18	
09289	LINDA	YUBA	7731	39 05	121 40	
09270	LINDSAY	TULARE	5206	36 11	119 05	
09258	LIVE OAK	SUTTER	2645	39 16	121 40	
09176	LIVINGSTON	MERCED	2588	37 20	120 45	
09068	LK. AROWHEAD	SANTA BARBAR	2682	34 10	117 10	
09212	LODI	SAN JOAQUINE	28691	38 07	121 18	
09079	LOMA LINDA	SANTA BARBAR	6804	34 05	117 13	
09092	LOMA LINDA	SANTA BARBAR	2993	34 05	117 13	
09014	LONE PINE	INYO	1241	36 35	118 04	

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

<u>CALIFORNIA</u>						
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG	
09051	LOOMIS	PLACER	1108	38 45	121	15
09177	LOS BANOS	MERCED	9188	37 04	120	51
09008	LOYALTON	SIERRA	945	39 41	120	15
09166	MAICOPA	KERN	740	00 00	000	00
09215	MANTEGA	SAN JOAQUINE	13845	37 49	121	15
09034	MARCH AFB	RIVERSIDE	2002	0 0	0	0
09290	MARYSVILLE	YUBA	9353	39 10	121	34
09235	MCCLOUD	SISKIYOU	1643	41 16	122	09
09158	MCFARLAND	KERN	4177	35 37	119	15
09110	MEDERA	MADERA	16044	0 0	0	0
09121	MENDOTA	FRESNO	2705	36 44	120	24
09178	MERCED	MERCED	22670	37 17	120	29
09032	MIRA LOUA	RIVERSIDE	8482	33 55	117	30
09246	MODESTO	STANISLAUS	61712	37 37	121	00
09155	MOJAVE	KERN	2573	35 02	118	11
09236	MONTAGUE	SISKIYOU	890	41 45	122	31
09083	MONTCLAIR	SANTA BARBAR	22546	33 57	117	45
09221	MORADA	SAN JOAQUINE	2936	0 0	0	0
09237	MOUNT SHASTA	SISKIYOU	2163	41 19	122	20
09134	MULBERRY	BUTTE	1795	00 00	000	00
09090	MUSCOY	SANTA BARBAR	7091	0 0	0	0
09197	NATIONAL CITY	SAN DIEGO	43184	32 39	117	06
09081	NEBO CNTR	SANTA BARBAR	1828	0 0	0	0
09084	NEEDLES	SANTA BARBAR	4051	34 51	114	36
C9012	NEVADA CITY	NEVADA	2314	39 16	121	00
09249	NEWMAN	STANISLAUS	2505	37 20	121	04
09035	NORCO	RIVERSIDE	14511	33 47	117	32
09186	NORTH ISLAND	SAN DIEGO	6002	00 00	000	00
09250	OAKDALE	STANISLAUS	6594	37 45	120	50
09198	OCEANSIDE	SAN DIEGO	40494	33 12	117	23
09159	OILDALE	KERN	20586	35 25	119	00
09291	OLIVEHURST	YUBA	8100	39 03	121	32
09085	ONTARIO	SANTA BARBAR	64118	34 04	117	38
09122	ORANGE COVE	FRESNO	3392	36 35	119	17
09144	ORLAND	GLENN	2884	39 45	122	13
09272	OROSI	TULARE	2757	36 31	119	17
09136	OROVILLE	BUTTE	7536	39 31	121	34
09184	OTAY-CASTLE PARK	SAN DIEGO	15445	32 33	117	00
09139	PALERMO	BUTTE	1960	39 27	121	34
09017	PALM DESERT	RIVERSIDE	6171	33 44	116	21
09036	PALM SPRGS	RIVERSIDE	20936	33 49	116	34
09140	PARADISE	BUTTE	14539	39 46	121	38
09123	PARLIER	FRESNO	1993	36 35	119	31
09251	PATTERSON	STANISLAUS	3147	37 29	121	10
09199	PENDLETON NORTH	SAN DIEGO	11803	33 15	117	23
09200	PENDLETON SOUTH	SAN DIEGO	13692	33 15	117	23
09040	PERRIS	RIVERSIDE	4228	33 48	117	12
09273	PIXLEY	TULARE	1584	35 58	119	20
09056	PLACER VILLE	ELDORADO	5416	38 43	120	50

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE AND LONGITUDE

<u>CALIFORNIA</u>						
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG	
09179	PLANADA	MERCED	2056	37 16	120 18	
09059	PLYMOUTH	AMADOR	501	38 29	120 52	
09278	POPLAR P	TULARE	1205	36 01	119 02	
09275	PORTERVILLE	TULARE	12602	36 05	119 02	
09276	PORTERVILLE NORTHWEST	TULARE	2517	36 05	119 02	
09277	PORTERVILLE WEST	TULARE	6200	36 05	119 02	
09006	PORTOLA	PLUMAS	1625	39 45	120 20	
09201	POWAY	SAN DIEGO	9442	32 57	117 00	
09230	PROJECT CITY	SHASTA	1431	40 42	122 24	
09007	QUINCY	PLUMAS	3343	39 56	120 56	
09202	RAMONA	SAN DIEGO	3554	33 02	116 52	
09018	RANCHO MIRAG	RIVERSIDE	1298	0 0	0 0	
09263	RED BLUFF	TEHAMA	7676	40 11	122 16	
09228	REDDING	SHASTA	16659	40 35	122 24	
09086	REDLANDS	SANTA BARBAR	36355	34 03	117 10	
09124	REEDLEY	FRESNO	8131	36 35	119 27	
09089	RIALTO	SANTA BARBAR	38370	34 03	117 21	
09266	RICHGROVE	TULARE	1023	35 46	119 08	
09156	RIDGECREST	KERN	7629	35 33	117 39	
09216	RIPON	SAN JOAQUINE	2679	37 44	121 08	
09042	RIVERSIDE	RIVERSIDE	140089	33 59	117 22	
09125	RIVERDALE	FRESNO	1722	36 26	119 53	
09252	RIVERBANK	STANISLAUS	3949	37 43	120 56	
09052	ROCKLIN	PLACER	3039	38 43	121 17	
09157	ROSAMOND	KERN	2281	34 52	118 10	
09053	ROSEVILLE	PLACER	17895	38 44	121 19	
09033	RUBIDOUX	RIVERSIDE	13969	0 0	0 0	
09253	SALIDA	STANISLAUS	1456	37 40	121 02	
09062	SAN AUDREAS	CALARERAS	1564	38 20	120 40	
09091	SAN BERNARDINO	SANTA BARBAR	104251	34 07	117 18	
09203	SAN DIEGO	SAN DIEGO	696769	32 45	117 10	
09030	SAN JACINTO	RIVERSIDE	4385	33 48	116 58	
09127	SAN JUAQUIN	FRESNO	1506	36 35	120 10	
09208	SAN MARCOS	SAN DIEGO	3896	0 0	0 0	
09126	SANGER	FRESNO	10088	36 41	119 35	
09193	SANTEE	SAN DIEGO	19321	32 51	117 00	
09209	SANTEE	SAN DIEGO	15858	0 0	0 0	
09088	SCARLE VALLEY	SANTA BARBAR	3828	35 30	117 36	
09128	SELMA	FRESNO	7459	36 34	119 38	
09188	SENTEE	SAN DIEGO	1786	00 00	000 00	
09161	SHAFTER	KERN	5327	35 30	119 16	
09207	SOLANA BEACH	SAN DIEGO	5023	32 58	117 17	
09106	SONORA	TUOLUMNE	3100	38 00	120 21	
09055	SOUTH LAKE TAHOE	ELDORADO	12921	39 03	120 00	
09137	SOUTH OROVILLE	BUTTE	4111	39 31	121 34	
09167	SOUTH TAFT	KERN	2214	35 08	119 28	
09243	SOUTH MODESTO P	STANISLAUS	1337	37 37	121 00	
09247	SOUTH MODESTO P	STANISLAUS	6552	37 37	121 00	

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

<u>CALIFORNIA</u>					
<u>CITY</u> <u>ID</u>	<u>CITY NAME</u>	<u>COUNTY NAME</u>	<u>POPULATION</u>	<u>LAT</u>	<u>LONG</u>
09255	SOUTH TURLOCK	STANISLAUS	1762	37 29	120 50
09261	SOUTH YUBA CITY	SUTTER	5352	39 09	121 36
09182	SPRING VALLEY	SAN DIEGO	29742	32 41	116 57
09196	SPRING VALLEY	SAN DIEGO	24493	00 00	000 00
09217	STOCKTON	SAN JOAQUINE	107644	37 59	121 20
09279	STRATHMORE	TULARE	1221	36 05	119 03
09041	SUN CITY	RIVERSIDE	5519	0 0	0 0
09025	SUNNY MEAD	RIVERSIDE	6708	0 0	0 0
09002	SUSANVILLE	LASSEN	6608	40 26	120 40
09060	SUTTER CREEK	AMADOR	1508	38 24	120 50
09259	SUTTER	SUTTER	1488	38 25	120 54
09168	TAFT	KERN	4285	35 08	119 28
09169	TAFT HEIGHTS	KERN	2108	35 03	119 30
09050	TAHOE	PLACER	1394	39 05	120 00
09162	TEHACHAPI	KERN	4211	35 08	118 27
09280	TERRA BELLA	TULARE	1037	35 58	119 03
09138	THERMALITO	BUTTE	4217	39 31	121 34
09222	TRACY	SAN JOAQUINE	14724	37 43	121 27
09009	TRUCKEE	NEVADA	1392	39 20	120 10
09282	TULARE	TULARE	16235	36 13	119 22
09283	TULARE EAST	TULARE	2361	36 13	119 22
09284	TULARE NORTHWEST	TULARE	1801	36 13	119 22
09238	TULELAKE	SISKIYOU	857	41 54	121 31
09107	TUOLUMNE	TUOLUMNE	1365	37 59	120 15
09256	TURLOCK	STANISLAUS	13992	37 29	120 50
09108	TWAIN HARTE	TUOLUMNE	1484	38 00	120 14
09096	UPLAND	SANTA BARBAR	32551	34 06	117 38
09097	VICTORVILLE	SANTA BARBAR	10845	34 31	117 17
09210	VISTA	SAN DIEGO	24688	33 12	117 15
09163	WASCO	KERN	8269	35 35	119 22
09257	WATERFORD	STANISLAUS	2243	37 37	120 46
09239	WEED	SISKIYOU	2983	41 26	122 23
09105	WEST MORLAND	IMPERIAL	1175	33 03	115 37
09248	WEST MODESTO	STANISLAUS	6135	37 37	121 00
09003	WESTWOOD	LASSEN	1862	40 20	121 00
09292	WHEATLAND	YUBA	1280	39 01	121 24
09142	WILLIAMS	COLUSA	1571	39 09	122 09
09145	WILLOWS	GLENN	4085	39 32	122 10
09172	WINTON	MERCED	3393	00 00	000 00
09213	WOODBIDGE	SAN JOAQUINE	1397	38 08	121 19
09286	WOODLAKE	TULARE	3371	36 26	119 07
09281	WOODVILLE	TULARE	1031	36 05	119 15
09082	YERMO	SANTA BARBAR	1304	34 55	116 50
09095	YOLLA VALLEY	SANTA BARBAR	3893	33 05	116 30
09240	YREKA	SISKIYOU	5394	41 44	122 39
09260	YUBA CITY	SUTTER	13986	39 09	121 36
09098	YUCAIPA	SANTA BARBAR	19284	33 59	117 00
09094	29 PALMS	SANTA BARBAR	5667	34 09	116 03

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

		<u>IDAHO</u>				
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG	
10026	ABERDEEN	BINGHAM	1542	42 57	112 50	
10001	AMERICAN FALLS	POWER	2769	42 47	112 50	
10033	AMMON	BONNEVILLE	1338	43 30	111 57	
10037	ARCO	BUTTE	1244	43 38	113 18	
10029	BELLEVUE	BLAINE	537	43 27	114 16	
10027	BLACKFOOT	BINGHAM	8716	43 13	112 20	
10002	BUHL	TWIN FALLS	2975	42 37	114 46	
10003	BURLEY	CASSIA	8279	42 32	113 48	
10038	CALDWELL	CANYON	14219	43 39	116 40	
10004	CHUBBOCK	BANNOCK	2924	42 55	112 26	
10005	DOWNNEY	BANNOCK	7586	42 26	112 12	
10049	DRIGGS	TETON	727	43 45	111 08	
10006	FILER	TWIN FALLS	1173	42 36	114 37	
10043	GLENNS FERRY	ELMOR	1386	42 57	115 19	
10046	GOODING	GOODING	2599	42 56	114 44	
10007	GRACE	CARIBOU	826	42 35	111 45	
10030	HAILEY	BLAINE	1425	43 31	114 19	
10008	HEYBURN	MINIDOKA	1637	42 33	113 46	
10009	HOMEDALE	OWYHEE	1411	43 37	116 55	
10032	HORSESHOE BEND	BOISE	511	43 55	116 11	
10035	IDAHO FALLS	BONNEVILLE	35776	43 30	112 01	
10010	INKOM	BANNOCK	522	42 48	112 15	
10034	IONA	BONNEVILLE	890	43 33	111 56	
10011	JEROME	JEROME	4183	42 44	114 31	
10031	KETCHUM	BLAINE	1454	43 41	114 23	
10012	KIMBERLY	TWIN FALLS	1557	42 32	114 23	
10013	LAVA HOT SPRINGS	BANNOCK	516	42 37	112 00	
10015	MALAD CITY	ONEIDA	1848	42 12	112 15	
10016	MARSING	OWYHEE	610	43 33	116 48	
10014	MC CAMMON	BANNOCK	673	42 39	112 12	
10039	MIDDLETON	CANYON	739	43 43	116 37	
10017	MONTPELIER	BEAR LAKE	2604	42 20	111 20	
10044	MOUNTAIN HOME	ELMOR	6451	43 09	115 42	
10045	MOUNTAIN HOME BASE	ELMOR	6038	43 09	115 42	
10040	NAMPA	CANYON	20768	43 35	116 34	
10018	OAKLEY	CASSIA	656	42 15	113 53	
10019	PARIS	BEAR LAKE	615	42 15	111 24	
10041	PARMA	CANYON	1228	43 49	116 58	
10020	PAUL	MINIDOKA	911	42 37	113 48	
10021	POCATELLO	BANNOCK	40036	42 53	112 26	
10025	PRESTON	FRANKLIN	3310	42 06	111 53	
10022	RUPERT	MINIDOKA	4563	42 37	113 40	
10028	SHELLEY	BINGHAM	2614	43 25	112 07	
10048	SHOSHONE	LINCOLN	1233	42 57	114 25	
10023	SODA SPRINGS	CARIBOU	2977	42 40	111 35	
10024	TWIN FALLS	TWIN FALLS	21914	42 34	114 30	
10036	UCON	BONNEVILLE	664	43 36	111 58	
10047	WENDELL	GOODING	1122	42 47	114 42	
10042	WILDER	CANYON	564	43 43	116 40	

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE AND LONGITUDE

<u>KANSAS</u>					
<i>CITY ID</i>	<i>CITY NAME</i>	<i>COUNTY NAME</i>	<i>POPULATION</i>	<i>LAT</i>	<i>LONG</i>
11020	ATWOOD	RAWLINS	1658	39 48	101 03
11018	BIRD CITY	CHEYENNE	667	39 45	101 32
11023	CIMARRON	GRAY	1373	37 49	100 20
11017	COLBY	THOMAS	4658	39 24	101 04
11025	DIGHTON	LANE	1540	38 28	100 28
11001	ELKHART	MORTON	2089	37 01	101 55
11026	FOWLER	MEADE	588	37 23	100 13
11010	GARDEN CITY	FINNEY	14708	37 57	100 54
11016	GOODLAND	SHERMAN	5510	39 20	101 43
11030	HOXIE	SHERIDAN	1419	39 21	100 27
11002	HUGOTON	STEVENS	2739	37 11	101 22
11004	JOHNSON	STANTON	1038	37 34	101 47
11009	LAKIN	KEARNEY	1570	37 57	101 16
11012	LEOTI	WICHITA	1916	38 28	101 22
11003	LIBERAL	SEWARD	13471	37 03	100 56
11027	MEADE	MEADE	1899	37 17	100 21
11024	MONTEZUMA	GRAY	606	37 35	100 27
11029	NESS CITY	NESS	1756	38 27	99 54
11015	OAKLEY	LOGAN	2327	39 08	100 53
11021	OVERLIN	DECATUR	2291	39 49	100 33
11022	QUINTER	GOVE	930	39 04	100 15
11006	SATANTA	HASKELL	1161	37 26	100 59
11013	SCOTT CITY	SCOTT	4001	38 28	100 55
11014	SHARON SPRINGS	WALLACE	1012	38 54	101 46
11019	ST FRANCIS	CHEYENNE	1725	39 47	101 47
11007	SUBLETTE	HASKELL	1208	37 28	100 52
11008	SYRACUSE	HAMILTON	1720	37 59	101 46
11011	TRIBUNE	GREELEY	1013	38 27	101 46
11005	ULYSSES	GRANT	3779	37 36	101 23
11028	WEST PLAINS	MEADE	857	37 16	100 40

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

		<u>NEBRASKA</u>				
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG	
12021	ALLIANCE	BOX BUTTE	6862	42 08	102 54	
12024	ANSLEY	CUSTER	631	41 19	99 22	
12034	ARAPAHOE	FURNAS	1147	40 19	99 52	
12025	ARNOLD	CUSTER	752	41 16	100 11	
12013	BAYARD	MORRILL	1338	41 46	103 20	
12035	BEAVER CITY	FURNAS	802	40 09	99 50	
12003	BENKELMAN	DUNDY	1349	40 02	101 31	
12012	BRIDGEPORT	MORRILL	1490	41 40	103 05	
12026	BROKEN BOW	CUSTER	660	41 26	99 38	
12027	CALLAWAY	CUSTER	523	41 18	99 55	
12036	CAMBRIDGE	FURNAS	1145	40 18	100 11	
12008	CHAPPELL	DEUEL	1204	41 06	102 29	
12029	COZAD	DAWSON	4219	40 51	99 59	
12001	CULBERTSON	HITCHCOCK	801	40 14	100 49	
12033	CURTIS	FRONTIER	1166	40 00	100 30	
12014	GERING	SCOTTS BLUFF	5639	41 50	103 30	
12041	GORDON	SHERIDAN	2106	42 48	103 12	
12030	GOTHEN	DAWSON	3154	00 00	00 00	
12042	HAY SPRINGS	SHERIDAN	682	42 41	102 42	
12022	HEMINGFORD	BOX BUTTE	734	42 20	103 05	
12004	HERSHEY	LINCOLN	526	41 09	100 59	
12039	INDIANOLA	RED WILLOW	576	40 16	100 24	
12011	KIMBALL	KIMBALL	3680	41 16	103 40	
12031	LEXINTON	DAWSON	5618	40 46	99 48	
12015	LYMAN	SCOTTS BLUFF	561	41 57	104 02	
12040	MCCOOK	RED WILLOW	8285	40 13	100 35	
12016	MINATARE	SCOTTS BLUFF	939	41 50	103 30	
12017	MITCHELL	SCOTTS BLUFF	1842	41 56	103 48	
12018	MORILL	SCOTTS BLUFF	937	41 58	103 58	
12038	MULLEN	HOOVER	667	42 03	101 02	
12005	NORTH PLATTE	LINCOLN	19447	41 09	100 45	
12009	OSHKOSH	GARDEN	1067	41 26	102 22	
12032	OVERTON	DAWSON	506	40 44	99 32	
12037	OXFORD	FURNAS	878	40 16	99 40	
12007	PAXTON	KIETH	503	41 08	101 22	
12043	RUSHVILLE	SHERIDAN	1137	42 45	102 27	
12028	SARGENT	CUSTER	789	41 39	99 22	
12020	SCOTTS BLUFF	SCOTTS BLUFF	14507	41 52	103 40	
12010	SIDNEY	CHEYENNE	6403	41 09	103 00	
12006	SUTHERLAND	LINCOLN	840	41 10	101 08	
12019	TERRYTOWN	SCOTTS BLUFF	747	41 49	103 40	
12002	TRENTON	HITCHCOCK	770	40 11	101 01	
12023	VALENTINE	CHERRY	2662	42 53	100 31	

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

<u>OKLAHOMA</u>						
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG	
13001	BOISE CITY	CIMARRON	1993	36 44	102	31
13003	GUYMON	TEXAS	7674	36 42	101	30
13004	HOOKER	TEXAS	1615	36 51	101	13
13002	KEYES	CIMARRON	569	36 48	102	13
13005	TEXHOMA	TEXAS	921	36 30	101	47
13006	TYRONE	TEXAS	588	36 57	101	02

<u>OREGON</u>						
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG	
14001	ALTAMONT	KLAMATH	15746	42 12	121	47
14002	BURNS	HARNEY	3293	43 36	119	03
14003	CHILOQUIN	KLAMATH	826	42 35	121	53
14004	FALCON HEIGHTS	KLAMATH	1389	00 00	000	00
14005	HINES	HARNEY	1407	43 34	119	04
14006	KLAMATH FALLS	KLAMATH	15775	42 14	121	47
14007	MERRILL	KLAMATH	722	42 02	121	37
14008	NYSSA	MALHEUR	2620	43 54	117	00
14009	ONTARIO	MALHEUR	6523	44 02	116	58
14010	VALE	MALHEUR	1448	43 59	117	15

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

		<u>TEXAS</u>			
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG
15056	ABERNATHY	HALE	1921	33 50	101 52
15071	ABERNATHY	LUBBOCK	704	33 50	101 52
15085	AMARILLO	POTTER	86477	35 14	101 50
15035	AMHERST	LAMB	825	34 02	102 26
15018	ANDREWS	ANDREWS	8625	32 19	102 34
15004	ANTHONY	EL PASO	2154	32 00	106 36
15025	ANTON	HOCKLEY	1034	33 51	102 12
15008	BALMORHEA	REEVES	655	31 00	103 46
15010	BARSTOW	WARD	614	31 27	103 24
15087	BIG LAKE	REGAN	2489	31 12	101 29
15062	BIG SPRING	HOWARD	28735	32 15	101 30
15002	BIGGS	EL PASO	4226	31 50	106 23
15064	BORGER	HUTCHINSON	14195	35 39	101 24
15038	BOVINA	PARMER	1428	34 31	102 54
15023	BROWNFIELD	TERRY	9647	33 11	102 16
15065	BUNAVISTA	HUTCHINSON	1402	00 00	000 00
15080	CACTUS	MOORE	644	36 03	102 00
15005	CANUTILLO	EL PASO	1588	31 05	106 37
15086	CANYON	RANDAL	8333	34 58	101 56
15041	CLAUDE	ARMSTRONG	992	35 06	101 22
15063	COAHOMA	HOWARD	1158	32 18	101 17
15016	CRANE	CRANE	3427	31 23	102 22
15049	CROSBYTON	CROSBY	2251	33 40	101 12
15030	DALHART	DALLOM	4340	36 05	102 32
15021	DENVER CITY	YOAKUM	4133	32 58	102 50
15029	DIMMIT	CASTRO	4327	34 33	102 20
15081	DUMAS	MOORE	9771	35 51	101 57
15032	EARTH	LAMB	1152	34 14	102 25
15001	EL PASO	EL PASO	322261	31 45	106 30
15006	FABENS	EL PASO	3241	31 29	106 21
15039	FARWELL	PARMER	1185	31 23	103 03
15053	FLOYDADA	FLOYD	4109	33 58	101 20
15083	FORT STOCKTON	PECOS	8283	30 54	102 54
15040	FRIONA	PARMER	3111	34 38	102 44
15066	FRITCH	HUTCHINSON	1778	35 39	101 36
15003	FT BLISS	EL PASO	13288	31 45	106 30
15011	GRANDFALLS	WARD	622	31 09	102 55
15045	GROOM	CARSON	808	35 12	101 03
15060	GRUVER	HANSFORD	1265	36 14	101 25
15057	HALE CENTER	HALE	1964	34 04	101 52
15089	HAPPY	SWISHER	627	34 44	101 52
15031	HEREFORD	DEAF SMITH	13414	34 49	102 25
15069	IDALOU	LUBBOCK	1729	33 40	101 40
15084	IRAAN	PECOS	996	30 42	101 56
15014	KERMIT	WINKLER	7884	31 49	103 07
15090	KRESS	SWISHER	578	34 22	101 46
15052	LAMESA	DAWSON	11559	32 43	101 57

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

<u>TEXAS</u>					
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG
15026	LEVELLAND	HOCKLEY	11445	33 35	102 23
15033	LITTLEFIELD	LAMB	6738	33 56	102 20
15054	LOCKNEY	FLOYD	2094	34 06	101 25
15050	LORENZO	CROSBY	1206	33 41	101 33
15070	LUBBOCK	LUBBOCK	149101	33 35	101 53
15092	MCCAMEY	UPTON	2647	31 09	102 14
15079	MIDLAND	MIDLAND	59463	32 00	102 09
15012	MONAHANS	WARD	8333	31 35	102 54
15024	MORTON	COCHRAN	2738	33 43	102 56
15028	MULESHOE	BAILEY	4525	34 14	102 44
15017	ODESSA	ECTOR	78380	31 50	102 23
15034	OLTON	LAMB	1782	34 12	102 08
15048	OZONA	CROCKETT	2864	30 43	101 13
15076	O'DONNELL	LYNN	1017	32 58	101 49
15044	PANHANDLE	CARSON	2141	35 21	101 24
15009	PECOS	REEVES	12682	31 25	103 30
15058	PETERSBURG	HALE	1300	33 52	101 35
15067	PHILLIPS	HUTCHINSON	2515	35 42	101 23
15022	PLAINS	YOAKUM	1087	33 12	102 50
15059	PLAINVIEW	HALE	19096	34 12	101 43
15055	POST	GARZA	3854	33 13	101 23
15042	QUITAQUE	BRISCO	601	34 23	101 04
15051	RALLS	CROSBY	1962	33 41	101 23
15093	RANKIN	UPTON	1105	31 14	101 56
15072	REESE	LUBBOCK	2545	00 00	000 00
15019	SEAGRAVES	GAINES	2440	32 56	102 35
15020	SEMINOLE	GAINES	5007	32 43	102 39
15074	SHALLOWATER	LUBBOCK	1339	33 41	102 00
15043	SILVERTON	BRISCO	1026	34 28	101 18
15046	SKELLYTOWN	CARSON	716	35 34	101 11
15075	SLATON	LUBBOCK	6583	33 26	101 40
15061	SPEARMAN	HANSFORD	3435	36 12	101 13
15078	STANTON	MARTIN	2117	32 07	101 47
15068	STINNETT	HUTCHINSON	2014	35 49	101 27
15088	STRATFORD	SHERMAN	2139	36 21	102 05
15036	SUDAN	LAMB	976	34 04	102 32
15027	SUNDOWN	HOCKLEY	1129	33 27	102 28
15082	SUNRAY	MOORE	1854	36 01	101 50
15077	TAHOKA	LYNN	2956	33 10	101 48
15091	TULIA	SWISHER	5294	34 32	101 46
15007	VAN HORN	CULBERSON	2240	31 03	104 51
15037	VEGA	OLDHAM	839	35 14	102 26
15047	WHITE DEER	CARSON	1092	35 27	101 11
15013	WICKETT	WARD	598	31 33	103 01
15015	WINK	WINKLER	1023	31 44	103 10
15073	WOLFFORTH	LUBBOCK	1090	33 30	102 02

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

<u>WYOMING</u>						
CITY ID	CITY NAME	COUNTY NAME	POPULATION	LAT	LONG	
16001	AFTON	LINCOLN	1290	42 44	110	55
16002	BASIN	BIG HORN	1145	44 24	108	02
16003	BIG PINEY	SUBLETTE	570	42 32	110	06
16004	BUFFALO	JOHNSON	3394	44 21	106	40
16005	CASPER	NATRONA	39361	42 50	106	20
16006	CHEYENNE	LARAMIE	40914	41 08	104	50
16007	CODY	PARK	5161	44 32	109	04
16008	DOUGLAS	CONVERSE	2677	42 48	105	23
16009	DUBOIS	FREMONT	898	43 32	109	36
16010	EVANSTON	UINTA	4462	41 16	110	58
16011	EVANSVILLE	NATRONA	832	42 51	106	16
16012	FOX FARM	LARAMIE	1329	00 00	000	00
16013	GILETTE	CAMBELL	7194	44 18	105	30
16014	GLENROCK	CONVERSE	1515	42 52	105	52
16015	GREEN RIVER	SWEETWATER	4196	41 33	109	27
16016	GREYBULL	BIG HORN	1953	44 30	108	02
16017	GUERNSEY	PLATTE	793	42 17	104	45
16018	JACKSON	TETON	2101	43 28	110	45
16019	KEMMERER	LINCOLN	2292	41 47	110	33
16020	LANDER	FREMONT	7125	42 49	108	44
16021	LARAMIE	ALBANY	23143	41 20	105	38
16022	LOVELL	BIG HORN	2371	44 50	108	15
16023	LUSK	NIOBRARA	1495	42 47	104	26
16024	LYMAN	UNITA	643	41 20	110	16
16025	MILLS	NATRONA	1724	42 50	106	24
16026	MOORCROFT	CROOK	981	44 15	104	58
16027	MOUNTAIN VIEW	NATRONA	1641	41 16	110	20
16028	NEWCASTLE	WESTON	3432	43 52	104	14
16029	ORCHARD VALLEY	LARAMIE	1015	41 04	104	50
16030	PARADISE VALLEY	NATRONA	1764	42 49	106	24
16031	PINE BLUFFS	LARAMIE	937	41 10	104	06
16032	PINEDALE	SUBLETTE	948	42 51	109	50
16033	POWELL	PARK	4807	44 45	108	46
16034	RAWLINS	CARBON	7855	41 46	107	16
16035	RIVERTON	FREMONT	7995	43 02	108	22
16036	ROCK SPRINGS	SWEETWATER	11657	41 35	109	13
16037	SARATOGA	CARBON	1181	41 28	106	48
16038	SHERIDAN	SHERIDAN	10856	44 48	106	57
16039	SHOSHONI	FREMONT	562	43 15	108	04
16040	SUNDANCE	CROOK	1056	44 23	104	22
16041	THERMOPOLIS	HOT SPRINGS	3063	43 39	108	12
16042	TORRINGTON	GOSHEN	4237	42 05	104	11
16043	UPTON	WESTON	987	44 05	104	36
16044	WARREN	LARAMIE	4527	00 00	000	00
16045	WHEATLAND	PLATTE	2498	42 03	104	57
16046	WORLAND	WASHAKIE	5055	44 01	107	58

TABLE 8. CITY ID, CITY NAME, COUNTY NAME, POPULATION, LATITUDE
AND LONGITUDE

<u>ARIZONA</u>					
COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME
401	APACHE	406	GREELEE	411	PINAL
402	COCHISE	407	MARICOPA	412	SANTA CRUZ
403	COCONINO	408	MOHAVE	413	YAVAPAI
404	GILA	409	NAVAJO	414	YUMA
405	GRAHAM	410	PIMA		

<u>COLORADO</u>					
COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME
501	ADAMS	522	FREMONT	543	MONTROSE
502	ALAMOSA	523	GARFIELD	544	MORGAN
503	ARAPAHOE	524	GILPIN	545	OTERO
504	ARCHULETA	525	GRAND	546	OURAY
505	BACA	526	GUNNISON	547	PARK
506	BENT	527	HINSDALE	548	PHILLIPS
507	BOULDER	528	HUERFANO	549	PITKIN
508	CHAFFEE	529	JACKSON	550	PROWERS
509	CHEYENNE	530	JEFFERSON	551	PUEBLO
510	CLEAR CREEK	531	KIOWA	552	RIO BLANCO
511	CONEJOS	532	KIT CARSON	553	RIO GRANDE
512	COSTILLA	533	LAKE	554	ROUTT
513	CROWLEY	534	LA PLATA	555	SAGUACHE
514	CUSTER	535	LARIMER	556	SAN JUAN
515	DELTA	536	LAS ANIMAS	557	SAN MIGUEL
516	DENVER	537	LINCOLN	558	SEDWICK
517	DOLORES	538	LOGAN	559	SUMMIT
518	DOUGLAS	539	MESA	560	TELLER
519	EAGLE	540	MINERAL	561	WASHINGTON
520	ELBERT	541	MOFFAT	562	WELD
521	EL PASO	542	MONTEZUMA	563	YUMA

TABLE 9. COUNTY ID AND COUNTY NAME

NEVADA

COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME
600	CARSON CITY	606	EUREKA	612	NYE
601	CHURCHILL	607	HUMBOLDT	614	PERSHING
602	CLARK	608	LANDER	615	STOREY
603	DOUGLAS	609	LINCOLN	616	WASHOE
604	ELKO	610	LYON	617	WHITE PINE
605	ESMERALDA	611	MINERAL		

NEW MEXICO

COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME
701	BERNALILLO	712	HIDALGO	723	SANDOVAL
702	CATRON	713	LEA	724	SAN JUAN
703	CHAVES	714	LINCOLN	725	SAN MIGUEL
704	COLFAX	715	LOS ALAMOS	726	SANTA FE
705	CURRY	716	LUNA	727	SIERRA
706	DE BACA	717	MCKINLEY	728	SOCORRO
707	DONA ANA	718	MORA	729	TAOS
708	EDDY	719	OTERO	730	TORRANCE
709	GRANT	720	QUAY	731	UNION
710	GUADALUPE	721	RIO ARRIBA	732	VALENCIA
711	HARDING	722	ROOSEVELT		

UTAH

COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME
801	BEAVER	811	IRON	821	SEVIER
802	BOX ELDER	812	JUAB	822	SUMMIT
803	CACHE	813	KANE	823	TOOELE
804	CARBON	814	MILLARD	824	UINTAH
805	DAGGETT	815	MORGAN	825	UTAH
806	DAVIS	816	PLUTE	826	WASATCH
807	DUCHESNE	817	RICH	827	WASHINGTON
808	EMERY	818	SALT LAKE	828	WAYNE
809	GARFIELD	819	SAN JUAN	829	WEBER
810	GRAND	820	SANPETE		

TABLE 9. COUNTY ID AND COUNTY NAME

<u>CALIFORNIA</u>					
COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME
901	ALPINE	908	LASSEN	915	PLUMAS
902	AMADOR	909	MADERA	916	RIVERSIDE
903	CALAVERAS	910	MARIPOSA	917	SAN BERNARDI
904	ELDORADO	911	MODOC	918	SIERRA
905	FRESNO	912	MONO	919	TUOLUMNE
906	IMPERIAL	913	NEVADA		
907	INYO	914	PLACER		

<u>IDAHO</u>					
COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME
1001	BANNOCK	1005	FRANKLIN	1009	POWER
1002	BEAR LAKE	1006	JEROME	1010	TWIN FALLS
1003	CARIBOU	1007	MINDOKA	1011	OWYHEE
1004	CASSIA	1008	ONEIDA		

<u>KANSAS</u>					
COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME
1101	CHEYENNE	1107	KEARNY	1113	SEWARD
1102	FINNEY	1108	LOGAN	1114	STANTON
1103	GRANT	1109	MORTON	1115	STEVENS
1104	GREELEY	1110	RAWLINS	1116	THOMAS
1105	HAMILTON	1111	SCOTT	1117	WALLACE
1106	HASKELL	1112	SHERMAN	1118	WICHITA

<u>NEBRASKA</u>					
COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME
1201	ARTHUR	1207	GARDEN	1213	MCPHERSON
1202	BANNER	1208	HAYES	1214	MORRILL
1203	CHASE	1209	HITCHCOCK	1215	PERKINS
1204	CHEYENNE	1210	KIETH	1216	SCOTTS BLUFF
1205	DEUEL	1211	KIMBALL		
1206	DUNDY	1212	LINCOLN		

TABLE 9. COUNTY ID AND COUNTY NAME

<u>OKLAHOMA</u>					
COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME
1301	CIMARRON	1302	TEXAS		

<u>OREGON</u>					
COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME
1401	HARNE	1403	LAKE		
1402	KLAMATH	1404	MALHEUR		

<u>TEXAS</u>					
COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME
1501	ANDREWS	1508	DEAF SMITH	1515	OLDHAM
1502	BAILEY	1509	ECTOR	1516	PARMER
1503	CASTRO	1510	EL PASO	1517	REEVES
1504	COCHRAN	1511	GAINES	1518	TERRY
1505	CRANE	1512	HARTLEY	1519	WARD
1506	CULBERSON	1513	HOCKLEY	1520	WINKLER
1507	DALLOM	1514	LAMB	1521	YOAKUM

<u>WYOMING</u>					
COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME	COUNTY ID	COUNTY NAME
1601	ALBANY	1609	HOT SPRINGS	1617	SHERIDAN
1602	BIG HORN	1610	JOHNSON	1618	SUBLETTE
1603	CAMPBELL	1611	LARAMIE	1619	SWEET WATER
1604	CARBON	1612	LINCOLN	1620	TETON
1605	CONVERSE	1613	NATRONA	1621	UINTA
1606	CROOK	1614	NIOBRARA	1622	WASHKAKIE
1607	FREMONT	1615	PARK	1623	WESTON
1608	GOSHEN	1616	PLATTE		

TABLE 9. COUNTY ID AND COUNTY NAME

APPENDIX 4

SUMMARY OF FEDERAL, STATE, AND PRIVATE ACTIONS
RECOMMENDED TO ACCELERATE GEOTHERMAL ENERGY
DEVELOPMENT IN THE SOUTHWEST REGION

Prepared by
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for the

Regional Operations Research Program
for Development of Geothermal Energy
in the Southwest United States

DOE Contract No. EG-77-S043992

June 10, 1978

New Mexico State University
New Mexico Energy Institute
Las Cruces, New Mexico

SUMMARY OF FEDERAL, STATE, AND PRIVATE ACTIONS
RECOMMENDED TO ACCELERATE GEOTHERMAL ENERGY
DEVELOPMENT IN THE SOUTHWEST REGION

1.0 INTRODUCTION

The New Mexico Energy Institute at New Mexico State University, in participation with the States of Arizona, Colorado, Nevada, New Mexico and Utah, is conducting a Regional Operations Research Program for Development of Geothermal Energy in the Southwest United States. The project is funded by the U.S. Department of Energy, Four Corners Regional Commission, and State of New Mexico Energy Resources Board.

The objectives of the program are:

- 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.
- To delineate the public actions, together with their schedules required, for the scenarios to materialize.
- To develop a computer-base data storage and retrieval system of a regional program progress monitor of the level of a preliminary working model which is capable of displaying program approach, but not loaded with all available data.

This document addresses the second of the above program objectives, but includes private actions as well as public actions necessary to accelerate geothermal energy development in the Southwest. This report is only one component of the work products directed toward the second objective. The NMEI Core Team and the five State Teams also describe Federal, State and private actions in their quarterly progress reports and in the first year final report. The context of this report is based largely upon a questionnaire prepared by the consultant and distributed to the State Teams and to the Regional Advisory Committee for the Southwest OR Project. It is also based upon direct communications which the consultant has had with the Core Team, the State Teams, geothermal industry representatives, and other State and Federal officials throughout the first year of the project.

This report summarizes recommended actions which are necessary to develop and utilize the geothermal energy resources which exist in the five States of the Southwest Region. The magnitude of the potential geothermal resource is considerable. Both electric and non-electric, direct thermal

applications exist and are being explored. As of this time, however, no commercial-scale geothermal project is in operation. The Federal and State governments and the private geothermal industry, including utilities, have strong interests in developing the geothermal potential. The actions recommended in this report, if implemented, would speed geothermal development on its way toward a significant contribution to the energy produced, consumed, and exported by the Southwest Region.

The report is divided into three major sections. Section 2.0 delineates actions required of the Federal, State and private sectors for the entire Southwest Region. The first seven "recommended regional actions" are in decreasing order of the priority generated by the questionnaire. The next six action items are not prioritized, except for being of lesser importance than the first seven. Section 3.0 lists actions required more specifically on a state-by-state basis, but include Federal and private actions as well as State actions. Section 4.0 tabulates the various recommended actions by the principal party responsible for implementation--Federal, State and private.

2.0 RECOMMENDED REGIONAL ACTIONS

2.1 Tax Incentives

The number one priority recommendation of the State Teams, the federal agency representatives, and the geothermal developers is to provide state and federal tax incentives to the geothermal industry by the 1980's. Tax incentives similar to those currently received by the oil and gas industry are typically specified, but other special incentives are advised also.

2.1.1 Depletion Allowance

Allowance of the 22 percent depletion allowance and the expensing of intangible drilling costs are the prime tax incentives that are recommended. Some question exists as to whether the geothermal resource is a depletable resource, and, therefore, does it technically qualify for a depletion allowance. However, the mere fact that the question is a real question testifies to the uncertainty of knowledge regarding the several forms of geothermal energy and to the risks to industry in expending funds for geothermal resource development.

It is certainly possible that a resource area may provide geothermal energy for an infinite period of time, but it is also possible that the rate of energy withdrawal may be sufficiently great to cause a short or long term depletion of the energy at the quality and quantity necessary for economic utilization. From the point of view of practical economics, geothermal developers and utility companies must generally scale their construction costs and production schedules on a thirty-year period of amortization and operation. Only actual experience over the next twenty-five to fifty years will prove whether geothermal resources are depletable and whether the thirty years production schedule is realistic. In order to obtain that experience, however, a geothermal resource depletion allowance will have to be provided or the development of geothermal energy will not readily occur.

2.1.2 Intangible Drilling Costs

The case for the expensing of intangible drilling costs for state and federal income tax purposes is identical to that offered by and provided to the oil and gas industry. The risks of obtaining dry holes in geothermal drilling are great. In addition, even if a hot or wet hole is obtained, considerable time elapses between drilling and energy production; these time

periods often see major changes in economic or political conditions which may jeopardize the advancement of the drilled well to an actual energy production well.

2.1.3 Property Taxes

The deferral of property taxes on the geothermal land and physical installation until energy production for commercial purposes occurs is a recommended special tax incentive for the geothermal industry. This recommendation originates not just within the framework of creative tax incentives but primarily because of the aforementioned time intervals between drilling for geothermal field development and energy production from a constructed power facility for commercial transmission and consumption. The time required can easily range from three to six years, so that significant tax savings and increased investment capital can be realized by the geothermal industry.

2.1.4 Exemptions for Non-Productive Leases

A related tax incentive calls for the elimination and or return of property taxes on land leases which have been proven to be non-productive for commercial energy purposes. While special provisions might be necessary to disallow speculative holdings of geothermal leases, the objective of this incentive is to encourage exploration for producing leases without a tax disincentive for non-producing leases.

2.1.5 Investment Tax Credit

An investment tax credit (10%) is advocated for the geothermal development industry. The tax credit would apply to physical equipment and facilities necessary for the production, conversion and transmission of energy of geothermal origin. As with other investment tax credits, the purposes of a geothermal investment tax credit are to stimulate investment of capital funds in geothermal energy equipment and to promote the increased development of geothermal energy as an alternative energy source.

2.1.6 Retrofit Incentive

A tax incentive for the outfitting or the retrofitting of existing business and industry buildings, equipment or processes to utilize direct thermal geothermal energy is recommended. For the energy-using sector of business and

industry, this incentive would complement those tax incentives recommended above for the energy-producing industry. The technology does exist for many low temperature, direct thermal applications of geothermal energy and the geothermal resources exist also. Nevertheless, a stimulus is believed necessary to allow business and industry to adapt their present facilities to a new energy form and to speed the development of specialized low temperature applications.

2.1.7 Early Adoption of Tax Incentives

The final recommendation on tax incentives is that they be instituted by the early 1980's at the latest, for three major reasons: First, the incentives are needed now to stimulate growth and competition within the geothermal industry. Second, the industry is small enough at the present time such that the total geothermal-related taxes going to state and federal treasuries are not all that significant; therefore, it is better to institute the tax credits and exemptions now before their impacts on the state and federal treasuries would require major adjustments in the flow of tax dollars. Third, tax incentives are viewed as absolutely essential for geothermal energy to make a significant contribution to the nation's energy needs.

2.2 Development Drilling

Tax incentives are viewed by the geothermal industry as the primary mechanism for instituting an expanded national and regional effort in geothermal resource assessment and exploration and geothermal field development; i.e. tax incentives would free up the capital necessary for industry itself to support a substantial increase in development drilling. However, geologists, developers, researchers, and state government officials all agree that development drilling must be expanded and supported financially for geothermal development to reach its potential in the Southwestern states. The objectives of an accelerated development drilling program should be (1) to define geophysically the resource areas and (2) to reduce the development risks to the geothermal industry.

Preferred mechanisms for accelerating development drilling are as follows:

- Provide tax incentives to the geothermal industry
- Eliminate stringent environmental restrictions on exploration drilling

- Continue the DOE Case Study Program on bottom-hole drilling information

2.3 Land Leasing and Time Delays

Considerable concern exists by all parties in the Southwest over problems with the leasing of federal and state lands and with time periods associated with regulatory or institutional actions. More specifically, four problems and solutions are identified:

2.3.1 Lease Acreage Limitations

Present Federal law restricts individual or corporate leaseholders of Federal geothermal leases to 2,560 acres per tract and 20,480 acres per state. These limitations were conceived primarily to promote competition among investors and developers and to prevent speculative holdings, but in actual fact are found to be highly restrictive to geothermal development. The time durations for leases and the lease fees are associated problems.

The limitation of 2,560 acres per tract is particularly restrictive because of the still undefined geophysical characteristics of most geothermal resources and the absence of proven knowledge of resource requirements for the economic application of geothermal energy. The 2,560 acre limitation creates severe development engineering and financing problems for a geothermal developer because a given geothermal resource often spans several tracts belonging to different lease holders.

The 20,480 acre per state limitation and the associated time limit of ten years of exploration leases poses another kind of problem. The time period from lease application to commercial energy production is six to twelve years, with a majority of those years required for the various regulatory and institutional processes (permits, EISs, etc.). This acreage limitation often forces a developer to release lands from lease before exploration and development can be completed. A developer is forced to make "speculative" judgements on which lands have energy producing potential in order to keep an active, integrated leasing, exploration, and development program underway in a state.

2.3.2 U.S. Forest Service Land Leases

A majority complaint (from the states of Arizona, Colorado, and New Mexico of the five Southwestern states) is with the inability of the U.S. Forest Service to process geothermal lease applications. The Forest Service has had

lease applications pending since 1974 and/or 1975 in Arizona, Colorado, and New Mexico. It is reported that the lease applications are a low priority item for the Forest Service, because of their lack of personnel and funds to process them. It is recommended that the U.S. Forest Service act more expeditiously on lease applications on a regular basis and act immediately to clear the outstanding applications.

2.3.3 Time Delays on Required Institutional/Regulatory Actions

Reference has already been made to the time intervals required to process lease applications, drilling permits, EISs, etc. At the present time, these actions constitute the majority of the time involved from lease application to energy production. The State Teams and the Core Team in the Southwest Project are currently analyzing the State and Federal procedures that must be followed and are compiling flow charts of sequential steps required. The evaluation has already revealed that, in almost all instances, no time limits are specified by the applicable legislation or the regulative procedures within which the administrative agencies must operate and render definitive actions. It is contended that a considerable reduction in processing time and a significant savings in costs to the developer would occur if specific time limits were prescribed. The geothermal industry would prefer to have a decision, whether positive or negative, than no decision at all.

2.3.4 Restrictive Feature of KGRA's

Federal law prescribes that federal lands will be designated as Known Geothermal Resource Areas (KGRA's), if two or more lease applications are filed for the same or adjoining land areas. The severe consequence of the KGRA designation is that the existing lease applications are voided and the KGRA is opened for competitive bidding. Once again, the KGRA was conceived to promote competitive bidding and to prevent speculative holdings. The actual consequence, however, has been to decelerate substantially geothermal exploration. Developers are highly reluctant to expose themselves to competitive bidding on lands for which they have only limited geochemical/geophysical/geological information bearing upon the geothermal potential. In most all areas of the Southwest, considerable exploration is still required to determine the geothermal potential. The costs associated with competitive bidding on unproven resources are actually a front-end cost deterrent to geothermal exploration and development.

2.4 Favorable Economic Conditions

As with most alternative energy sources and systems (e.g. solar, wind, oil shale, coal gasification, etc.), favorable economic conditions and realistic fuel pricing must prevail for geothermal energy to be competitive economically within state and regional markets. In order to place geothermal energy in a realistic position, two actions are recommended. The first is that oil and natural gas be priced at the world market value or at energy replacement values. The second is that more quantitative supply and demand analyses of geothermal energy be conducted to define the economic conditions required to support geothermal energy development.

2.5 Influence of Environmental Advocates

Among the private, state and federal participants in the Southwest Geothermal Project, there is a very strong posture that environmental advocacy groups have an unduely large influence on and have significantly hindered geothermal development. The negative effect of their actions is regarded as not representative of the majority of citizens and of state and local governments. It is recommended that less attention be given by legislative, regulatory and administrative agencies at both the state and Federal levels to the actions of the environmental advocacy groups and that a more balanced appraisal of energy development and environmental protection be provided.

2.6 Standardization of State Regulatory Provisions

Current restrictions on geothermal development in the Southwest have included that certain states have not generated legislative and regulatory provisions specifically for geothermal energy and that legal definitions of the geothermal resource have not existed. Some states are in the process of approving new regulations; defining leasing terms; etc. Unfortunately, the fluid and unsettled nature of regulations at the state level have caused significant delays of exploration and development action by the geothermal industry.

The Southwest States in general appear to support the development of geothermal energy and are participating cooperatively in the Southwest OR Project. The OR Project does encompass an examination of institutional and regulatory procedures. Yet no concerted, collaborative action has been initiated by the State governments at either the legislative or executive levels to examine the beneficial features of standardized regulatory provisions. It is

recommended that such a detailed examination be a major component of the continuing OR project.

2.7 Environmental Restrictions on Exploration

The existence of environmental factors as a limitation on geothermal development in the Southwest appears twice in the above listings. It appears again here within the specific context of severe limitations on the exploration phase. The geothermal industry regards exploration as that phase of overall development which is essentially 100% financial risk to industry but is their investment for the nation in seeking new energy resources.

The physical aspects of exploration do require moving equipment over relatively unexplored or untouched lands and do cause minimal disturbances to the natural environment. Each new hole drilling is based upon information gained from the preceeding holes drilled and the exploration decisions are made largely in the field; in other words, the drilling pattern and locations can not often be prescribed precisely in advance. Therefore, the exploration phase does not lend itself to the highly specific requirements of EISs and similar regulatory proceedings. In particular, the industry finds that the archaeological impediments to exploration permits give rise to frequent time delays and to additional costs of exploration. In general, the industry finds that there are more environmental barriers to exploration than there are incentives and aids to a positive exploration ethic.

2.8 Low Temperature Technologies

In inventorying the geothermal resources and applications, the State Teams have identified extensive opportunities for low temperature utilization of geothermal energy throughout the Southwest. Many of these applications are for business and industry operations and processes which have not previously been engineered for direct thermal geothermal energy. Technology development is required both for the capturing of the energy from the low temperature reservoirs and for specific business, industrial, and agricultural applications. The Arizona State Team has compiled an extensive list of direct thermal applications and is evaluating their potential for Arizona business and industry.

2.9 Demonstration Projects for Low Temperature Applications

The more advanced of the low temperature, direct thermal applications

of geothermal energy are greenhouse heating and municipal district heating. Several communities throughout the Southwest have feasibility studies underway, have demonstration project proposals pending with the DOE, or are strongly interested in district heating applications. These communities are in need of planning and design assistance from their State governments or consulting engineers; more specifically, the communities need the funds to support these activities. In addition, with an increasing awareness of the potential for district heating (largely generated by the activities of the State Teams during the past year), communities are calling for a continuation and expansion of the DOE program for direct thermal geothermal demonstration projects.

2.10 Water Resources and Water Rights

Concern exists throughout the entire Western region over the effect that the withdrawal of geothermal waters will have on existing water tables used for agricultural, municipal and other purposes. Examples of temporary draw-down of local water tables from geothermal operations have been reported in Utah, for example. The geothermal industry maintains that their deep wells for electrical power production are far below the depths of municipal and agricultural wells and into entirely different aquifers. The question of water rights immediately impinges on geothermal development whenever surface waters or aquifers which supply surface waters are touched by the development. The specific recommendation on this subject is that more attention and more funding be provided to an analysis of water resources and water rights as geothermal development proceeds. In addition, the geothermal industry prefers a legislative remedy, rather than judicial judgement, to the definition of geothermal waters; the industry appears to prefer the DOE proposal to remove "geothermal water" from the Federal "water resource."

2.11 DOE Case Study and Loan Guarantee Programs

The DOE Case Study (bottom hole information) and Loan Guarantee Programs are highly regarded by geologists, geothermal developers, and State government representatives in the Southwest Region. These programs are supportive of the geothermal industry. Whereas both programs initially received cool attention from the geothermal industry, the Case Study Program is drawing more and more participation and the Loan Guarantee Program has several applications approved

or in process. It is being recommended that the Case Study Program be extended beyond its current cut-off date of

The geothermal industry regards the Loan Guarantee Program as a more effective program for stimulating development and commercialization than cost-sharing demonstration projects. Indeed, the Loan Guarantee Program applies at the point of commercialization and revenue generation, which is where the industry prefers to operate. However, the program is not fully useable by the larger geothermal companies, (a) because of the limitation of guarantees of \$25 million per project and \$50 million per borrower, and (b) because no large company will risk default on such small loans anyway.

Three specific recommendations are advanced to enhance the Loan Guarantee Program: (1) The Congressional limit of \$200 million for the entire outstanding amount of guaranteed loans needs to be increased to provide for the surge of geothermal projects that are potentially possible in the 1980's; (2) the requirement for the geothermal "borrower" to put up 25% of the project financing should be modified to allow credits for the actual prior investments by industry to bring the project to the commercialization/loan guarantee stage; i.e. the value to the project at the time of loan guarantee application should apply to the 25% financing requirement; and (3) the allowable interest rate by the lender should be reduced to the prime rate rather than 25% over the prime rate (the industry investment of 25% of project financing should be sufficient to guarantee low risk financing to the lender).

2.12 Public Education

Geothermal energy development has not received the financial support nor the public attention that other alternative energy sources have, particularly solar. For the general public, geothermal energy is still largely a mystery and is viewed with scepticism and misunderstanding. The contrast in public perception between solar energy and geothermal is most striking: solar derives from the brilliant radiance of the sun and geothermal derives from the mysterious, dark bowels of the earth! Similarly, solar is promoted as free of environmental impact and geothermal is challenged on land, air, and water factors.

The State Teams have witnessed this dramatic disparity in public perceptions as they have discussed the prospects of geothermal energy use with businesses and communities. Some residents of rural communities will not even listen to proposals for geothermal use. This lack of knowledge and broad misunderstanding of geothermal energy extends throughout the general populace.

The situation allows environmental advocacy groups to dominant decision-making, not only at the local level, but also at the Federal level when energy program funds are allocated.

It is recommended that the DOE and State governments sponsor a major public education program which puts forward the potentials and advantages for geothermal energy.

2.13 Handbooks of Institutional/Regulatory Procedures

As previously mentioned, the State Teams and the Core Team for the OR Project are compiling and analyzing information on the institutional and regulatory procedures for the entire geothermal process. The institutional/regulatory process is different in each State, with different principals, agencies and practices involved. In addition, the process is often complex, providing for different points of entry, time elements, and options for the government decision-maker.

While these procedures are often known to the large geothermal developers and to the utilities, they are generally not known, understood, or accessible to the individual lease applicant, community official, small business/industry energy user, out-of-state investor, etc. Therefore, it is recommended that handbooks of flow charts and instructions be prepared which cover the institutional and regulatory procedures from lease application to specific end uses of the geothermal energy.

3.0 RECOMMENDED STATE-BY-STATE ACTIONS

Many of the recommended actions in Section 2.0 apply to all of the States in the Southwest. In addition to those actions, the following specific actions are needed within the individual States to accelerate geothermal development.

3.1 Arizona

3.1.1 Approval and application of the proposed new State geothermal rules and regulations in order to activate again the leasing of geothermal lands.

3.1.2 Expanded exploratory drilling to assess the geothermal resource potential throughout the State.

3.1.3 Technological studies and technology transfer information on new, primarily direct thermal, uses of geothermal energy by business, industry, and agriculture.

3.1.4 Technology development of absorption cooling and heat pumps for space cooling applicaitons to reduce the demand for electrical energy.

3.2 Colorado

3.2.1 Issuance of leases by the U.S. Forest Service on applications pending since 1974.

3.2.2 Development of geothermal space heating applications to relieve the demand for natural gas.

3.2.3 Financing and planning assistance for community and small business geothermal projects.

3.3 Nevada

3.3.1 Participation of the geothermal industry in the formulation and legislation of State laws and regulations regarding geothermal energy resources in order to provide an institutional/regulatory process conducive to geothermal development.

3.3.2 Integration of State and Federal leasing and regulatory actions to accomodate the fact that 86% of Nevada is Federal land.

3.3.3 Expanded Federal lease acreage allowance per tract and per State to allow access to and utilization of adjoining State and Federal lands.

3.4 New Mexico

3.4.1 Extension of the State lease duration from five years to ten years to conform to Federal standards and to activate leasing of State lands again by the State Land Department.

3.4.2 Eliminate Federal drilling restrictions on depth in order to promote deeper well drilling for space heating applications.

3.4.3 Rejection of unreasonable demands by environmentalists that would halt geothermal development.

3.5 Utah

3.5.1 Industry needs to acquire more drilling rigs to match the requirements indicated by the Utah development scenarios for production well drilling over the next 20 years.

3.5.2 U.S. Congress needs to authorize higher dollar limits for Loan Guarantee Program and make Program applicable to the larger geothermal companies.

3.5.3 State government needs to specify the tax rates on geothermal developments in order to allow the industry to calculate that element of its development costs.

4.0 SUMMARY

In this final section, an attempt is made to summarize the recommended actions by the principal parties which must implement the actions--Federal, State, or private; naturally some multiple responsibility exists.

4.1 Federal Actions

- Provide tax incentives
- Support development drilling
- Accelerate and expand leasing of lands
- Reduce time delays of institutional/regulatory procedures
- Generate favorable economic conditions
- Reduce influence of environmental advocates
- Reduce environmental restrictions on exploration
- Develop technologies and provide demonstration programs for low temperature applications

- Analyze water resources and water rights
- Continue DOE Case Study Program
- Expand Loan Guarantee Program
- Education of the public

4.2

State Actions

- Accelerate leasing of lands
- Reduce time delays of institutional/regulatory procedures
- Standardize regulatory procedures and legal definition of the geothermal resource
- Reduce environmental restrictions on exploration
- Provide planning assistance to communities for low temperature applications
- Clarify water rights related to geothermal resources
- Education of the public
- Provide handbooks of institutional/regulatory procedures

4.3

Private Sector Actions

- Development Drilling
- Participation in DOE Case Study Program
- Utilization of Federal Loan Guarantee Program
- Education of the public
- Expand drilling rig capacity
- Assist in formulation of State laws and regulations
- Develop low temperature technologies