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FINAL REPORT

DIRECT HEAT APPLICATIONS OF GEOTHERMAL ENERGY IN THE GEYSERS/CLEAR LAKE REGION

Volume 1, Final Report

Geotechnical Assessment, Agribusiness Applications,
Socioeconomic Assessment, Engineering Assessment

August 1977

Work Performed Under Contract No. EG-77-C-03-1326

Geonomics, Incorporated
Berkeley, California

U. S. DEPARTMENT OF ENERGY Geothermal Energy

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FINAL REPORT

**DIRECT HEAT APPLICATIONS OF
GEOTHERMAL ENERGY IN THE
GEYSERS/CLEAR LAKE REGION**

**VOLUME I
GEOTECHNICAL ASSESSMENT,
AGRIBUSINESS APPLICATIONS,
SOCIOECONOMIC ASSESSMENT,
ENGINEERING ASSESSMENT**

Prepared by

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AUGUST 1977

GEONOMICS PROJECT NO. 76.0132

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Prepared for

**ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
DIVISION OF GEOTHERMAL ENERGY**

Under Contract No. EG-77-C-03-1326

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**ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
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SECTION ONE

INTRODUCTION

The present combined geotechnical, environmental, socio-economic impact, and engineering study has been undertaken to identify the different uses to which geothermal heat and fluids could be applied as a direct utilization of resource or as heat utilization. The primary research objective of the current phase, Phase Zero, of the project is to determine optimal direct heat utilizations for agricultural, industrial and/or space heating uses, to determine optimal differential benefits, and to recommend the studies for the next phase of development and construction of such facilities.

Optimal utilization of the resource for nonelectric uses is determined by a multiplicity of interactive factors. For example, undeveloped geothermal resources are believed to occur in a number of locations in the study areas. The economic/geotechnical feasibility of developing them for some specific uses must be weighed against the feasibility of purchasing steam at the wellhead from the resource companies who are developing that resource, at present for electrical power generation only. On the other hand, major environmental factors may militate against some development plans while favoring others. A still different consideration--societal needs of the local population --may tend to favor some agricultural or industrial processes while relegating others to a lower level of desirability.

Six potential geothermal sites were identified in The Geysers-Clear Lake KGRA, four of which are located in Lake County, one in Sonoma County and one in Napa County. These sites were selected for comprehensive assessment, and are the subject of the combined study of direct heat availability, either from local sources or from waste heat from geothermal power plants in the area.

These sites are:

- Site No. 1: Sulphur Bank/High Valley/Borax Lake
- Site No. 2: Thurston Lake/Mt. Konocti
- Site No. 3: Collayomi Valley/Middletown
- Site No. 4: High Valley Creek/Cobb/Glenbrook

Site No. 5: Alternative Site/Calistoga, Napa Co.

Site No. 6: Alternative Site/The Geysers, Sonoma Co.

See Figures 2.2, 2.9 and 2.10 in Section 2, Geotechnical Assessment, for delineation of these study areas.

Specifically, this Phase Zero prefeasibility study has the following rationale and objectives:

a. Geotechnical Assessment: Assessment of existing and potential geothermal resources in the areas which are applicable to direct-heat agricultural and industrial processes. To that end, publicly available geological, geochemical, geophysical, and hydrogeological data relating to geothermal resource occurrence were gathered, analyzed, and presented.

b. Agricultural and Industrial Applications: Assessment of the optimum agricultural enterprises (environmentally controlled growth or processing) which would be suitable at each of the identified potential sites. Low-enthalpy geothermal fluids from either the exhaust of geothermal power plants or from low-base-temperature wells in the area may be utilized for a variety of industrial processes. Some of these, if proven to be feasible, could result in environmental improvements.

c. Environmental Assessment: Comprehensive consideration of the physical, chemical and biological environmental impact of new development of geothermal energy in order to identify potential environmental degradation.

d. Socioeconomic Assessment: Description of the social and economic milieu in which geothermal development is proceeding; definition of impacts on Lake County; and identification of nonelectric applications compatible with values and needs of the county.

e. Engineering Assessment: A preliminary assessment was made of the engineering feasibility of transportation of geothermal fluids from their source of supply to the likely point of utilization.

In summary, the purposes of this study are:

- (a) To determine the feasibility of developing low-enthalpy agricultural/ industrial processes which can utilize geothermal heat.

- (b) To investigate the methods of integrating a number of nonelectrical uses in an integrated system, utilizing by-product heat of the electrical generation system, wells uneconomical for electrical production or isolated well groups too small for electrical power generation.
- (c) To indicate the characteristics of several possible agricultural and industrial uses, and their potential for the several geothermal areas in The Geysers-Clear Lake KGRA.
- (d) To indicate the environmental and socioeconomic effects of geothermal energy development and nonelectric applications on the local and regional level.

The five tasks have been carried out by the following organizations and project personnel:

Task 1 - Geotechnical Assessment: Geotechnical assessment of all sites, including geological and geochemical analysis and hydrogeology. This task was carried out by Geonomics, under the direction of Dr. Tsvi Meidav.

Task 2 - Potential Agribusiness and Industrial Applications: Evaluation of alternative agricultural and industrial development. This task was carried out by Ag West, under the direction of Mr. Ken Aoyama, with Dr. Richard Matherson as consultant.

Task 3 - Environmental Assessment: Environment and ecological assessment. This task was carried out by Ecoview, under the direction of Dr. James Neilson.

Task 4 - Socioeconomic Assessment: Socioeconomic assessment, including social and economic profiles of the Lake County sources of revenue, plus principal problems unique to the area. This task was carried out by Geonomics, under the direction of Dr. Mae Z. Meidav.

Task 5 - Preliminary Engineering Study: Engineering, heat transportation, and well site and power plant parameters associated with proposed applications. This task was carried out by the Ben Holt Company, under the direction of Mr. Anker Sims.

The reports on the investigations carried out under each of these tasks have been written by the organizations and staff as indicated. Task 2 and Task 5 have been submitted in conformity with the format and editing style of the entire report. Task 3 is submitted as received from the subcontractor with no format or editing changes.

Dr. Richard Matherson served also as an overall project consultant, providing general project guidance.

Geonomics, as prime contractor, has been responsible for Section One and Section Seven of this report.

1.1 BACKGROUND

The developed portion of The Geysers geothermal field is in Sonoma County, bordering Lake County. It is likely that the high-quality, vapor-dominated reservoir extends into Lake County. Manifestations of shallow geothermal resources in four other sites within the county make the county an outstanding region for potential geothermal resource development of all types.

Geothermal development for electrical generation in The Geysers-Clear Lake KGRA of Sonoma, Lake, and Napa counties in California has generated varying degrees of both resistance and support from the public. A significant part of resistance stems from county residents who are concerned about the potential negative effects of odor, health hazards, and noise, with the Lake County Energy Council being the most vocal and organized proponent of that position. Resistance also stems from those small communities in Lake County which are in the vicinity of The Geysers geothermal power development in the northwest corner of Sonoma County. These communities neither received nor perceive any benefit from the development in Sonoma, yet have borne the brunt of the undesirable air and noise pollution. In a study of public opinion concerning geothermal development in Lake County, a highly polarized pattern of pro and con was found to exist, with the majority of respondents favoring geothermal development (Vollintine and Weres, 1976). Of four groups categorized along environmental impact perception and economic expectations, almost all of those who perceive no negative impacts and expect economic benefits, favor development. Of the two groups who perceive negative impacts, the most divided are those who both perceived negative impacts and expect economic benefits. Of those who both perceive negative impacts and expect no economic benefits, as predicted, no one supports development. The same study found no demographic correlates of pro and con attitudes. Rather, attitudes and opinions in regard to geothermal development were formed largely by public debate and the media. A large majority of respondents favored regulation of geothermal development; this was true for even the most pro-geothermal group. The broad and diverse spectrum of public opinion and interest groups is described in Section Five.

Nonelectrical uses could be associated with planned electrical generating complexes effectively, to utilize the portion of the heat that will be wasted. Alternatively, in the geothermal areas which have not been developed so far for any purpose, and where the heat sources are insufficient to permit economical electrical generation using current methods, it would be feasible for several possible types of nonelectrical uses to be installed.

Lake County's resources have largely been exploited by firms from outside the county. Consequently, comparatively little of its natural wealth has remained to be reinvested or to insure the renewability of these resources. Its lumber resource is largely gone and little or no effort has been made to maintain or renew the resource. Much of the watershed resource has been contracted to other counties. The development of geothermal energy, especially for electric power generation, is often perceived as producing only limited economic and employment opportunities for Lake County residents. On the other hand, nonelectric applications are commonly perceived as more directly beneficial to the residents.

1.2 SOME TECHNICAL CHARACTERISTICS OF GEOTHERMAL RESOURCES

Geothermal energy has a number of unique characteristics which set it apart from other energy resources. Geothermal energy tapped for power production purposes may fall into one of two states: (a) vapor dominated (dry steam), or (b) liquid dominated (saturated steam). Vapor dominated reservoirs are rather rare.

Classical liquid-dominated reservoirs are characterized by a temperature in the range of 180°-260°C (356°-500°F), although both higher and lower temperatures are possible. When drilled and allowed to flash, part of the superheated water will flash into steam while the bulk of it will be carried along as boiling water. In conventional flashed-steam geothermal power plants, the steam fraction is separated from the boiling water in a separator. The steam is conducted into the turbine at a temperature of about 140°C (284°F), while the boiling water, at the same temperature, is generally discharged into a nearby stream after some further cooling off, or reinjected underground. Usually about 70-80% of the mass of the superheated geothermal fluid is discharged as boiling water, and only 20-30% is utilized as dry steam for power generation.

Many geothermal specialists have expressed concern about the waste involved in discharging the liquid portion without

making any further use of it. Hence, some recent geothermal resource development plans have been based upon total resource utilization. About half the energy contained in the geothermal fluid is in the water portion, which to date has been traditionally wasted through discharge. If the total cost of development of a geothermal field is charged against the steam supply for a power plant, the cost of the separated geothermal brine at the wellhead is practically zero.

A normally productive geothermal well with a production diameter of 20-22 cm (8-9 in.) will produce 100-200 tons of fluid per hour. The amount of calorific energy which is thus available for direct heat uses is of the order of 8-16 million kilocalories per hour per well. Smaller diameter wells would provide a smaller amount of energy output.

The hot brine is typically too saline for direct agricultural or other human consumption because of the usually high content of dissolved solids in the water. At times it may be corrosive, containing minerals which are detrimental to agriculture even in very small quantities (e.g., boron). Hence, the chief use envisioned for the geothermal brine is in the extraction of heat for agricultural and industrial uses, and not for direct utilization of the cooled fluid for agriculture or industry.

High mineral content in the geothermal brine may require the utilization of a binary heat exchanger to extract the energy without causing undue fouling or corrosion of the pipes. This is indeed how geothermal energy is utilized in Melun, France. On the other hand, the Oregon Technical Institute in Klamath Falls, Oregon, is directly heated by geothermal fluids, without a heat exchanger. A careful water and gas analysis must be conducted of the produced fluids in order to establish their corrosive and potentially harmful biological qualities.

From the above, it is to be noted that the amount of energy produced for power production is very large, compared to any possible direct heat use in the area itself. Nonelectric uses may be developed as a side aspect of electric power development efforts, or as separate, small scale direct-heat development.

The final section of this report summarizes the chief findings of this study.

SECTION TWO: TASK ONE

GEOTECHNICAL ASSESSMENT

2.1 INTRODUCTION

Six areas have been selected for preliminary study to determine optimal nonelectric uses to which geothermal resources may be harnessed. These studies include an assessment of the available data on the geotechnical factors required for decision making. The concluding section of this task (2.4) summarizes our findings.

Available data on geothermal hot springs - their flow, geochemistry and significance - have been studied in conjunction with available geologic, hydrogeologic and geophysical information to permit an overall assessment of the resource potential.

The geochemical data on hot springs and water wells is incomplete as of this moment, particularly in regard to the analysis of elements and compounds which serve as indicators of geothermal reservoirs. However, in a recently completed study not yet released to the public (Donnelly, et al. 1977), the United States Geological Survey (USGS) will provide some key information on the geochemistry of hot springs in the Clear Lake region.

Hot springs are transient features which may cease due to a number of causes. Among these is fault movement or self-sealing caused by precipitation of dissolved minerals in the channel-ways of the spring. Many favorable areas underlain by hot ground water may exist which do not exhibit surface thermal indications. In some areas, thermal springs may exist which are only local phenomena and do not derive their water from large hot ground water reservoirs. Hence, in order firmly to establish whether a potential of hot ground water exists, geotechnical exploration techniques must be carried out.

Only limited geochemical or geophysical data has been published regarding the geothermal resources of the Clear Lake region. Much work has been done by private companies, but that information is not available to the public. Within The Geysers steam field sufficient data is now available for setting up a geologic model. Here, the reservoir exists primarily within

the greywackes of the Franciscan Formation. Northward of the Collayomi fault the limited data at hand suggests that the reservoir apparently changes from the vapor-dominated type to the liquid-dominated type, within the younger volcanics present to the northeast (Figure 2.1). However, that model is not necessarily certain. Both types of reservoirs require the presence of a cap rock, an impervious layer of rock overlaying the actual reservoir. At such locations where leakages to the surface occur, along fault planes or fractures, manifestations of the reservoir exist. However, due to self-sealing or other factors, such manifestations are more often absent than present.

The hydrologic regime of the areas of study is of importance, as specific mineral presence within the overall dissolved mineral content frequently is, or can be, indicative of a thermal reservoir.

The absence of complete data other than geologic maps makes it imperative that additional, more detailed studies be undertaken to aid in localizing and determining the presence of potentially exploitable hot ground water sources within the areas selected for study.

In the following discussion we review the geology, hydrogeology, and geophysics of The Geysers-Clear Lake area and the Calistoga area. The conclusions (Section 2.4) suggest that a number of localities outside the dry steam field are likely targets for shallow hot water development for nonelectric uses.

2.2 GEOLOGY AND GEOHYDROLOGY

2.2.1 Introduction

The six study areas occupy the southern portion of Lake County and adjoining portions of Sonoma and Napa Counties (Figure 2.2). In this region, late Mesozoic, predominantly marine sedimentary rocks (the Franciscan Formation for the greater portion, and limited exposures of the Knoxville Formation of the Great Valley Sequence), are locally unconformably overlain by Quaternary lacustrine deposits (the Cache Formation) and unconformably overlain and intruded by Quaternary volcanic rocks (the Sonoma and Clear Lake volcanic fields). Recent alluvial deposits fill all main valleys (Figure 2.3).

Unravelling the geologic puzzle in the study sites is an extremely difficult task, due to very complex structure, poor

rock exposure and extensive ground cover. Despite this, field mapping has been done by several workers, the most recent being Hearn, et al. (1976) who mapped a region that included Sites 2, 3, 4, 6 and the southern portion of Site 1 at 1:24,000 scale. A larger 1:62,500 scale map (Brice, 1953) is also available, although it is substantially less detailed. Figure 2.4 presents a generalized geologic column of The Geysers-Clear Lake area.

2.2.2 Stratigraphy and Lithology

A brief description of the lithology of individual units is presented below in chronological order, from oldest to youngest. The areal distribution of these units is shown on the generalized geologic map of The Geysers-Clear Lake area and the Calistoga area (Figure 2.3).

2.2.2.1 The Franciscan Formation

The oldest and most widespread rocks in the study areas belong to the Franciscan Formation of late Jurassic to Cretaceous age. The Franciscan Formation forms the basement complex of the area and is typical of Franciscan rocks over a large part of California (McLaughlin, 1975). The majority of rocks in Sites 1, 3, 6 and the northern portion of Site 4 belong to the Franciscan Formation. Hsü (1971) considers the Franciscan Formation to be a tectonic mélange (a mixture of rocks derived from more than one depositional realm) and describes the three major rock types found in the Franciscan in order of descending abundance as: 1) marine sediments; 2) ophiolitic rocks; and 3) biogenic sediments.

Marine sediments form the great majority of the Franciscan and consist largely of greywacke with minor shale. Ophiolitic rocks occur as altered intrusive and extrusive igneous rocks (greenstone) consisting largely of pillow basalts, breccias, tuffs, minor gabbro and large, generally concordant bodies of diabase and serpentized ultramafic rocks. Minor amounts of chert (biogenic sediments) usually appear as interbedded with shale but also as discontinuous bands and isolated blocks.

The Franciscan rocks have been metamorphosed and repeatedly deformed. The marine sediments are often highly faulted, fractured and sheared to the point where few original bedding features can easily be recognized. Serpentine is present along most faults and within highly sheared zones.

The Franciscan Formation forms the basement complex of the area and is the host rock for the geothermal reservoirs of The

Geyser steam field; its primary porosity is quite low. The major zones of porosity and permeability in this formation occur as secondary features along fault and fracture planes.

2.2.2.2 The Knoxville Formation

The metamorphosed Franciscan Formation is in tectonic contact with the younger, shallow-water marine and continental, consolidated sediments assigned to the Knoxville Formation of the Great Valley sequence. These sedimentary rocks are extensively exposed and form continuous units to the east of Clear Lake and in the eastern portion of Site 1. Elsewhere in the study areas these rocks exist only as disconnected folded and faulted blocks.

The Knoxville Formation is composed largely of dark green to black shale, siltstone and minor interbedded greywacke, fine grained sandstone and conglomerate. It is distinguished from the Franciscan Formation by its predominance of shale in relation to greywacke. In contrast to the rocks of the Franciscan Formation, the rocks of the Knoxville Formation are only mildly deformed by faulting and folding.

Upson and Kunkel (1955) describe the permeability of the Knoxville Formation as low and the formation is considered as essentially non-water bearing. Hot water is likely to occur in that formation primarily in fracture zones.

2.2.2.3 The Cache Formation

The Cache Formation of Pliocene age is found locally around Clear Lake. This formation consists of a thick sequence of slightly folded and faulted lacustrine clay, silt, sand and gravel beds with minor amounts of tuff. It is exposed along the southern arm of Clear Lake in the vicinity of Clear Lake Highlands (Site 1) and Lower Lake (Site 2).

The Cache Formation is the oldest unconsolidated sedimentary body in the area. The yields from most wells penetrating the Cache Formation are low and frequently insufficient for domestic needs. However, this formation has been penetrated by only a few wells and not much is known about its waterbearing properties. Upson and Kunkel (1955) estimate the Cache Formation could probably yield moderate quantities of fresh water. It is expected that areas of shallow warm water in the area where the Cache formation is near the surface would be useful targets for exploration for low-enthalpy thermal water for nonelectric uses.

2.2.2.4 The Late Tertiary and Quaternary Volcanic Rocks

Late Tertiary and Quaternary volcanic rocks occur in two separate volcanic fields. The older Sonoma volcanics of Pliocene age extend from the vicinity of Mt. St. Helena at the boundary of Lake and Napa counties southward to San Francisco Bay. The younger Clear Lake volcanics, Holocene in age, occupy the southern portion of the Clear Lake topographic basin and extend southward towards the crest of the Mayacmas Range (Figure 2.5). These two groups of volcanics are geographically and temporally separate.

The Sonoma volcanics form most of the mountainous areas bordering Napa Valley. Site 5, at the head of Napa Valley not far from the base of Mt. St. Helena, is completely included within the Sonoma Volcanics. These volcanics consist mainly of andesite tuff and flow with rhyolite and diatomaceous members.

Water occurs throughout the Sonoma volcanics within the zone of saturation. Principal aquifers occur in tuffs. Flows of andesite and basalt are generally impermeable.

Many wells in the vicinity of Calistoga (Site 5) obtain water from the Sonoma volcanics, but few well logs are available and the principal aquifers are not recognized. The water temperature in most wells in this area is considerably above the expected average for the regional geothermal gradient. Three wells directly northwest of Calistoga (Site 5) periodically discharge hot water and steam.

The younger and more northern Clear Lake volcanics of Holocene age occupy the southern part of the Clear Lake topographic basin and extend southward toward the crest of the Mayacmas Range. The Geysers geothermal production area is beyond the southwest border of the field. These volcanics have been extensively described by Hearn, et al. (1975).

Site 2 is almost completely dominated by a cover of the Clear Lake volcanic rocks. The southern portion of Site 4 also lies within this volcanic veneer.

The Clear Lake volcanics consist of basalt, andesite, dacite and rhyolite, which occur as domes, flows and pyroclastic deposits. These volcanic rocks exist in a structurally and chronologically complex sequence.

Most of these volcanics have not been penetrated by wells because their terrain is a rough, untillable land. However, they may absorb appreciable quantities of water from rain and

melting snow, storing the water in joints and fractures. Numerous small carbonated warm springs occur within the volcanic fields at the southern edge of Clear Lake.

It is interesting to note that the age of volcanism generally decreases in a northeastward direction from The Geysers. This may suggest that the shifting locus of magmatic activity may be responsible for the development of newer geothermal reservoirs whose expressions near Clear Lake are not as well developed as those in The Geysers. We expect that a number of warm-water reservoirs would be discovered in the area surrounding Clear Lake, based upon the existing evidence.

2.2.3 Recent Alluvium

Recent alluvial deposits fill the main valleys of the study sites. These valleys include High and Burns Valleys (Site 1), Excelsior Valley (southern portion of Site 2), Collayomi and Long valleys (Site 3) and Napa Valley (Site 5).

The alluvium consists of unconsolidated gravel, sand and clay deposited on alluvial fans of moderate slope, in creek and river channels, on flood plains and in playas. The deposits range in thickness from a few centimeters to 60 meters. This recent alluvium is the only important fresh water bearing material in The Geysers-Clear Lake area. It is conceivable that the recent alluvium would serve as a warm-water reservoir in some places.

2.2.4 Structure

Structural grain in the study site is predominantly northwest, concordant with the general structural grain of the Coast Ranges and the San Andreas Fault zone. The dominant northwest structural grain is due largely to the prevailing fault pattern. Faults within the study site trend from northeast to northwest, the northwest trend being dominant. Faults can often be recognized by the presence of serpentinite trending along the fault.

The fault pattern in the Franciscan Formation is highly complex. Major faults within the Franciscan metamorphic terrain seldom occur as single structural features, but more often as zones of faults or highly sheared rock. The prevailing fault pattern in the Franciscan consists of: 1) imbricate northeast- southeast- and southwest-dipping high-to-low angle thrust faults that separate tectonic slabs within the Franciscan, and 2) later steeply-dipping northwest trending faults with vertical and strike-slip components over-printed over the earlier thrusts (McLaughlin and Stanley, 1975).

Because of the complexity of this faulting, it is difficult and, in some cases, impossible to distinguish early faults from later faults, or whether recent displacement occurred along an old fault plane. The Collayomi fault zone, north of area 3, is such a fault zone (Figure 2.6). The zone of fracture can be wider than 400 meters (one quarter mile). The Collayomi fault can be traced by linear topographic features, drainage offsets and the presence of serpentinite along the strike of the fault.

Also following the dominant northwest tectonic trend is the Konocti Bay fault zone which bisects Site 2 and the central portion of the Clear Lake volcanic field. This fault can be traced by steep scarps, aerial photography lineaments, and by the presence of warm water 25°-52°C (77°-125.6°F) in springs and wells (Goff, et al. 1976). The thermal waters that seep from the fault zone have a high magnesium content, suggestive that serpentine lies at shallow depth all along the fault zone (Goff, 1976), (Figure 2.3).

Pre-Tertiary rocks near The Geysers area (Sites 3, 4 and 6) comprise an extremely complex southeastward-plunging antiform known as the Mayacmas antiform. The Mayacmas antiform is a secondary flexure in the northward extension of the broader Diablo antiform and its core is composed of rocks of the Franciscan Formation (McLaughlin and Stanley, 1975). The axis of this fold plunges southeast through Sites 6, 4 and 3. The southwest side of the Mayacmas antiform is flanked by a system of steeply dipping, northwest trending strike slip faults. Also present are prominent northwest and east-west-trending fault sets which traverse the antiform, locally displacing Quaternary deposits.

2.3 GEOPHYSICS

2.3.1 Introduction

Several geophysical studies have been conducted relating to regions of geothermal potential extending into Lake County. Taken together, they define a fairly consistent picture for a deep magma source beneath Mt. Hannah, where the near surface volcanic and thermal manifestations tend to be centered. Following is a summary of the results pertaining to the area of the six potential sites upon which this report concentrates (Figure 2.2), in The Geysers-Clear Lake area and the Calistoga region.

The usual reconnaissance methods of geophysics have been air photography, infrared surveys, electrical resistivity, aeromagnetic and gravity surveys. In geothermal areas, reliance upon these techniques has lessened in recent years, and increasing attention has been given to regional structure and plate tectonic theory, followed by geoelectric, passive seismic techniques, and the drilling of temperature gradient and heat flow holes.

2.3.2 Gravity

A major gravity low centered over Mt. Hannah drew the attention of several workers, and Chapman (1966) first suggested a deep magma chamber as a possible source. W. F. Isherwood (1975) added considerably to the existing data base. The resulting residual gravity map (Figure 2.7) presented several significant features:

- a. The major gravity feature is the Mt. Hannah low, a circular depression of about 30 km in diameter. Its steep gradients seem unaffected by the northwest-southeast structural trends. This low is centered at the southwest edge of the Quaternary volcanic field, and extends well into the Franciscan metamorphic terrain.
- b. The recognized volcanic vents south of Clear Lake correlate with residual gravity lows, suggesting a genetic relation.
- c. A secondary closed low is apparent in the steam production region of The Geysers, the overall Mt. Hannah low being divided by a higher gravity ridge.
- d. A gravity high centered over the southeast end of Clear Lake does not have any clear correlation with surface geology. Rough approximations of the depth to sources of these various anomalies may also be found in Figure 2.7.

Meidav (1974) has concluded that the gravity low may be associated with a magma chamber whose volume is approximately 1,000 cu km (240 cu mi). The presently known vapor-dominated field is considered a small expression of the much larger heat source below. The gravity data suggests that the effect of the magma chamber may extend to the east side of Clear Lake.

2.3.3 Aeromagnetics

The results of an aeromagnetic survey compiled by the USGS in an open-file report (1973) have been summarized by Isherwood (1975):

- a. A complex pattern of high magnetic relief shows a major high to the northeast. No surface exposure can account for this anomaly, but it lies on the trend of major serpentinite bodies.
- b. Other magnetic highs correlate well with mapped ultrabasic bodies, as has been noted throughout the California coast ranges.
- c. Several local magnetic highs and lows correspond to volcanic peaks dependent upon normal or reversed magnetization.

The main field component was removed, with the resultant residual magnetic field showing no major differences. Filtering the anomalies by upward continuation provided further depth estimates and conclusions:

- a. The highs associated with ultrabasic rocks disappear quickly with upward continuation, with the exception of the Collayomi fault zone serpentinite which may have considerable depth beneath the volcanics.
- b. The low beneath southeast Clear Lake may represent a dipole low to the Collayomi fault high, supported by their having roughly the same depth.
- c. Although these central sources may extend several kilometers deep, none are as deep as the surrounding (northeast and southwest) anomalies would imply for their sources.

Pseudogravity, spectral and filtering techniques used by Isherwood (1975) in comparing gravity and magnetic data all favor a low density mass above its Curie point temperature. The high temperature accounts for the lack of central magnetic anomalies to correlate with the Mt. Hannah gravity low. This mass is probably centered from 10-13 km (6.2-8.1 mi), with a radius near 7 km (4.3 mi), and must have a density approaching that of magma. Apparently there is a roof pendant or caprock which directs hydrothermal activity toward the steam field at The Geysers along fractured zones (this is also supported by some seismic data).

2.3.4 Seismicity

The Clear Lake region is seismically active, with minor and medium shock epicenters reported in the Mayacmas Mountains and in the Lakeport area on the west shore of Clear Lake (Garrison, 1972). The strongest historic tremor was to the north in 1962, with an epicenter approximately 10 miles northwest of Kelseyville, at intensity VII.

Microearthquake surveys have been conducted near The Geysers area (Lange and Westphal, 1969; Hamilton and Muffler, 1972). Hypocenters generally lie outside the region of the possible anomalous mass which has been described above. However, two foci were located at 4 and 6 km (2.5 and 3.7 mi) depths within the ridge of higher gravity separating the Mt. Hannah low from the production low. General shallowness of earthquake foci can be construed as evidence of shallow elevated temperatures and lack of brittleness in the rock, in which case the two aforementioned foci could represent fracture or collapse within a roof pendant between two cupolas of a magma chamber (Isherwood, 1975).

2.3.5 Geoelectrical

Electrical surveys show a well-defined resistivity low beneath the south-central part of the volcanic field. It is in part coincident with the gravity low and extends to a depth of at least 5 km (3.1 mi) (Stanley, Jackson and Hearn, 1973).

It is possible to interpret this resistivity low as being due to either a thick section of marine shale, hot saline brines, or both. Neither the structurally complex lithology of available sections nor drill hole data suggest marine shales of great thickness, and the low is most likely due to elevated temperature and salinity of water above a heat source at depth. Thus, the resistivity survey suggests that certain areas in the Clear Lake region possess the potential of encountering hot water at a relatively shallow depth. That data may serve as a useful basis for locating sites for more detailed exploration.

Two similar zones of low resistivity have been observed 8.1-12.9 km (5-8 mi) northwest of The Geysers and one closed low resistivity anomaly 2-3 km (1.2-1.9 mi) deep has been observed 6.5 km (4.0 mi) southeast of Geysers Resort at Castle Rock Springs (Stanley, et al. 1973). Unlike The Geysers anomaly, however, there is some indication of structural control along the fault blocks of this region.

A very interesting and, in our opinion, quite a significant resistivity low occurs on the east side of Clear Lake centered more or less around the Sulphur Bank mine area. This may suggest that a large high temperature reservoir occurs in the Sulphur Bank area. That area appears to be a particularly promising target for exploration for shallow geothermal reservoirs.

2.3.6 Summary

The geophysical investigations described above agree fairly well with the simple geophysical model of Isherwood (1975), Figure 2.8. The geology of the Franciscan terrain is exceedingly complex, however, and it is a certainty that larger deviations from any model will exist on a detailed local scale. Unfortunately, much site-specific data is proprietary in nature. Special arrangements or new investigations may be necessary for the next phases related to these specific sites, depending upon what further data is needed as the study progresses.

2.3.7 Thermal Waters in the Six Study Sites

Six areas in The Geysers-Clear Lake area and the Calistoga area have been selected for survey of geothermal resources capable of being developed at low cost. The characteristics of the principal hot springs and geothermal wells of the area are summarized in Table 2-I and Table 2-II and their locations are shown in Figures 2.9 and 2.10.

Wells drilled for various purposes which upon completion showed the presence of thermal waters may be used for nonelectric purposes, depending on the applicability of the water to the specific use. Criteria needed to establish whether or not a thermal water is usable, depending on the planned nonelectric use, are:

- a. water temperature;
- b. volumetric discharge;
- c. water chemistry, including the corrosive nature of the fluid, content of dissolved gases, and mineral constituents having adverse effects on products to which the thermal water will be applied, such as plant and animal life;
- d. methods of disposal of waste water in cases where the fluid may not be discharged directly into the drainage system.

The two main sources of spring locations, descriptions and chemical analyses are G. A. Waring (1915) and C. F. Berkstresser (1968).

Data on water chemistry of natural springs in the area is incomplete and does not give information on the type or total amount of dissolved mineral constituents necessary to evaluate the potential nonelectric use of the thermal water.

Table 2-I describes the physical appearance of the naturally occurring springs, their reported temperature, reported discharge and chemical analyses of some springs as available. Following is a brief summary of thermal activity in each specific site:

- a. Site 1--The only recognizable sources of natural thermal waters are several small, migratory springs issuing from the walls of the Sulphur Bank Mine, an abandoned sulfur and mercury working (Figure 2.9). Temperature of thermal waters reaches 49°C (120°F) at the surface and 80°C (176°F) at 94.5 m (310 ft). Present waters are extraordinarily high in ammonia (464 ppm) and boron (620 ppm).
- b. Site 2--Several carbonated springs issue along the southwest shore at Clear Lake within the boundaries of Site 2 (Figure 2.9). Discharge of water is small. These waters have a high gas content and bubble out of the lake water. Seeps of ammonia are known to occur in the Thurston Lake area (Garrison, 1972). It is probable that the ground water is hot in this area. Temperature of thermal waters reaches approximately 35°C (95°F) at the surface. Drilling to 1,220 m (4,000 ft), temperatures in excess of 177°C (350°F) have been encountered. These thermal waters have a high boron concentration (greater than 100 ppm).

Union Oil Company has applied for permits to drill three geothermal wells south of Thurston Lake. McCulloch Oil has a well under permit south of Konocti Bay (Figure 2.9, Table 2-III).

- c. Site 3--The main thermal features in Site 3 are the Castle Rock Geothermal field and the Ford Flat Prospect field (Figure 2.10). In 1969, Signal Oil and Gas Company discovered the Castle Rock field and to date a large number of dry steam wells have been completed in this field (Table 2-III).

Available chemical analysis from Castle Creek Spring reveals thermal water to be low in fluoride (0.6 ppm), boron (0.72 ppm) and ammonia (0.5 ppm).

This entire area is leased by private companies, with the prospect of developing high quality dry-steam wells in much of that area. A steam well drilled by McCulloch has been mentioned as being available for nonelectric uses.

Another potential prospect for shallow hot ground water in Site 3 is Harbin Springs, near the farmland of Collayomi Valley to the north of Middletown.

- d. Site 4--There is only one small recognizable naturally occurring hot spring in Site 4 (Figure 2.10). However, Site 4 hosts the Cobb Valley geothermal field. To date, at least four proven geothermal wells have been drilled in this field. A geothermal well completed in the Franciscan terrain of the Cobb Valley area yielded the condensate, which is chemically presented in Table 2-IV, and is presumed to represent the chemistry of other wells in the area. Much of the Cobb Valley area is likely to be underlain by a vapor-dominated geothermal reservoir.
- e. Site 5--Thermal waters occurring near Calistoga have been reported since the 1880's. The water temperature in most wells drilled in the Sonoma volcanics is considerably above the average geothermal gradient. The mud bailed from well 9N/7W - 26 P during drilling was 60°C (140°F). Two wells in section 9N/7W - 26J periodically discharge hot water and steam in the manner of a geyser (Kunkel and Upson, 1960; Figure 2.10). Chemical analysis for the Calistoga hot spring (9N/6W - 31M) reveals a high amount of fluoride (12 ppm) and a high amount of boron (9.2 ppm). Hot springs near Calistoga reach a temperature of 78°C (173°F). Drilled wells have reached temperatures of 137°C (278°F).
- f. Site 6--The Geysers geothermal field lies within the boundaries of Site 6. About 100 proven geothermal wells have been drilled within the limits of this site. A chemical analysis of the condensate from Pacific Gas and Electric Company Unit 4 is given in Table 2-V.

The Geysers and Castle Rock springs (Site 3) are the two groups of hot springs known to be related to vapor-dominated geothermal systems in The Geysers area. They are characterized by:

- 1) high temperatures;
- 2) high concentrations of sulfate; and
- 3) low concentrations of chloride (Garrison, 1972).

The Geysers geothermal field is a vapor-dominated steam field. The likelihood of developing any of the shallow warm water aquifers for direct heat uses is considered minimal, because of their limited extent, the rough topography in the area.

2.4 CONCLUSIONS REGARDING AVAILABILITY OF GEOTHERMAL ENERGY FOR NONELECTRIC USES

Geophysical data, combined with geothermal geochemistry of the water in The Geysers and Clear Lake geothermal province, all point to the likelihood of occurrence of a number of vapor-dominated and liquid-dominated geothermal reservoirs in that region. The heat source for the entire geothermal system is believed to be a shallow magma chamber, as evidenced by gravity data.

Figure 2.11 presents a tentative classification of geothermal reservoirs in The Geysers-Clear Lake region for non-electric uses. We have subdivided the region into three categories:

- a. an area where dry steam has already been encountered or is likely to be encountered
- b. areas where warm water of interest to nonelectric applications is likely to be encountered at shallow depth, and
- c. areas where warm water will probably be encountered at a shallow depth, but present data at our disposal is not as conclusive as the data in the area designated as Likely Warm Water Reservoir.

Figure 2.11 should be considered as a very preliminary map of regions of interest from a geothermal point of view in The Geysers-Clear Lake region. It is based upon geological/geophysical inference as much as on the limited data at hand. The

best data available is that for The Geysers dry steam field where more than 100 wells have already been drilled, and the results of drilling are reasonably well known.

The Geysers dry-steam field covers Sites 4, 6 and part of 3 (Figure 2.11). The dry steam field will be developed primarily for power production purposes. However, it is quite conceivable that in some places test wells will encounter reservoirs which will behave as liquid-dominated systems. In those cases, the developers of the geothermal resource may consider direct heat applications.

The nature of the geothermal field north of the Collayomi fault is not fully known because of the paucity of data. However, one well to a depth of 2,000 m (6,562 ft) on Ely Flat, and another at Sulphur Bank mine, suggest that liquid-dominated reservoirs do occur north of the fault. Donnelly, et al. (1977) believe that the Collayomi fault marks the approximate northern boundary of the dry steam field. Furthermore, their geochemical analyses suggest that the liquid-dominated geothermal reservoir which covers much of the Clear Lake region is characterized by base temperatures on the order of 195°-210°C (383°-410°F). Such analyses do not permit the determination of the actual depth at which the water which has emanated as a hot spring reaches its base temperature. Such a determination may be estimated by geophysical methods and finally proven by actual drilling. Drilling at the Sulphur Bank mine to a depth of 440 m (1,440 ft) has encountered water at a temperature of 185°C (365°F). The Sulphur Bank mine area is located in the midst of a resistivity low and hence a much broader region in Site 1 is likely to be characterized by shallow moderate-to-high temperatures (Figure 2.11).

Seepage of gases along the south shore of Clear Lake is strongly suggestive of leakage manifestations from a high temperature reservoir at depth. Therefore, the southeastern portion of the Clear Lake shoreline belt is classified as probable shallow warm water reservoir region. That region probably extends across Thurston Lake. Further to the north, the Soda Bay springs emanate at temperatures of up to 51°C (124°F). These are suggestive of a possible structural situation (perhaps crossed faults) which allows water to ascend from greater depth and to cool down through mixing with shallower, colder ground water.

It is not possible to estimate the depth to which it would be necessary to drill holes which would encounter ground water at some high temperatures, say 90°C (194°F). That depth is likely to vary from 30 m (98 ft) and upwards. However, it is

reasonable to assume that in the entire area marked as Likely Warm Water Reservoir (Figure 2.11), water at that temperature may be found in different places from depths as shallow as 30-300 m (98-980 ft) in the more favorable locations. Favorable locations are probably associated with fault zones in the area, where hot water has had an opportunity to ascend from the deeper reservoir without losing all of its heat through conduction or mixing with colder ground water. Agribusiness enterprises can specify the areas of greatest interest from their standpoint and the geothermal specialist will probably be able to locate the potential shallow hot water prospects in the immediate vicinity.

Permeability and flow rates are likely to be variable. However, based upon drillers' experience in the Clear Lake region, production rates of the order of 114-379 liters per minute (30-100 gallons per minute) from a standard size well are normal. Depth to water table is variable, generally depending upon the elevation relative to the elevation of Clear Lake. In some separate water basins this cannot be considered as valid.

To structure an orderly program of development of the thermal resources believed to exist within all six sites, it is recommended that geophysical methods be employed to determine reservoir depths and possibly their parameters in the most favorable areas. Temperature gradient drilling has proven to be a successful exploration tool in The Geysers area and should be equally valid in the surrounding sites.

Concurrent with these investigations, a program of stimulation of natural manifestations could be attempted by drilling to a depth of several hundred feet in the vicinity of such manifestations, after undertaking adequate geologic and geophysical studies required to determine the subsurface location of potential upflow zone.

Basically, the thermal manifestations indicate reservoir leakage, thereby establishing the presence of the geothermal reservoir. With the low temperatures encountered and the limited effluent discharges, only limited use can be made of such naturally occurring discharges.

It is recommended that the following program be undertaken:

- a. Resampling of thermal waters and gases for analysis and interpretation of results to determine if parameters indicating the existence of geothermal reservoir are present;

b. Geophysical investigation of the most promising areas to determine the indicated presence of the geothermal reservoir and its depth;

c. Shallow drilling to establish the presence of near-surface geothermal reservoirs, and for temperature gradient studies

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Figure 2.1 A sketch of the approximate limits of the vapor dominated reservoir area of the Geysers-Clear Lake area (after Donnelly, et al, 1976)

Figure 2.2 Location of six potential sites for development of non-electric uses of geothermal energy

Figure 2.3 A generalized geologic map of the Geysers-Clear Lake-Calistoga area (modified from Hannah, 1975)

AGE	ROCK UNIT	COLUMN	FEET	DESCRIPTION
QUATERNARY	Alluvium, landslides, and terrace deposits	Qal, Qls, Qt	1-200	Gravel, sand, silt, clay; landslides are mostly volcanic debris and/or serpentine
	Konocti volcanics	Qdv	100-1500	Quartz-, olivine-, and sanidine-bearing dacitic and andesitic lavas
	Obsidian	Qro	50-700	Black, rhyolitic
	Pyroclastic dacite	Qpd	100-300	Black, siliceous, glassy
	Cobb Mt. volcanics	Qr	200-1500	Rhyolitic flows and tuffs
	Boggs Mt. flows	Qs	100-500	Dark gray porphyritic andesitic lavas
	Parini Hill flows	Qs	100-500	Andesitic flows bearing xenocrysts of quartz and xenoliths of aluminous rocks
	Olivine basalt	Qob	50-500	Mostly quartz-bearing
	Rhyolite tuff	T-Qr	0-200	White coarse- to fine-grained tuff
	Cache fm.	T-Qc	300-6500	Fresh-water deposits of gravel, silt, and clay, except near top of section where tuffaceous sediments, marl, limestone, and diatomite predominate
UPPER JURASSIC	Knoxville Group	Ja	10,000+	Mostly gray shale interbedded with smaller amounts of gray chert-type sandstone; conglomerate locally prominent; little chert, greenstone, and schist. Large bodies of serpentine
	Franciscan Group	Jf	15,000+	Mostly graywacke-type sandstone, some shale and conglomerate; little chert; intruded by serpentine (sp) and greenstone (gp). Scattered areas of schistophane

Figure 2.4 A generalized columnar section of the Geysers-Clear Lake area. (modified from Brice, 1953)

Figure 2.5 Location of late Tertiary and Quaternary volcanic groups in Lake, Napa and Sonoma counties

The V pattern indicates Quaternary volcanic rocks and the line pattern late Tertiary volcanic rocks

Figure 2.6 Generalized structural map of the Geysers area showing Quaternary volcanic rocks (V pattern) and major fault zones in the Cobb Mountain-Ford Flat area. (after Goff and McLaughlin, 1976)

A. Sixth-order surface fit to regional gravity; 5 mgal contour intervals. Shaded rectangle is the portion used to adjust complete Bouguer gravity values.

B. Residual gravity reduced at 2.67 g/cm³; 2 mgal contour interval

C. Depth estimates from gravity anomalies

Anomaly	Half-width estimate to center (km)	Gradient estimate to top (km)
Mt. Hannah low	11.5(sphere)	7.5
Production low	2.2(cylinder)	1.9
SE Clear Lake high	4.5(sphere)	2.3

Figure 2.7 Regional and residual gravity maps for the Geysers-Clear Lake area with some depth estimates for source of residual anomalies (from Isherwood, 1975)

Figure 2.8 Generalized cross section through the Geysers-Clear Lake geothermal region (after Isherwood, 1975)

Figure 2.9 Location of hot springs in Sites 1 and 2

Figure 2.10 Location of hot springs in Sites 3, 4, 5 and 6

Figure 2.11 Tentative classification of geothermal systems in the Geysers-Clear Lake region for non-electric uses

TABLE 2 -I DESCRIPTION OF SPRINGS IN THE SIX STUDY SITES

Name of Owner or User	Location	Temperature C° (F°)	Elevation m (ft)	Geologic Formation	Reported Discharge (gpm)	Physical Appearance, Development & Use (as of date)	Water Type and Related Remarks	References
<u>SITE 1:</u>								
<u>Bradley Mining Co.</u>	13N/7W-5L	99 (210)	408 (1340)	Clear Lake Volcanics	--	This is an artificial geyser from a well about 457 m (1500 ft) deep. Unused.	Sodium bicarbonate Odor of hydrogen sulfide	Berkstresser
<u>Sulphur Bank Mine</u>								
Sulphur Bank, spring on north wall	13N/7W-5X	69 (157)	396 (1300)	Clear Lake Volcanics	--	Unused (1968)	--	Roberson & Whitehead
Spring #1	--	69 (156)	--	--	--	--	--	Berkstresser
Spring #2	--	77 (170)	--	--	--	--	--	Roberson & Whitehead
Thermal Spring at Hermann Pit	--	41 (105)	--	--	--	--	--	Waring, Roberson & Whitehead
Bubbling Thermal Spring at Hermann Pitt	--	53 (128)	--	--	--	--	--	Waring, Roberson & Whitehead
<u>Unnamed Springs</u>	14N/7W-23B	20 (68)	--	--	--	--	--	Upson & Kunkel (1955)
	14N/7W-23J	18 (64)	--	--	--	--	--	"
	14N/7W-24N	18 (65)	--	--	--	--	--	"
<u>SITE 2:</u>								
<u>Carbonate Spring</u>	13N/8W-10x	36 (96)	411? (1350?)	Clear Lake Volcanics	5	Drinking (1915)	Warm carbonate sps issue for 25 yd along the lake margin. 440 yds farther south, numerous other springs rise with a stretch of 200 yds long.	Waring (1915)
<u>Soda Bay Springs</u>	13N/8W-6x	31-51 (87-124)	404 (1326)	Cache	400	Springs issue from many poorly defined orifices in bedrock. Discharge is largely below the surface of Clear Lake as indicated by gas bubbles in the lake. Domestic (1915). Unused (1968)		Waring (1915) Berkstresser (1968)

<u>Name of Owner or User</u>	<u>Location</u>	<u>Temperature</u> C° (F°)		<u>Elevation</u> m (ft)	<u>Geologic Formation</u>	<u>Reported Discharge</u> (gpm)	<u>Physical Appearance, Development & Use</u> (as of date)	<u>Water Type and Related Remarks</u>	<u>References</u>
<u>SITE 3:</u>									
<u>Harbin Hot Springs</u>									
<u>Sulphur Spring</u>	11N/7W-20Q	48	(119)	506 (1660)	Franciscan	5.0	Spring is covered by rock cribbing. Water is piped into swimming pool. Very little variation in flow reported. Resort use (1968)	Sodium bicarbonate water tastes of sulfides. Strong odor of H ₂ S	Berkstresser (1968)
<u>Iron and Soda Spring</u>	11N/7W-20Q	47	(116)	506 (1660)	Franciscan	0.5	Spring is covered. Water is piped to edge of walkway. Resort use (1968)	Sodium bicarbonate	Berkstresser (1968)
<u>Arsenic Spring</u>	11N/7W-20x	32	(90)	488 (1600)	Franciscan	1.0	--	Calcium bicarbonate	Berkstresser (1968)
<u>Magnesium Spring</u>	11N/7W-20x	15	(59)	488 (1600)	Franciscan	1.5	Slight flow. Spring reportedly issues from shale behind main building. Resort use. (1968)	Sodium bicarbonate	Berkstresser (1968)
<u>Anderson Hot Spring</u>	11N/8W-25R	53	(128)	494 (1620)	Franciscan	>0.4	Spring issues from cracks in an old mine tunnel. Unused (1968)	Calcium magnesium bicarbonate, odor of H ₂ S and sulfide taste.	Berkstresser (1968)
<u>Castle Hot Spring</u>	11N/8W-35x	73	(163)	731 (2400)	Franciscan	8.0	Resort use (1915)	Water is mildly sulphurated but is otherwise only slightly mineralized.	Napas (1976) Waring (1915) Barnes et al
<u>Unnamed spring</u>	11N/7W-29A	17	(62)	427 (1400)	--	>3.0	Spring consists of many seeps in spring channel. Water is collected and delivered by pipe to roadside. Public supply use (1968)	Magnesium bicarbonate	Berkstresser (1968)
<u>SITE 4:</u>									
<u>Gordon Hot Spring</u>	11N/8W-3x	33	(92)	731 (2400?)	Franciscan	5.0	Unused (1915)	--	Waring (1915)

<u>Name of Owner or User</u>	<u>Location</u>	<u>Temperature C° (F°)</u>	<u>Elevation m (ft)</u>	<u>Geologic Formation</u>	<u>Reported Discharge (gpm)</u>	<u>Physical Appearance, Development & Use (as of date)</u>	<u>Water Type and Related Remarks</u>	<u>References</u>
<u>SITE 5:</u>								
<u>Pacheteau's Calistoga Hot Spring</u>	9N/6W-31M	99 (210)	107 (350)	Alluvium	520	Drilled well, 152 ft deep. Resort use (1968)	Sodium chloride. Silica deposits in pipes. Much gas and steam. Temp. 214°F.	Berkstresser (1968)
<u>SITE 6:</u>								
<u>The Geysers</u>	11N/9W-13A	45 (113)	549 (1800)	Franciscan	--	--	Acid magnesium sulfate.	Berkstresser (1968)
Unnamed spring	11N/9W-13H	44 (112)	427 (1400)	--	--	Spring issues from seeps along creek. Unused (1968)	Magnesium bicar- bonate sulfate. Weak odor of H ₂ S. Sulphur and metal- lic sulfides deposi- ted in spring channel.	Berkstresser (1968)
<u>The Devil's Kitchen</u>	11N/9W-13x	100 (212)	427 (1400)	Clear Lake Volcanics	--	--	Ammonia Sulfate	
<u>Geyser Develop- ment Company</u>	11N/9W-13x	53 (128)	427 (1400)	Franciscan	--	Spring supplies water to bath house. Resort use (1968)	Magnesium bicar- bonate. Weak odor of H ₂ S.	Berkstresser (1968)

TABLE 2-II CHEMICAL ANALYSES OF SPRINGS DESCRIBED IN TABLE 2-I
(in parts per million)

Name of Owner or User	Ca	Mg	Na	K	HCO ₃	SO ₄	Cl	As	Hg	Ba	NH ₄	NO ₃	F	PO ₄	B	H ₂ S	CO ₃	TDS	pH	Date of Analysis
<u>SITE 1:</u>																				
<u>Bradley Mining Co.</u>	26	23	1,340	44	2,600	680	900	0.5	0	0.3	354	14	1.4	0.32	828	+	0	7,300	8.1	10-4-66
<u>Sulphur Bank Mine</u>																				
Sulphur Bank spring on north wall										276									6.8	2-7-57
Spring #1	20	55	1,190	23	3,290	598	644	0	-	0.3	464	0	1.0	-	620	12	0	7,430	6.8	3-26-57
Spring #2	-	-	-	-	2,960	454	690	-	-	-	476	-	-	-	-	3.6	-	-	3.6	7-18-57
Thermal Spring at Hermann Pit	-	-	-	-	1,470	279	13	-	-	-	59	-	-	-	-	-	-	-	6.9	9-30-58
Bubbling Thermal Spring at Hermann Pit	-	-	-	-	4,060	31	760	-	-	-	460	-	-	-	-	9.4	-	-	7.2	9-30-58
<u>SITE 2:</u>																				
<u>Soda Bay Springs</u>																				
Temp. = 31°C	85	113	115	9.5	-	trace	60	-	-	-	4.8	-	-	trace	-	-	480	1,022	-	(1910)
Temp. = 32°C	92	118	104	12	-	trace	60	-	-	0	2.6	0	-	trace	-	-	529	1,070	-	(1910)
Temp. = 51°C	trace	2.1	1,722	29	-	trace	897	-	-	-	376	-	-	-	-	-	1,112	5,766	-	(1888)
Temp. = (un- known)	trace	0.1	1,547	trace	-	trace	879	-	-	-	421	-	-	-	-	-	1,171	5,324	-	-

TABLE 2-II CHEMICAL ANALYSES OF SPRINGS DESCRIBED IN TABLE 2-I
(in parts per million)

Name of Owner or User	Ca	Mg	Na	K	HCO ₃	SO ₄	Cl	As	Hg	Ba	NH ₄	NO ₃	F	PO ₄	B	H ₂ S	CO ₃	TDS	pH	Date of Analysis
<u>SITE 3:</u>																				
<u>Harbin Hot Springs</u>																				
Sulphur Spring	0.7	0.2	138	0.6	240	11	30	trace	0	-	1.0	0.1	3.7	0.01	1.3	+	24	384	9.0	10-5-66
Iron and Soda Spring	0.9	0.1	138	0.6	236	10	31	0	0	-	0.9	0	3.7	0.02	1.3	+	28	388	9.0	10-5-66
Arsenic Spring	62	26	23	1.3	361	7.1	7.9	-	-	-	-	-	-	-	-	-	0	-	7.6	10-31-56
Magnesium Spring	17	2.3	133	0.4	324	24	33	-	-	-	-	-	-	-	-	-	0	-	8.0	10-31-56
<u>Anderson Hot Spring</u>	106	46	38	6.7	286	335	1	0	0	0	15	0.1	0.4	-	0.2	+	0	1,020	7.9	10-5-66
<u>Castle Rock Hot Spring</u>	14	1.9	64	3.2	192	24.4	6	-	-	-	0.5	-	0.6	-	0.72	-	2	-	8.14	-
<u>Unnamed Spring</u>	19	68	7.9	0.1	362	6.0	3.5	trace	-	0	0	0.7	0.2	0.1	0	0	20	322	8.6	10-5-66
<u>SITE 4:</u>																				
<u>Gordon Hot Spring</u>	195	68	211	7	-	532	216	-	-	-	-	-	-	-	-	-	226	-	-	-
<u>SITE 5:</u>																				
<u>Pacheteau's Calistoga Hot Spring</u>	4.5	0	193	8.8	52	12	215	.13	0	0	0.6	0.1	12	0.6	9.2	+	42	663	9.0	10-13-66
<u>SITE 6:</u>																				
<u>The Geysers</u>	42	453	9.5	2.6	0	8,060	1,590	-	-	-	-	-	0.2	-	3.6	-	0	15,800	2.2	9-21-54
Unnamed Spring	32	58	4.7	0.9	180	139	1.3	.01	0	0	11	3.4	0.3	0.14	0.6	+	0	599	7.5	10-12-66
<u>The Devil's Kitchen</u>	47	281	12	5	0	5,710	0.5	-	-	-	1,400	-	-	-	3.1	-	0	-	1.8	-
Geyser Develop- ment Company	32	60	5.5	1.2	212	160	1.1	0	0	0	7.7	0.9	0.2	0.05	0.7	+	0	670	7.2	10-12-66

TABLE 2-III

GEOHERMAL WELLS LOCATION AND OWNERSHIP
IN SPECIFIED SITES, LAKE COUNTY, CALIFORNIA
(after H.G. Sisk, 1963)

SITE	* STATE OF WELL	COMPANY	WELL NAME	SEC.	T.	R.
3	P	AMINOIL	ABEL No. 1	26	11	8
3	P	AMINOIL	BARROWS No. 1	35	11	8
3	A	AMINOIL	BIANCHI No. 1	23	11	8
3	P	AMINOIL	CA- 956 73-34	34	11	8
3	P	AMINOIL	CA-958 76-35	35	11	8
3	P	AMINOIL	CA- 1862 26-27	27	11	8
3	A	AMINOIL	DAVIES ESTATE No. 1	36	11	8
3	A	AMINOIL	DAVIES ESTATE No. 2	31	11	7
3	P	AMINOIL	DILLINGHAM & VOUGHT	27	11	8
3	P	AMINOIL	Mc KINLEY No. 1	26	11	8
3	A	AMINOIL	Mc KINLEY No. 2	26	11	8
3	P	AMINOIL	Mc KINLEY No. 3	35	11	8
3	P	AMINOIL	Mc KINLEY No. 4	35	11	8
3	P	AMINOIL	Mc KINLEY No. 5	26	11	8
3	P	AMINOIL	Mc KINLEY No. 6	26	11	8
3	P	AMINOIL	Mc KINLEY No. 8	26	11	8
3	P	AMINOIL	M L M No. 1	26	11	8
3	P	AMINOIL	THORNE No. 1	27	11	8
3	P	AMINOIL	THORNE No. 3	27	11	8
3	P	AMINOIL	THORNE No. 5	27	11	8
3	P	AMINOIL	THORNE No. 6	26	11	8
-	A	AMINOIL	B-J No. 1	18	10	6
3	A	AMINOIL	DAVIES ESTATE No. 3	36	11	8
3	A	AMINOIL	DAVIES ESTATE No. 4	6	10	7
3	A	CHEVRON OIL	CHEVRON No. 1	5	10	7
4	P	Mc CULLOCH OIL	FRANCISCO No. 1	5	11	8
4	P	Mc CULLOCH OIL	FRANCISCO No. 2	5	11	8
4	P	UNION OIL	HORNER STATE 4596	6	11	8
4	P	UNION OIL	PHELPS	9	11	8
6	U	UNION OIL	BINKLEY	36	12	9

* P = Proven well
A = Abandoned well or dry hole
U = Well under permit

TABLE 2-III

SITE	* STATE OF WELL	COMPANY	WELL NAME	SEC.	T.	R.
3	P	SHELL OIL	CA-949 11-1	1	10	8
3	P	SHELL OIL	CA-949 11A-1	1	10	8
3	U	SHELL OIL	E	1	10	8
3	A	SHELL OIL	BOUNSALL	16	10	7
-	U	REPUBLIC GEO., INC.	GIUSTI No. 1	30	12	7
-	U	REPUBLIC GEO., INC.	BOUSCAL No. 1	30	12	7
-	A	E.B. TOWNE	SULLIVAN No. 1	18	12	8
2	A	GETTY OIL	KETTENHOFEN No. 1	28	13	8
1	A	EARTH ENERGY INC.	BRADLY MINING No. 1	5	13	7
1	A	HAWAII THERMAL POWER CO. & MAGMA POWER CO.	CLEAR LAKE No. 1	5	13	7
1	A	EARTH ENERGY INC.	BRADLY MINING No. 2	5	13	7
3	A	SOUTHERN UNION PROD. CO.	DAVIES No. 1	36	11	8
2	A	MAGMA ENERGY INC.	WATSON No. 1	20	13	8
2	U	MAGMA ENERGY INC.	WATSON No. 2	28	13	8
2	U	UNION OIL	JORGENSEN No. 1	36	13	8
2	U	UNION OIL	JORGENSEN No. 2	35	13	8
2	U	UNION OIL	JORGENSEN No. 3	6	12	7
3	U	AMINOIL	P.D.C. No. 1	22	11	8
3	U	AMINOIL	BIANCHI No. 2	23	11	8
3	U	AMINOIL	BADGER	23	11	8
3	U	AMINOIL	MLM No. 2	26	11	8
1	A	SULPHUR BANK GEOTHERMAL POWER CO.	SULPHUR BANK No. 1	5	13	8

* P = Proven well
A = Abandoned well or dry hole
U = Well under permit

TABLE 2-IV

CHEMICAL ANALYSIS OF A GEOTHERMAL CONDENSATE FROM A WELL COMPLETED
IN THE FRANCISCAN FORMATION, COBB VALLEY, CALIFORNIA

MAJOR ANIONS	MG/L*	ME/L**	DETERMINATION	MG/L*	DETERMINATION	MG/L*
SO ₄ - Sulfate	17.		Alkalinity - Total	230.	F-Fluoride	0.06
Cl - Chloride	7.4		Calcium Hardness CaCO ₃		B-Boron	14.
HCO ₃ - Bicarbonate	280.		Magnesium Hardness CaCO ₃	< 1	Al-Aluminum	< 0.2
CO ₃ - Carbonate	0		Total Hardness CaCO ₃	< 1	Mn-Manganese	< .06
NO ₃ - Nitrate	< 0.1		Total Dissolved Solids 180°C	61	Fe-Iron	.57
TOTAL ME/L**			Ammonia-N	63	Phenol	
MAJOR CATIONS			Sulfide	360	Grease & Oil	
Ca - Calcium	< 1					
Mg - Magnesium	< 1				Heavy Metals (As Group)	
					Mercury	0.006
			Turbidity (Turbidity Units)	36	ABS	
Na - Sodium	< 0.3					
K - Potassium	0.05		Hydrogen Ion Concentrate (pH)	6.1		
TOTAL ME/L**			Sp. Cond.-Micromhos 25°C	475		

* Milligrams Per Liter

** Milliequivalents Per Liter

Date of Collection: 8/7/76

TABLE 2- V

CHEMICAL ANALYSIS OF PG&E UNIT 4 CONDENSATE*
(after Hanck and Nekoksa, 1975)

pH	7.6-8.5
Conductance, μ mhos/cm	1430-2080
Ammonia, mg/l as N	145-242
Nitrate, mg/l	<0.1
Sulfate, mg/l	202-616
Boron, mg/l	103-208
Chloride, mg/l	<5.0
Alkalinity as CaCO_3	189-495
H_2S in hot condensate, mg/l	15 (average)
H_2S in cold condensate, mg/l	5 (average)
O_2 in hot condensate, mg/l	0
O_2 in cold condensate, mg/l	0.1-6.9

*Ranges obtained from seven samples during 1974
without any H_2S abatement

SECTION THREE: TASK TWO
POTENTIAL AGRICULTURAL AND AGRIBUSINESS
APPLICATIONS
(Ag-West)

3.1 INTRODUCTION

This pre-feasibility study was conducted to determine the potential agricultural and agribusiness applications of geothermal energy as it exists in the Clear Lake KGRA. In this Phase Zero report an attempt has been made to avoid hypothetical projections based on insufficient evidence, as well as figures and charts that are irrelevant at best, and confusing at worst.

The entire Clear Lake KGRA was studied in order to determine the overall limitations, needs and potentials for agricultural development as they relate to geothermal development in the future.

Sites in six study areas were evaluated for potential agribusiness uses. It became clear that the array of uses had considerable overlap from site to site. Therefore, it was decided that a detailed explanation of a single site would be more profitable to this report than separate reports for each. The High Valley Creek area site was selected as a demonstrative example for the following reasons: 1) this site, i.e., McCulloch Oil Corporation's Franciscan Well No. 1, is the only site with a producing geothermal well which might be available at this time for nonelectric uses; 2) this well has both hot water and steam up to 166°C (330°F); 3) McCulloch Oil Corporation and the land owner are cooperating in this study; 4) there is a potential of approximately 0.13 sq km (32 acres) that may be considered for some sort of development; 5) at this location an agricultural complex could be incorporated into the natural environment. However, conclusions regarding this site may be applicable to other sites.

The actual agricultural enterprises which will form the demonstration complex will be discussed in the context of this pre-feasibility study. The intent of this Phase Zero task is to specify enterprises and complex organization that, at this stage, seem practical and beneficial to Lake County. These enterprises have been evaluated as to present market conditions, area considerations and projected growth; recommendations will be made for in-depth feasibility studies necessary

for responsible decision-making to be conducted in Phase One and Phase Two.

3.2 AGRICULTURAL ASSESSMENT OF LAKE COUNTY

3.2.1 Description of Lake County Agricultural Economy

The gross value of Lake County's agricultural assets approaches twenty million dollars, though in recent years the trend has been downward. Problems plaguing Lake County's agriculture have been due, in part, to the nation-wide economic decline and to regional water shortages. Lake County has a population of approximately 25,500, with approximately 8,600 (25%) over the age of 65. In 1975, Lake County had 15.8% unemployment, almost twice the national average. The County has approximately 113 sq km (28,000 acres) (3.2%) of total county acreage of agricultural land. In 1972, 24 sq km (6,000 acres) were irrigated. The Federal Government owns 46% of the land in the county. Though 1975 was down 8.5% from 1974, agriculture is the number one contributor to the economic activity of the county. The total fruit and nut revenue of the County in 1975 was \$13,378,335, \$11,482,055 of which came from pears. Total field crops averaged \$2,461,595, livestock gross was \$2,482,055, and eggs \$236,330. Seasonal employment for pears and walnuts in the months of August through October accounted for the employment of 2,000 people.

Lake County lies approximately 210 km (130 mi) from both Sacramento and San Francisco. The Clear Lake recreational facilities attract summertime tourism, which is also a major economic activity of the county.

Lake County has approximately 3,400 sq km (849,000 acres), of which 1,960 sq km (485,000 acres) are under zoning laws. Of the zoned acreage, approximately 810 sq km (200,000 acres) are zoned and/or leased for geothermal use.

3.2.2 Problems Affecting Agricultural Geothermal Development

Several major factors affecting agriculture generally were observed in Lake County:

- a. The county has very little agricultural diversification. Revenue is predominantly from Bartlett pears.
- b. The county has very little riparian water rights and a limited supply of subsurface fresh water for irrigation.

- c. The revenue from agricultural crops is seasonal, limited to several months in the summer.
- d. The county has a high percentage of retired people and a high unemployment level.
- e. The county has poor highway transportation systems for trucks, and no railroad or commercial air freight service.
- f. Other than low-cost energy sources, Lake County lacks commercial agribusiness benefits to attract industry.
- g. The Clear Lake KGRA has a limited amount of good soil for farming and not much level land.
- h. The known geothermal resource areas have predominantly low temperature energy supply.
- i. Among the potential sites to be considered, only one has an actual producing geothermal well which may be immediately available for nonelectric uses--Site No. 4, High Valley Creek/Cobb/Glenbrook area.

3.2.3 Needs for Future Development of Lake County

- a. Lake County needs to develop agricultural diversification in revenue-producing enterprises, including the introduction of new crops, new agribusiness, and increased year-round employment.
- b. The Lake County Pear industry needs stimulation in marketing its products.
- c. The county needs to attract new sources of income such as agro-industry, and to avoid such a heavy dependence on agricultural production income.
- d. Improvement of the county surface water supply system by introducing new dam/reservoir projects, etc., is needed, for increased agricultural and industrial production.
- e. The county drastically needs to improve its access road system and to build a railroad or airport system, if agro-industry is to be economically viable and competitive.

3.3 SITE ASSESSMENT FOR POTENTIAL AGRICULTURAL DEVELOPMENT

Agricultural assessment of sites in the Clear Lake KGRA for potential geothermal related developments was conducted in four general areas:

- Site No. 1: Sulphur Bank/High Valley/Borax Lake Area
- Site No. 2: Thurston Lake/Mt. Konocti Area
- Site No. 3: Collayomi Valley/Middletown Area
- Site No. 4: High Valley Creek/Cobb/Glenbrook Area

3.3.1 Assessment of Site No. 1, Sulphur Bank/High Valley/ Borax Lake Area

Farming in the Sulphur Bank/Borax Lake is, in general, limited to some small prune and walnut orchards on the hill-sides. The soil is shallow, compact and granitic in nature. The soil mixture is basically a red-laterite clay/adobe texture, allowing only poor root and water penetration. An assessment of growing fruit trees indicates the top growth is approximately one half that of normal growth in ideal growing areas. This area has very high boron content in the soil and ground water, far too high for normal growing of crops. The area has potential geothermal resources but, at the present, no detailed geotechnical information is available for evaluation. Without pertinent temperature and flow data at a given location, no reliable estimation of a multi-use agricultural or agribusiness complex can be made. Suburban residences placed near the prime agricultural areas may result in land-use conflicts, but these conflicts can be mitigated by proper siting and control systems. (cf. Section Four, study areas I-A and I-B). Further assessment of this area may be conducted in subsequent phases of this project.

The High Valley area is a small valley approximately 1.5 mi (2.3 km) wide and 3 mi (4.8 km) long at approximately 1,800 ft (600 m) elevation. It is partially wind-protected and subject to some frost in winter and early spring. The closest community is Clear Lake Oaks, which is 2 mi (3.2 km) south. The access road to High Valley is narrow, characterized by a moderately steep grade for trucks. This valley is generally under private ownership, primarily by livestock ranchers. The surrounding hills are leased to geothermal exploration companies for potential geothermal development. At present, there are no producing wells in the area. Geotechnical information of value for nonelectric use developers is yet to be established for this area. When low cost geothermal energy is available, this area could be utilized for controlled environmental livestock and poultry operations. Potential also exists for some small greenhouse operations. (cf. Section Four, study area I-C).

It is recommended that this area be considered for future potential nonelectrical geothermal development of an agrarian nature. Although not enough information is available to project potential development, this appears to be the second most likely area for an agricultural geothermal complex. The area is recommended for inclusion in the proposed subsequent phases of this project.

3.3.2 Assessment of Site No. 2, Thurston Lake/Mt. Konocti Area

The Thurston Lake/Mt. Konocti area is of lesser importance for agricultural use as compared to other site locations. The current trend of semi-rural and residential development in this area is likely to continue as more people are attracted to the semi-rural recreational living which this area has to offer. The Shoul Valley area was reviewed for potential agricultural development use, but that area offers no major benefit in terms of agricultural use. The entire area lacks adequate top soil, drainage of lowland areas and an adequate supply of fresh water for agricultural use. It is almost impossible to obtain riparian rights to the Clear Lake water supply.

The Thurston Lake/Mt. Konocti area presently has as yet no producing geothermal wells which can be assessed for nonelectrical agricultural use. Without adequate geotechnical information for the area, the establishment of an agricultural uses complex is problematic at this time. It is of little value to develop a hypothetical assessment without an in-depth socio-economic study of this area. It is recommended that such a study be mounted to determine if the area can support a potential geothermal-influenced residential community composed of:

- a. recreational development
- b. condominium complexes
- c. institutional-type development: retirement complex; high school or community college; California geotechnical institute
- d. light industries
- e. single unit residential homes
- f. hospitals
- g. other small business units
- h. municipal utilities

Once geothermal wells have been drilled in this area, it is recommended that the area be reassessed for nonelectric geothermal development. On the other hand, a modest exploration program by the county, supported by ERDA, may accomplish the same goal.

3.3.3 Assessment of Site No. 3, Collayomi Valley/Middletown Area

The Upper Collayomi area offers some major advantages for agricultural uses. The Collayomi Valley has ample flat land areas for agricultural use, and moderately usable soil type. The depth of top soil in this valley is fairly adequate for orchards, vineyards, and for greenhouse use. This valley has the potential of developing surface storage facilities for the runoff water from the Putah Creek watershed, which is just north of the valley and also flows through the center of the valley. It is recommended that an engineering hydrology firm conduct a study of the area in a subsequent phase of this project. Availability of adequate fresh water in sufficient quantities is critical to a major agricultural development complex. This is the closest area in Lake County to the San Francisco/Bay Area market.

The potential for geothermally related agricultural or agribusiness complexes depends greatly on the availability of effluent waste-heat (40°-60°C) (104°-140°F) energy from future local electrical power generating plants or upon tapping moderately high temperatures (100°-150°C) (212°-302°F) at shallow depths. The Anderson Spring area to the north of Collayomi Valley is currently being explored for future geothermal power development. The nonelectrical use complex may be able to utilize the intermediate temperature geothermal heat as well as some direct feed from the geothermal well through cascading-use planning, where the heat is used through a series of descending temperature agro-industrial and agricultural uses. The entire cascading system can be contained in a closed system to prevent any damage to the local environment. The nonelectrical use complex must be designed at each potential site to suit the needs of the community. Since geotechnical data for this area is limited, the practical layout of a complex cannot be set forth in this Phase Zero task. It is proposed that a feasibility study be carried out in a subsequent study phase, which will evaluate in depth the Collayomi Valley potential. Table 3-1 shows a list of enterprises and temperature requirements for use in agriculture and agro-industries.

Figure 3.1 shows one conceptual design for Site No. 3, Collayomi Valley/Middletown Area, which has approximately 0.12 sq km (30 acres) of usable land. This figure presents a schematic of the descending temperature flow of heat from a power

generating plant through agro-industrial uses--through controlled environment livestock and greenhouse facilities, under the outdoor nursery hot bed area, and finally into cooling systems for the power generating plant or into reinjection wells. It is assumed here that in addition to the waste heat, some high-quality, high-temperature geothermal fluid is also available for nonelectric uses. A detailed feasibility study is proposed for a subsequent phase of this project for this site.

3.3.4 Assessment of Site No. 4, High Valley Creek/Cobb/ Glenbrook Area

This area in High Valley Creek (cf. Section Four Study Area IV-B) was selected as the most likely site for near-term development of demonstration complexes for nonelectrical geothermal uses. After careful analysis, a general plan for an agriculturally-oriented enterprise complex was developed on the basis of the characteristics of an existing geothermal well and the available acreage. This area offers approximately 0.13 sq km (32 acres) of usable land that need little or no modification. The availability of a producing geothermal well 166°C (330°F) and the interest of McCullough Oil Corporation in developing a nonelectrical geothermal demonstration center were also key factors in the selection of this site.

Another characteristic of major importance is the high percentage of available land area with maximum daylight hours in the valley. This is essential for greenhouse or for any plant growth type agricultural enterprise. It is recommended that an in-depth annual weather, wind direction and velocity, temperature, rainfall and degree sunlight day study be conducted in subsequent phases of this project.

The access road to the well site is best described as an improved, wide, single-lane gravel road. The gravel road and access bridge can be further improved and paved if necessary. The well site is approximately 2.4 km (1½ mi) from a two-lane paved county road. The best method of bulk transportation to the site would be by truck.

3.3.5 Recommendations for an Integrated Agricultural Development Complex

The following recommendations are made, based on the availability of low-cost energy, either for heating or refrigeration. The economic compatibility of all enterprises as self-sustaining businesses, and as enterprises allowing for common usage and/or product compatibility is also taken into consideration, justifying integration into the total complex system. For example, feedmill livestock operations and waste

processing (by-product) facilities have interrelated uses and heat requirements (cf. Section Four, Study Area IV-A).

3.4 ANALYSIS OF POTENTIAL AGRICULTURAL APPLICATIONS

The agricultural potentials that are practical to the area and that lend themselves to the use of low-cost geothermal heat have been identified for possible followup in subsequent phases. Some of the tasks mentioned in the original proposal have been eliminated as either not economically feasible, or beyond the scope of this study.

3.4.1 Criteria for Selection

The selection of potential agribusiness applications was based on the following criteria:

- a. Almost all agricultural applications require low-cost geothermal heat for a short period during critical seasons, but are not continuous or constant users throughout the year; therefore, their requirements must be compatible in terms of sharing energy, possible integration of prime and by-product uses, etc.
- b. Availability of usable surface land area and of fresh water for irrigation and other agribusiness uses.
- c. Agricultural potentials that currently require a low-cost energy source as a major cost input for their operation.
- d. Agricultural enterprises that are economically feasible for Lake County.
- e. Agricultural enterprises that have potential markets for their products.

3.4.2 Rejected Alternatives

The potential alternatives that were not discussed in detail in this Phase Zero report are the following.

- a. Dairy operations, due to the relatively poor acceptance of dairies in the Lake County area. Contributing to this poor acceptance is lack of ample feed, forage and silage, and the relative transportation problem in moving bulk products to and from the valley. As geothermally-assisted livestock operations become popular, dairies and dairy processing may become practicable.

- b. Beef cattle are recommended for the livestock phase of the project, but do not necessarily need geothermal heat energy to sustain themselves in the Lake County KGRA area. Beef cattle would be users of feed to be produced by the feed mill or by the grass culture greenhouse.
- c. The aquaculture phase of the project is limited to the production of stock, fresh water and game fish. Shellfish potential may develop in the future for geothermally heated sites, but the current production of shellfish is itself limited to research, as disease problems remain to be solved before production becomes economical. Aquaculture shows great future potential and should be considered for site experimentation in Phase One of this project.
- d. Citrus and avocados can be grown in Lake County, but geothermally-assisted production is currently not economically practical. These crops are best grown in Southern California and the present market will not sustain additional production.
- e. Processing and heat treatment of municipal sludge was not addressed. That task is recommended as a part of a subsequent phase to help develop usable irrigation (fresh) water for agricultural use, and to solve a local sewage treatment problem.
- f. Research involved in processing natural gas and developing methane gas for retail sale is beyond the realm of this study.
- g. The problem confronting the Lake County (and California) pear industry is one of oversupply for current market demand. University research might be done in relation to frost protection utilizing hot geothermal fluid radiation from enclosed fluid circulating systems in pear orchards. The effect of low-cost geothermal refrigeration at a lower cost than normal electrical refrigeration must be studied.

3.5 SPECIAL APPLICATION OF LOW COST GEOTHERMAL ENERGY TO ALGAE HARVESTING

3.5.1 Description of the Process

With the current problem of uncontrollable algae growth in Clear Lake and the need to clean up this recreational asset, it

is recommended that this algae crop be harvested. Modified harvesting tug boats can cut, pick, strain, and remove solid foreign material, chop the algae mat, and then blow the harvested algae onto a towed barge. The fully loaded barge is then towed to the plant by another tugboat and a replacement empty barge substituted to continue cleaning up the lake. Once the algae is loaded onto the transport barge, it is towed to a processing plant which utilizes geothermal heat, located on the shoreline with a floating receiving dock. The barge is made with several sectional tank-compartments that can be pumped full of water to tilt it. When the barge pulls up alongside of the dumping dock, the compartment closest to the dock is pumped full of water, tilting the barge to that side and allowing the wet algae to open the cargo compartment and flow into the dump hopper.

Once the algae is in the receiving dump hopper, hydraulic or mechanical means start the algae up into the protein processing facility. The first step in processing algae for protein is to extract the free surface water from the algae mass. When the water is extracted, it can be recycled back for flushing algae out of the barge, or it can be dumped back into the lake. The algae mass next goes into an inclined squirrel case, to separate the solid foreign material, and then proceeds into a taped (wire mesh) squirrel cage centrifuge further to separate the free surface water. The algae is then ready to go through a series of squeeze presses to extract the liquid fluid out of the micro-organisms. This liquid is collected at each squeeze station and is further processed for concentrated liquid high quality protein and vitamin-rich supplements. The first squeeze can be processed for a low protein concentrate supplement. All subsequent squeeze fluids will be a higher protein concentrate. The fluid extraction can be considered as a by-product of the primary process.

The liquid protein fluid is then pumped into a geothermal radiant heated concentrator, transforming the liquid into a slurry-concentrate high in protein, vitamins and minerals. The concentrate can be used in livestock feed rations and poultry rations or further processed for human consumption as a food additive.

Dry matter is conveyed into tumble-rotating dehydrating drums with forced air geothermal heated dryers applying heat in the 104°C (220°F) range. The continuous flow rotating unit dehydrator carries the algae matter to a cooling area and then to a hammer mill-type pulverizing unit, depending on use. The algae is broken down into powder form for further processing. The dry algae is approximately 50 to 55% protein and useful in both livestock and human consumption.

Single cell protein micro-organisms provide high quality protein and vitamin-rich food. High protein content, year-round growing possibilities and technological potential in a controlled environment are some of its advantages. Algae can obtain their nutrients from animal manure or domestic sewage. The use of algae in combination with bacteria is an ideal biological method of reclaiming waste water and recovering potable water. Integrated with conventional agriculture, micro-organisms can recycle minerals, thus contributing to efficient use of energy and capital.

Experimental work with these organisms has indicated their production potentials. Commercial adaptation of algae culture has been limited by the need to maintain the culture medium at about 30°C (86°F) and by the energy requirements for harvesting. The diminutive algae cells make centrifugation, which is energy intensive, the most efficient processing technique. The water temperature in which the algae cells grow is an important determinant of production rate and biological stability. Low temperatures prevent algae cells from using available light energy in an efficient manner. Maintaining constant basin temperatures also allows desired species to compete well with less desirable organisms. Recent experiments have shown that high protein production rates can be obtained with algae using swine manure as a substrate. Temperature control of the algae basis could be achieved by pumping warm geothermally-heated water through pipes immersed in the basins. Desirable basin temperatures range from 24°-36°C (76°F-96°F). Spacings and sizes of submerged pipes depend on climate conditions and heat source temperatures.

Controlled environment algae could act as a supplementary source of raw product, especially during cooler winter months. The size of the algae farm varies inversely with the production from natural growth in the Clear Lake habitat.

3.5.2 Application to Clear Lake

Commercial production information necessary for an economical analysis of algae agriculture is not currently available. Until recently algae was grown only in experimental laboratories. Mass culture of algae would be ideal in the Lake County KGRA for the following reasons:

- a. Lake County's Clear Lake has an overabundance of algae growth, constituting a recreational nuisance.
- b. Lake County KGRA has ample geothermal resources for low-cost energy processing and growing. Controlled environment ponds could provide a continuous supply.

- c. Clear Lake has a suitable natural growing environment for most of the year; i.e., shallow water depth, geothermal springs around and within the lake proper; ample degree of daylight hours during most of the year; and constant supply of domestic sewage.

3.6 DEVELOPMENT OF AN INTEGRATED AGRIBUSINESS, GEOTHERMAL COMPLEX IN LAKE COUNTY

3.6.1 Selection of Site No. 4 for Demonstration Model

This type of agricultural or agribusiness application demonstration model may apply to any given location with geothermal energy or effluent waste-heat from geothermal power plants. Specific enterprises may vary to suit the physical needs of an exact location. Though geotechnical advantages may be present, the majority of the areas are limited by agricultural, fresh water supply, usable land availability or economic problems.

Therefore, Site No. 4, High Valley Creek/Cobb/ Glenbrook Area, is recommended for development of a near-term demonstration model. McCulloch Oil Corporation's Franciscan Well No. 1., a producing geothermal well with both hot water and steam, could be utilized by the proposed development. Wellhead temperature is 166°C (330°F) and is a major advantage of this specific site. Another contributing factor is the availability of approximately 0.13 sq km (32 acres) usable land, requiring little or no surface modification. Several small creeks and low areas offer potential reservoir storage for fresh water runoff of the surrounding watershed. The area may also provide an underground water source to supplement the surface reservoir. Nonelectrical agricultural enterprises should be environmentally compatible with this location. The valley is somewhat secluded from Lake County's central area, and may be found to be less objectionable to agribusiness development.

The proposed plant is designed for the purpose of creating a multi-use complex which can best integrate the use of low-cost heat energy. Proper integration would utilize energy on an individual enterprise basis and would allow reduced temperature fluid or steam to be used again in enterprises with lower temperature requirements. During periods of nonuse, the fluid or steam could simply be diverted. The integrated use of each product or by-product is also an important aspect of a multi-use complex. Basically, the complex is a horizontally and vertically integrated assortment of agribusiness enterprises.

3.6.2 Major Potential Applications

The complex is divided into five major groups of potential applications:

- a. power plant and distribution unit
- b. agro-industrial units
- c. demonstration-educational center and office
- d. plant growing units
- e. livestock, fish and poultry units

Each of these five units will be discussed in detail and their practical applications described.

3.7 ANALYSIS OF INDIVIDUAL ENTERPRISES

3.7.1 Power Plant

The McCulloch Oil Corporation's Franciscan Well No. 1 is producing hot water and steam at wellhead temperatures around 166°C (330°F). The availability of both fluid and steam makes this site highly suitable for closed hot fluid radiation application, and also for higher temperature heat forced air radiation application. The power plant would be a small scale (10-15 MW) electrical power generating unit for local electrical power needs, and for power distribution to the complex (see Figure 3.2). Heat exchangers would convert heat energy to provide coolants for cold storage in other industrial applications.

3.7.2 Meat Processing

The agro-industrial complex is designed to support growing and livestock portions of this complex. Industrial applications generally use a higher temperature 155°C (330°F); specifics for them would be engineered in Phase One of this project. The meat processing unit could be vertically integrated to accommodate poultry and livestock feed lots. The adjoining cold storage plant could be cooled to several different temperature levels, accommodating cold storage facilities for meat products, vegetables, cut flowers, mushrooms, etc. Both plants would be using approximately the same fixed capacity of heat units during the entire year. By-product cool/moist air could be used in the greenhouse during the hot summer months.

3.7.3 Lumber Drying

Subsequent by-product heat energy from the meat processing plant could be cascaded to a lumber drying enterprise, utilizing temperatures of approximately 160°C (320°F). The temperature required to dry green lumber will fluctuate according to type of drying facility and volume of lumber required to dry per time unit.

Though the practical application of artificial raw lumber dehydration is still in its infancy, the use of solar and geothermal energy for this is now being given more consideration. Lake County is not a major lumber producer, but could possibly intercept raw lumber from northern California en route to San Francisco. The lumber could be processed through the geothermal drying facility and then continue to San Francisco or southern California market areas.

Raw lumber could be off-loaded from trucks with fork lifts, and stored in an open yard to begin sun curing. The lumber would then be placed into the enclosed geothermal dehydration plants and cured by controlled temperature forced air circulation.

3.7.4 Grain Drying

The lumber drying facility could also be used to dry livestock feed transported from the Sacramento Valley for complex use. Feed and processed feed blends may have potential markets in the dairy areas of Sonoma and Mendocino Counties, but would not be economical for export to the Central Valley. This dehydration facility would require special consideration to serve a dual purpose, and would be fully engineered and designed as part of Phase One. The limited seasonal energy requirement of grain drying does not warrant the capital expenditure of a separately operated plant.

3.7.5 Fruit and Sprout-Grass Drying

A diversified fruit and vegetable sprout-grass dehydrating facility would be included in the complex. The dehydrator would be designed for a parallel flow, flow-through system. A parallel flow system has the raw product entering the drying tunnel at the end, where the forced-air temperature is at its maximum intensity. The maximum temperature input is approximately 140°C (284°F) and the minimum temperature is approximately 80°C (176°F), attained by mixing direct heat from the heat exchanger with an appropriate amount of recycled lower temperature air. It is recommended that the multi-use dehydrator be designed in Phase One of this project.

3.7.6 Feedmill

The feedmill in this industrial complex is a support facility for the livestock, fish and poultry operations. The mill facility could also process and mix dehydrated sprout-grass feed grown in one of the greenhouses. Imported grain, once dried, could be stored in silos and utilized in feed blends throughout the year. Ground and mixed with dehydrated grass feed, the grain can be utilized in livestock, fish and poultry feed pellets. There is good potential for the manufacturing of livestock and dairy special ration feeds, with a market in the north coast dairy areas. A separately located cattle feed lot operation might be feasible in the near future if wholesale meat prices continue to improve. For a feed mill operation, the grain feed must be pre-steamed and rolled to make dairy ration mix. The grinding, rolling, drying and conveying mechanisms could all be powered with steam over hydraulic motors. The feedmill, and all agro-industrial enterprises, could be programmed to utilize more heat units during summer months, when growing and livestock needs may drop.

3.7.7 Greenhouse Production of Cut Flowers, Vegetables and Sprout-grass Feed

In greenhouse production, air temperature, relative humidity and air circulation are carefully controlled. Because of rapid alternate heating and cooling requirements, greenhouses are difficult structures to heat. With current techniques, heat is usually supplied by steam or hot water-heated radiators. The energy for heating is usually derived from coal, natural gas, diesel oil or electricity. Cooling requirements are met by ventilation alone, or ventilation in combination with evaporative cooling pads. Ventilating air is drawn through a water soaked curtain or pad and cooled by providing energy to evaporate water from the pads. Warm water can conveniently be used to provide heating energy for greenhouses. The design of the heating system would depend on water temperature. If the temperature is sufficiently high, conventional finned-tubed heat exchangers can be used. Water temperatures should be higher than 40°C (104°F). At lower temperatures the size of the finned-tube heat exchangers rapidly increases and a more expensive installation results.

McCulloch Oil Corporations's Franciscan Well No. 1 could provide ample steam and hot water above the temperature requirement. Greenhouse warming could be accomplished by circulating warm water through a network of underground pipes. The soil is maintained at the desired temperature, and the heat escaping through the soil warms the greenhouse air. Theoretical consideration and experimental measurements indicate, however, that the heating capacity would not be sufficient to

keep the greenhouse air temperature more than a few degrees above the outside air temperature. Auxiliary heating systems would be required. Soil warming has been demonstrated to increase production of flowers and vegetables.

Heat energy requirements for greenhouses depend greatly on the type of greenhouse construction, the size, type of heating and cooling system, solar incidence, outside design temperature, and desired inside temperature. Heating systems can be designed to lower the water temperature various degrees, depending on the initial temperature and amount of flow. In general a -3.9°C (25°F) approach to inside temperature is economical. A closer approach can be achieved with more costly heating systems.

Data given:

- a. Size of greenhouse: 6.4 m x 59 m x 2.4 m (21 ft x 192 ft x 8 ft)
- b. Outside design temperature: -12°C (10°F)
- c. Inside temperature: 24°C (75°F)
- d. Estimated temperature drop through heating system = $\Delta T = 10^{\circ}\text{C}$ (50°F)

Calculation:

Figuring BTU's needed

Formula: Exposed area = $(L \times H \times 2) + (W \times H \times 2) + (W \times R) + (1.054 \times W \times L)$

L = Length

W = Width

R = Roof

H = Height

2 = (2) sides

1.054 = Constant

$$(192' \times 8' \times 2) + (315' \times 8' \times 2) + (325' \times 84') + (1.054 \times 315' \times 192') = (3,072) + (5,040) + (26,460) + (53,746) = 98,318 \text{ sq ft } (9,134 \text{ sq m})$$

BTU's per hour needed from table of factors:

Heat = (factor) x (sq ft)

Heat = $(102) \times (98,318 \text{ ft}^2) = 10,028,436 \text{ BTU/hr}$

Heat = $10,028,436 \text{ BTU/hr} + (20\%) \text{ for heat losses/hr} = 2,005,687 \text{ BTU/hr}$

Total Heat = $10,028,436 + 2,005,687 = 12,034,123 \text{ BTU/hr}$

The following procedure enables the engineer to determine maximum flow of geothermal hot water required for a given outside design temperature.

Figuring Max. Flow (GPM) needed:

$$\text{Flow (max. GPM)} = \frac{\text{BTU's Needed}}{500 \times \Delta T}$$

ΔT = change in temperature
500 = constant

McCulloch Example: Determine flow requirements for a standard size arch greenhouse located in Lake County KGRA. The heating system lowers the temperature of the geothermal fluid from 66-38°C (150°-100°F).

Figuring Max. Flow (GPM) needed:

$$\text{Flow} = \frac{\text{BTU's Needed}}{500 \times \Delta T} = \frac{12,034,123}{(500) \times (50)}$$

$$\frac{12,034,123}{25,000} = 481.36 \text{ GPM}$$

If the geothermal fluid input is at a flow rate of approximately 500 GPM, it is estimated that 5,574 sq m (60,000 sq ft) of greenhouse can be adequately heated in the Lake County KGRA. The annual heating consumption for the greenhouse complex is estimated to be approximately 234,000 therms. Based on the 1976 average rate of \$0.251 per therm for natural gas, the equivalent heating cost or saving would be \$58,700, neglecting capitalization of the geothermal heating system.

The following are cost estimates for the construction of a 5,570 sq m (60,000 plus sq ft) greenhouse as described in the quotation. An estimation of start-up costs for a cut-flower greenhouse operation is included, and covers:

- a. land, building and equipment
- b. initial growing materials
- c. materials over initial 120 day cultivation period
- d. labor requirements for initial preparation of beds and planting
- e. cultivation of plants over 120 day period.

Also included is a start-up time schedule chart.

Start-up Costs - Growing cut flowers under 5,570 sq m
(60,000 sq ft) of greenhouse.

1.	Basic Land, Buildings and	
	Equipment Land 0.01 sq km (2½ acres)	\$ 15,000
	Greenhouse (Wood and Plastic)	180,000
	Cement Slab	2,000
	Water and Irrigation Lines	4,500
	Water pump	500
	Gas Fired Unit Heaters	4,800
	Connect Gas Lines	3,500
	Heating Tubes	250
	Well and Storage Tank	3,000
	Spray Guns and Line	100
	Spray Pump	1,200
	Packing House	20,000
	Refrigeration Room	8,000
	Storage Shed	500
	Tools	300
	Buckets	450
	Bicycles	200
	Pickup	1,500
	Stake Truck	2,000
	Supplies	500
	Office Supplies	250
	Legal Expenses	300
		<u>\$254,950</u>
2.	Initial Growing Materials	
	Plants (75,000 at \$0.13)	\$ 975.00
	Sterilizing Soil	500.00
	Sterilizing Cover materials	50.00
	Calcium Nitrate (2 1/2 tons at \$160)	400.00
	Sawdust (250 yds at \$2.40)	600.00
	Superphosphate (1½ tons at \$90)	112.50
	Dolomite Ag 65 (2½ tons at \$50)	125.00
	Potash (1/5 ton at \$200)	40.00
		<u>\$2,802.50</u>
3.	Materials Over Initial 120 Day Cultivation Period	
	Insecticides and Fungicides	\$ 375
	Fertilizer (1½ tons at \$200)	300
	Tying and Support Materials	1,500
	Soil Tests	120
		<u>\$2,295</u>

Start-Up Costs - Minimal Labor Needs During Start-up Period.

1. Initial Preparation of Beds and Planting

	<u>Man-Hours</u>
Tractor Tillage of Soil	35
Spread and Work in Redwood Soil	
Amendment and Fertilizers	30
Sterilize Soil	25
Place Irrigation Lines and Adjust	200
Form and Prepare Beds for Planting	400
Planting	300
Total	990

2. Cultivation of Plants over 120 Day Period

Watering	60
Pinching	175
Installation of Caging	500
Disbudding	500
Calyx Tape to Prevent Splits	100
Pest and Disease Control	50
Fertilization	100
Ventilation Adjustment	60
Total	1,545

3. Schedule of Hired Workers

	<u>No. of Workers</u>
June 1 - July 15 (Start-up Construction)	5
July 15 - Nov. 30 (Initial Growth Period)	2
Dec. 1 - (Regular Production)	3

3.7.8 Outdoor Soil Warming Nursery Facility

Soil and air temperatures are important climatic factors affecting plant growth. Optimum soil temperature varies with plant species and variety. Control of temperature in agricultural activities has been limited primarily to greenhouse horticulture. Several approaches to increasing soil temperature in open fields have been considered. Lower intensity geothermal heat offers the potential of open field soil warming by pumping warm water through a network of underground pipes. Resulting temperature distribution would depend on source temperature, air temperature, and depth and spacing of the heat

sources. Increased soil temperature has proven to increase plant maturity considerably, but the economics of this must be weighed against the capital investment. To maximize net requirements, return for open field soil warming, high value crops or crops that will mature early enough to be in production pre-season should be considered. Some potential crops would be: a) fruit - varietal wine grapes, tomatoes, kiwi, strawberries and berries etc.; b) vegetables - asparagus, winter crop, fresh vegetables, early sweet corn, etc.; c) ornamental and nursery stock - potted plants, trees, fruit tree root stock, heat-treated disease free tree stock, varietal grape root stock, native trees and exotic plants.

The economic potential of soil warming in the open field could be enhanced through the use of wider heat source spacing, thus decreasing capital cost. Both crop varieties more responsive to soil warming and decreased energy source costs would contribute to a more realistic approach.

The effect of soil warming on air temperature is minimal in most applications. The average daily air temperature cannot be expected to increase by more than about 2.8°-2.9°C (5°-7°F) using this technique.

3.7.9 Mushroom Production Facility

Mushroom production requires intensive labor and energy use for operational efficiency. The compost or bedding material consists of horse manure or straw mixed with soil and activated, then pasteurized to kill all weeds, bacteria and other organisms. Pasteurization is done in a growth room with heated air of approximately 60°C (140°F) for a period of six hours (for room temperature), and 63°C (145°F) for a period of twelve hours (for bed temperature). The air in the room is changed every five to seven hours. Once beds are pasteurized, mushroom spawn is spread over the compost material and allowed to incubate for a period of 200 hours in a temperature range of 16°-21°C (60°-70°F). As the spawn starts to grow, room temperature decreases to 17°-20°C (63°-68°F) for another 200 hours. As the mushrooms achieve proper growth, the beds are harvested daily for a period of approximately 40 days. An average crop yield is around 12.2 kg/sq/m/crop (2.5 lbs/sq ft/crop). When the harvesting period is over, compost beds go through "cook-out" and are pasteurized again with room temperatures of 66°C (150°F) for a period of eight hours. Lastly, beds are fumigated with temperatures of 68°C (155°F) for a period of eight hours. The total energy requirement for mushroom production is estimated at \$1.18/sq m/crop (\$0.11/sq ft/crop). A detailed analysis of the feasibility of mushroom production follows:

3.7.9.1 Mushroom Production Feasibility Report, Stationary Bed Operation

a) Description of houses and general farm layout.

Each mushroom house is a separate entity with steam lines for heating, vents for air circulation and stationary beds for production surfaces. The mushroom houses must be isolated and upwind from the composting area. They must also be above ground level and constructed so that good sanitary conditions can be maintained. A concrete floor and probably concrete block construction is necessary.

General layout

Mushroom houses - should be near an energy source

Composting area:

- Downwind from mushroom houses
- Concrete slab foundation
- Equipped with water supply
- Adequate drainage
- Storage area for compost ingredients

Buildings:

- Office
- Maintenance area
- Refrigeration and storage room
- Shipping area

b. Determination of production cycle.

7 days - Pasteurization Phase	)	
14 days - Spawn Run Phase	)	- Growing Period
14 days - Casin and Case Holding Phase	)	
7 days 1st Flush	)	
7 days 2nd Flush	)	
7 days 3rd Flush	)	- Harvesting Period
7 days 4th Flush	)	
7 days 5th Flush	)	
<u>4</u> days - prepare house for next crop		

74 days TOTAL CYCLE (1 crop)

$365 \text{ days/year} \div 74 \text{ days/crop} = 4.93 \text{ crops/year}$

Assume 1 crop will average 12.1 kg/sq m (2.5 lbs/sq ft) of production surface area.

$2.5 \times 4.93 \text{ crops/year} = \sim 60 \text{ kg/sq m/yr (12.33 lbs/sq ft/year)}$

$12.33 \text{ lbs/sq ft/year} \div 52 \text{ weeks} = 1.15 \text{ kg/sq m/wk (0.2371 lbs/sq ft/week)}$

c. Determination of size of operations as it relates to average weekly production.

Square foot of production surface is to mushroom growing and production as acres of tilled soil are to row crop production.

A basically linear relationship exists in the determination of total production desired over a production period.

Weekly production may be determined as follows:

<u>Production Surface</u>		<u>Average Weekly Production</u>	
sq m	sq ft	lbs	kg
2,320	25,000	2,690	5,928
4,645	50,000	5,380	11,855
6,970	75,000	8,070	17,782
9,290	100,000	10,750	23,710
11,610	125,000	13,440	29,638
13,940	150,000	16,130	35,565
16,260	175,000	18,820	41,492
18,580	200,000	33,760	74,420
20,900	225,000	24,200	53,348
23,230	250,000	26,890	59,275
25,550	275,000	29,580	65,202
27,870	300,000	32,260	71,130
30,290	325,000	34,950	77,058
32,520	350,000	37,640	82,985
34,840	375,000	40,330	88,912
37,160	400,000	43,020	94,840
41,800	450,000	48,400	106,695
46,450	500,000	53,770	118,550

Production pattern per house:

<u>Weeks picked</u>	<u>kg/sq m/wk</u>	<u>lbs/sq ft/week</u>
1	3.9	0.8
2	3.4	0.7
3	2.4	0.5
4	1.5	0.3
5	1.0	0.2
	<u>12.2</u> kg/sq m/crop	<u>2.5</u> lbs/sq ft/crop

3.7.10 Livestock and Poultry Facilities

Heating requirements for livestock and poultry operations in Lake County KGRA were studied by an agricultural engineer, R. G. Curley, a specialist in energy requirements for California agriculture. Two types of operations were chosen: poultry brooding and hog farrowing. Both require a significant quantity of heat for production purposes in this area. Other livestock operations would be adaptable to the Lake County KGRA but do not require artificial heat for operation. Cattle feed lots in reasonable proximity to the geothermal complex would be subsidized with feed grain, feed mix or sprout-grass grown or processed at the complex. Cattle manure from such facilities could be processed at the complex's geothermal heat treated drying and packaging facilities. Compatible livestock facilities served by low-cost geothermal resources are not limited to the High Valley Creek site, but may be considered for several locations. However, heat requirements for this type of livestock and poultry operations vary greatly during the year and economical utilization of geothermal heat would depend on integration with other applications.

3.7.10.1 Heating Requirements for Poultry Brooding

The brooding procedure is basically the same for both friers and pullets. Chicks are placed in the brooder when they are one day old and heat is provided. The amount of heat and length of heating period depends on weather conditions and climate as well as type and condition of housing. In warm weather the heating period may last 2 to 4 weeks and in cold weather 8 to 10 weeks. Research has shown no benefit from heat for laying hens unless temperatures in the house drop below 16°C (60°F). Friers are marketed between 7½ and 8½ weeks of age. Pullets remain in the brooding house until 20 weeks of age when they are transferred to laying houses. Because they remain in the brooder houses for a longer time, the number of birds per unit of floor space is reduced to about 0.7 of that for friers. This increases the heat requirement per bird on an inverse basis. For example, the brooding heat per 1,000 pullets can be determined by dividing the brooding heat per 1,000 friers by 0.7 (assuming the weather and houses are the same).

Most producers of friers average about 4½ broods per year, allowing time to clean and disinfect the houses between broods. Pullet brooders normally produce two broods per year. No cooling is required for brooding chicks; however, evaporative cooling is used for laying hens.

Figure 3.6 shows the total brooding heat requirement per 1,000 friers based on the time of year the brood is started and

an 8 week brooding period. These data were calculated from the fuel bills of two frier operations in San Joaquin County for broods in 1975 and 1976. The tabulated data from these fuel records are shown in Table 3-II.

Air temperatures are measured 5.1-7.6 cm (2-3 in.) above the floor. Initial temperatures are set for 90°F under the hover and 27°-29°C (80-85°F) outside the hover. Temperatures are reduced approximately 1.1-1.7°C (2-3°F) per week after the third day to a minimum of 21°C (70°F).

The minimum size economic production unit varies somewhat according to the specific situation. The following can be considered minimum size units: (a) friers - 100,000 birds per week. (b) laying hens - a flock of 20,000. The number of replacement pullets required by a laying operation each year is variable, but 30% is a reasonable value.

Peak energy demand for friers and pullets occurs during the winter period. Peak heating demand on a daily basis occurs at night and in the early morning when outside temperatures are lowest. The daily peak heating demand (BTU/hr) is estimated to be approximately 50% greater than the average heating load for a brooding period.

Electricity is used for the following:

- a. Pumping drinking water: The power requirement is extremely variable since it depends on pumping depth. (Pullets at 20 weeks will consume as much as 151 liters (40 gal) per 1,000 birds per day and 10 week old friers half that amount.)
- b. Lighting: A typical lighting procedure for friers provides 20 watts per 1,000 birds for an average of approximately 8 hours per night. This is the equivalent of 1.3 kWh per 1,000 friers raised. Although a different lighting scheme is used for pullets, the electrical energy is estimated to be about the same as for friers.
- c. Feeding: A 1 hp electric motor will operate a mechanical feeder for approximately 20,000 birds on a time schedule that is increased, as the birds grow, to a maximum of 15 minutes on and 15 minutes off. Estimated electrical energy requirement is 20 kWh per 1,000 friers and 60 kWh per 1,000 pullets.
- d. Heating: Pumps are used to circulate hot water in cases where hot water heating is used. A 1 hp pump is typical for a house that is 110 m (360 ft) long

with a capacity of 20,000 friers. Pump operating time is determined by demand for heat. Based on an estimated average operating time of 30%, the pump would use approximately 20 kWh of electricity per 1,000 friers or pullets. Peak electrical demand would occur at night on a daily basis and during the winter on a seasonal basis due to heating and lighting requirements.

Although some pullet brooding operations sell pullets to egg producers, most are in conjunction with a laying operation. A laying operation would require additional energy input as follows:

- a. If mechanical feeders are used, the electrical energy required for their operation is estimated at 511 kWh per 1,000 hens per year. (Based on 1 hp per 10,000 hens operating five periods/day at 15 minutes each.)
- b. Electricity is required to operate fans, if enclosed housing is used with evaporative cooling for warm weather. Evaporative cooling would require approximately 1/8 hp of fan capacity per 1,000 hens. Estimated use of electricity for summer cooling would be 240 kWh per 1,000 hens. An estimated 72 kWh per 1,000 hens would be used for ventilation during the balance of the year.
- c. Based on a light intensity of 1 watt/0.3,716 sq m (1 watt/4 sq ft) of floor area, 1 hen per sq ft of floor area, and average light operation of 4 hours/day, the energy required for lighting is 365 kWh/1,000 birds/year.
- d. The heat required to wash eggs is 4.4×10^5 BTU/ton or 2.75×10^4 BTU/1,000 eggs. Based on a production rate of 0.63 eggs/hen/day, the egg washing heat requirement is 1.73×10^4 BTU/1,000 hens/year.
- e. For processing other than washing (handling, candling and cooling) the electrical requirement is 70.51 kWh/ton of eggs or 4.4 kWh/1,000 eggs. Based on a production rate of 0.63 eggs/hen/day, this is 2.8 kWh/1,000 hens/year.

Peak electrical demand for egg production would be expected to occur during the daytime and in the summer period. This peak demand can be estimated by adding the following:

Mechanical feeders - 0.1 kW per 1,000 hens
Cooling fans - 0.125 kW per 1,000 hens
Total - 0.225 kW per 1,000 hens

The electrical use rate for egg processing would have a negligible effect on peak load.

The amount and type of labor required varies. For friers and pullet brooding, an owner-operator can handle 50,000 birds without hired help. Total labor requirements per brood of 50,000 birds is approximately 470 hours per year. Supplemental labor for larger operations can be unskilled. For egg production, the labor requirement is dependent upon the degree of mechanization. A typical owner-operator can handle 25,000 laying hens with a small amount of part-time labor (about 1/4 time for a second person).

Wage rates vary with location. Typical rates for hired labor are \$2.50 to \$2.75/hr on a part-time basis and \$3.00/hr full time.

Other major inputs include:

a. Friers or pullets

Feed - 3.74 kg (8.25 lb)/bird/8 week growing period

Water - 246 liters (65 gal)/1,000 birds/day at the end of an 8 week growing period.

b. Egg production

Feed - 113 kg (250 lb)/1,000 layers/day

Water - 227-454 lit (60-120 gal)/1,000 layers/day

Initial investment for a complete operation is the following:

a. Friers or pullets - \$1,500/1,000 birds not including the land

b. Egg production - For environmentally controlled and highly mechanized housing the investment is approximately \$3.50/layer (not including land). For open housing with partial mechanization the investment is \$2.00 - \$2.25/layer (not including land).

Egg producers generally replace about 30% of their hens per year. Therefore a 100,000 hen laying operation would require a brooder capacity of 30,000 pullets per year.

The market area for friers and eggs is normally within 320-480 km (200-300 mi). Sacramento and the San Francisco Bay Area would be potential markets for friers produced in Lake County. Pullets use a more local market, within 80-160 km (50-100 mi).

The economic potential for expanded frier production in California is not encouraging. Lower feed and operating costs in the southern United States have made it difficult for California producers to compete. This situation has been further aggravated by a reduction in freight rates for the shipment of meat into California. California producers must receive a 4.4-8.8 cent/kg (2-4 cent/lb) price premium over the price of southern friers in order to compete. They have been able to get a premium by advertising freshness and better quality.

A major drawback to the use of geothermal heating for frier or pullet production is the concentration of birds and the danger of serious disease problems. The minimum size economic unit for friers is one that will produce approximately 100,000 birds/week. Some commercial producers prefer to break the operations down into sub-units that will produce a maximum of 100,000 birds/week and maintain a separation of 0.8 km ($\frac{1}{2}$ mi) between these units for disease control purposes.

Heating costs for brooding of friers range from \$4/1,000 birds with natural gas to \$12/1,000 birds with L.P. gas based on 1975-76 prices for these fuels. UC Leaflet 2648 "Chicken Fryer Production" (May, 1976) shows brooding fuel costs of \$18/1,000 birds, total cash costs of \$962/1,000 birds and total costs of \$1,002/1,000 birds. A fuel cost of \$18/1,000 birds represents only 2% of the cash costs and a slightly smaller percentage of total costs.

A major problem in the establishment of a poultry industry at the geothermal site in Lake County is that feed supplies would have to be hauled in, thus adding to the cost of feed. Some feed companies charge extra for feed on a ton-mile basis for any haul greater than 80 km (50 mi). The fuel required for trucking would be approximately 3.8 liters (1 gal) of diesel for each 56.25 ton-mile based on a one-way haul with the return empty.

Another problem to be considered in concentrated poultry production is the disposal of manure. The best disposal method is to spread it on nearby farm land for fertilizer. The potential for this method of disposal should be evaluated as part of a detailed study on poultry production in the area.

3.7.10.2 Heating Requirements for Hog Farrowing

The typical methods of heating the farrowing barns are: in-floor heat (electric heating cables or hot water pipes) plus heat lamps; and heat lamps only. Floor heat is provided on a continuous basis summer and winter in order to keep floor temperature under the pigs at 32°C (90°F), although the amount of heat required in summer is considerably reduced. Floor temperature under the sows is kept at 13°-16°C (55°-60°F). Some farrowing barns are ventilated with fans in the summer and some are cooled with evaporative coolers. Cooling by mechanical refrigeration is being tried on a small scale in the southern San Joaquin Valley.

Electric radiant heat is provided in the weaning barn for approximately two weeks after the pigs are placed there. Cooling is not provided in the weaning barns in summer. No heat is provided in the fattening barns. Cooling is provided by fogging type sprinklers.

Data for a 30 sow farrowing operation in Tulare County (1976) using heat lamps shows a peak winter heating requirement of about 325 kWh (1.1×10^6 BTU)/sow. It is estimated that heating in the summer months would be 30 - 40% of the peak requirement in winter. Clear Lake heat requirements would probably be somewhat greater than Tulare County, but an in-floor hot water heating system is probably more efficient than heat lamps so these two factors would tend to offset each other.

The minimum size operation from an economic standpoint is approximately 250 sows.

Peak heating requirements occur during the winter period. Cooling requirements occur during the warm months and peak in July and August. Total energy use data from three operations in Tulare County indicates that energy use for summer cooling tends to offset the reduction in heating resulting in nearly constant monthly energy use for a year-round operation. Cooling requirements for Lake County may be somewhat less than for Tulare County. Based on 1975 records, total energy costs for a Tulare County operation represented approximately 6% of total costs (overhead and operating costs).

The labor requirement for a 250 sow operation is normally one herdsman and one worker or one man per 125 sows. The herdsman is a person with good technical knowledge of hog production and the worker can be a laborer.

Typical wage rates are \$1,000/month for the herdsman and \$3.00/hr (plus fringe benefits) for laborers.

Major inputs other than heat are feed and water. Feed requirements are 4.0 kg/kg (4.0 lb/lb) of animal marketed including breeding stock. Water requirements for drinking are about 1.9 liters (0.5 gal)/animal/day. The water requirement for washing down and cooling varies and is affected to a large extent by the type of waste disposal system. Tulare County data shows very little water use where the wash-down water is caught in a pond and reused. A partial slatted floor system used 7.2 liter (1.9 gal)/head/day and a solid floor system with wash-down water going into the irrigation system used 17.8 liter (4.7 gal)/head/day. To determine feed and water use on the basis of sows farrowed, multiply the use per head marketed by 7.5.

The initial investment for a farrow-to-finish hog operation (concrete and steel with insulated farrowing and weaning) would be \$800-\$900 per sow not including all the labor, and \$1,000-\$2,000 per sow on a contract basis with all construction labor provided. This includes in-floor heating, cooling, and lagoon and waste disposal systems. The price does not include land.

California now has only one slaughter house for hogs and it is located in the Los Angeles area. This factor works against hog production in central and northern California because of transportation costs required in marketing.

Several factors have discouraged hog production in California, even though it is a deficit-producing state. Much of the corn required for hog production in California has traditionally been produced in the midwest and shipped in. Recent changes in freight rates have encouraged the shipment of carcasses to California from the midwest, and California now receives 80 to 85% of its pork in carcass form from the midwest.

The remoteness of the Lake County geothermal sites from feed production and market areas are strong factors against hog production there. Other negative factors are the lack of good transportation facilities and the possibility of waste disposal problems. Most hog operations use manure lagoons or put the waste on crops in irrigation water. Odors can be a problem around hog production facilities.

3.7.11 Aquaculture - Fish Raising Facility

Aquaculture is the growing of fish under controlled conditions. Though practiced for centuries, its commercial value has only recently been recognized. Though many fish species of commercial value have a limited optimum temperatures range, possible production capacity benefits by temperature control are great. For example, shrimp grow 8% faster in 27°C (80°F)

water than in 20°C (68°F) water. Large amounts of energy are required to heat open air water basins for fish culture. Energy costs would be prohibitive if produced by current electrical or fossil fuel sources; thus, there is a possible advantage in basins that could be heated by pumping warm water through submerged pipes or an external heat exchanger. Water temperature should be approximately 35°-40°C (95°F) to 104°F. The size of the heating system would be determined by climatic conditions and desired water temperature.

The greatest aquacultural potential lies in the production of high protein food for human consumption and for supplementary high protein livestock feed. Aquaculture would be an important component of an integrated agricultural production complex.

3.7.11.1 Design of Fish Raising Farm

A fish farm should be engineered and designed to allow a constant temperature of approximately 21°-29°C (70°F-85°F) in the pond, depending on the needs of individual fish stock being raised. Refinements and compromises necessary for economical construction, suitable for fish habitats and security and ease of harvest, have produced many designs from which to choose.

Recommended for geothermal application is the linear flow type of pond, where water is purified, filtered and recycled back through growth ponds. The linear flow, or raceway method, is the most common form of fish basin. Oxygen is replenished by a series of spillways over dams at the head of each basin. These separate basins contain fish of different sizes and age. Each basin has a temperature control system to monitor, meter and regulate the flow of heated or fresh water as needed for optimum growth. The basins can be made of fiberglass, stainless steel, concrete or wood, or they can be gravel lined in the ground on an approximate 60° slope.

Subsurfaces of the pond can be treated with sealing compound to prevent excessive water seepage. This natural habitat for the stock allows a better chance for adjustment when released into streams and rivers. Raceway length may vary with the producing capacity of the plant, but is generally 91-122m (300-400 ft) long and 3.7-4.6 m (12-15 ft) wide. The water depth may vary according to heating system capability and fish stock volume, but is generally three to five feet deep. Water flow velocities also vary according to heating system design and type and volume of fish in the pond. Generally the flow rate is 1.5-427 cm/sec (0.05-14 ft/sec). Increased flow rate, which increases the rate of water oxidation, may be necessary to support a larger volume of fish stock. Also, size and relative activity of the fish variety must be considered.

Earthen ponds have the lowest initial capital investment, but also have the highest maintenance and upkeep costs. Ponds should be dried and maintained to prevent deterioration once a year. Earthen ponds have a tendency toward algae growth, which may harbor virus or bacterial diseases.

3.7.11.2 Parameters Involved in Management of Fish Farm

Management of a fish farm is based on being able to adjust variable parameters or tolerance levels in accordance with the fixed parameters to a predetermined standard. The following are some general parameters:

- a. Water quality, quantity available
- b. Water flow velocity
- c. Type of basin system - depth, width and length
- d. Capacity and efficiency of the geothermal heating system.
- e. Type of recirculating system
- f. Fish variety
- g. Fish weight - volume
- h. Fish number - volume
- i. Fish size - number - basin
- j. Amount of fish - surface area
- k. Type and feeding rate
- l. Feeding efficiency
- m. Fish growth efficiency
- n. Oxidation method and rate
- o. Oxygen consumption rate
- p. Ammonia concentration in water
- q. Other factors to consider: cost of labor, cost of production, capital investment, markets and marketability of the product, new return on investment.

3.8 RECOMMENDATIONS FOR SUBSEQUENT WORK

The best possible nonelectrical use of geothermal heat resources in Lake County KGRA is through diversified agricultural and agro-industrial applications.

Interviews and observations indicate that people in Lake County are "sick and tired of the pie in the sky approach" to the utilization of a natural resource within their local area. Suspicion that the highly technical and theoretical reports presented by researchers, power companies and consultants are glorifications, designed for the moment, has led to a generally negative attitude towards growth. Objections to outside pressures urging rapid development have understandably fostered concern over preservation, reasonable utilization and development of the county's natural environment and resources.

The following activities are recommended:

- a. Public involvement in all phases of discussion relating to geothermal development.
- b. Development of a general education program on nonelectrical use of geothermal resources.
- c. An agricultural-geothermal development master plan and subsequent demonstration model, to be open to the public.

As part of this preliminary feasibility study, many possible approaches to geothermal development have been investigated, but the enclosed recommendations have been limited to a few agricultural alternatives. This does not rule out other alternative agribusiness opportunities.

Developments which would establish the practicality of nonelectrical use of geothermal resources are necessary and desirable. The opportunities discussed above are by no means the only ones. However, based on the limitations of the scope of the task, we have developed an integrated enterprise complex enabling a use potential demonstration of one geothermal well. Similar types of development, or modified versions thereof, may suit almost any location within Lake County which meets the necessary criteria of adequate geothermal energy and fresh ground water.

The subsequent task should be an engineering design phase of developing actual layout plans, use plans, installation cost estimates, production cost estimates, enterprise operating cash flow budgets, management and control programs. During that phase of the project, the introduction of private industries

actually to operate the various enterprises will be helpful to the ultimate success of the demonstration complex. Their input will be extremely helpful to the final Phase Two task of constructing and operating the demonstration complex.

In the next phase, research and development of the application of geothermal energy to algae harvesting (Section 3.5 of this report) is strongly recommended. The harvesting of algae from the Clear Lake recreational area is beneficial for environmental improvement as well as to produce a by-product, i.e., single-cell algae. Engineering and design of the demonstration processing facility will provide an excellent example of a high energy user conversion to low cost geothermal energy. Residents and tourists of the Clear Lake recreational area would all derive some benefit from the project.

3.8.1 Summary Recommendations

The future of nonelectrical geothermal development in Lake County requires a thorough understanding of its limitations and potentials as an alternative low cost energy source. The practical utilization of geothermal energy in agricultural enterprises requires economic consideration of conversion costs as well as overall business concerns. In order to justify development costs, an integration of several complementary agricultural enterprises is recommended. These enterprises must be considered in both individual and collective context. That the complex and its components fill a real need and attract private support after initiation is a necessity. This can be best achieved by: 1) considering low cost geothermal energy on the merits of a continued supply of replacement heat energy; 2) by considering the complex and its components as new business relevant to the area rather than the solution to all current agrarian or economic problems.

AREA FOR POTENTIAL
GEOTHERMAL DEVELOPMENT
(OUTLINED IN YELLOW)

Figure 3.5

SITE #4-HIGH VALLEY CREEK

LAYOUT OF AGRICULTURAL AND AGRI-INDUSTRIAL ENTERPRISES

ESTIMATED TOTAL POSSIBLE
ACREAGE = 32,714

AG WEST INC
WEST SACRAMENTO,
CALIFORNIA

Figure 3.6 Heat Required for Brooding, Eight Week Brooding Period

Figure 3.7 Typical Poultry Brooding House with Hot Water Brooder
Plan View House Capacity Approx. 19,000 Birds

Note: Hot water pipes spaced 9"-12"
 Heating system capacity approx.
 50 BTU/hr/ft pipe
 Insulated pipes under sows

Figure 3.8 Hog Farrowing Barn with Hot Water Heat Plan View

NOTES

1. FERTILE FISH EGGS TRANSPORTED TO THIS LOCATION FROM OUTSIDE SOURCES
2. THIS FACILITY USED FOR RAISING HATCHERY STOCK UP TO 90/lb SIZE
3. FACILITY DESIGNED FOR CONTINUOUS FLOW FRESH WATER WITH <300°F STEAM PASTORIZATION OF RECYCLED POND WATER TO KILL ALL HARMFUL PATHOGENS & PARASITES
4. THIS PLANT TO BE USED FOR BOTH WARM WATER OR COLD WATER GAME FISH; IE, BASS, CATFISH, PERCH, MOUTOUT, STEELHEAD, & SALMON

Figure 3.9

KERR #2	ERDA PROJECT LAKE COUNTY (KERR)	AGWEST INC. APRIL 1977 JRS
GEOTHERMAL - CONTROL ENVIRONMENT FRESH WATER FISH HATCHERY		
CONTINUOUS FLOW SYSTEM - PROPOSED PLANT CAPACITY 3.5 TO 4.0 MIL./YR

Figure 3.10

TABLE 3-I POTENTIAL AGRICULTURAL RELATED APPLICATIONS
OF GEOTHERMAL ENERGY

Lake County KGRA

°C	°F	Relative Minimum Temperature Range
200	392	
190	374	Electrical power generation (10 MW)
180	356	Refrigeration (close circuit brine exchanger)
170	338	Convert H_2SO_3 to heavy water
160	320	Drying timber
150	302	Sugar beet processing
140	284	Dehydration of fruits (pear-prune)
130	266	Evaporation in sugar refining
120	248	Distillation for fresh water
110	230	Dehydration food processing--dehydration of vegetable, seaweed, organic material and single-cell algae
100	212	Intense de-icing operation (frost protection for pear, grapes, walnuts, etc.)
90	194	Space heating--indoor domestic, industrial, greenhouses
80	176	Milk pasteurization--low temperature refrigeration
		Space heating--animal environment
70	158	Hot bed heating--outdoors
60	140	Manure processing
		Poultry processing, hatching and brooding
50	122	Cheese manufacturing
		Mushroom growing
40	104	Soil warming, outdoor; rootstock growing
30	86	Wine fermentations
20	68	Fish hatchery
		Soil warming, farming

TABLE 3-II
HEAT USED FOR POULTRY BROODING
February 17, 1977

Table 1.

Date Birds Put Down	No. Birds Put Down	Finished	Fuel Cost Dollars Per Brood	Amount of Fuel		BTU/Brood Gas Input	BTU Output Per 1000 Birds 70 % Efficiency
				Gallons	Therms		
3/ 7- 9/75	76,000	72,200	\$339.19		2610	261.0 x10 ⁶	2.53 x10 ⁶
4/11-13/75	77,000	68,400	150.94		1126	112.6 x10 ⁶	1.15 x10 ⁶
5/25-26/75	78,500	74,575	198.52		1490	149.0 x10 ⁶	1.399 x10 ⁶
7/ 4- 6/75	78,150	74,242	112.76		830	83.0 x10 ⁶	.7826x10 ⁶
10/ 3- 6/75	78,200	74,290	242.76		1855	185.5 x10 ⁶	1.748 x10 ⁶
12/27-29/75	76,000	72,200	628.44		4790	479.0 x10 ⁶	4.64 x10 ⁶
1/20-22/76	77,030	73,179	408.85		2725	272.5 x10 ⁶	2.61 x10 ⁶
AVERAGE -							2.130 x10 ⁶

Natural gas with hot water heaters. Fuel costs were converted to therms of gas by PG&E.

6/15/75	59,030	56,788	\$ 395.18	1205	110.86 x10 ⁶	1.367 x10 ⁶
9/ 7/75		54,340	318.98	973	89.52 x10 ⁶	1.153 x10 ⁶
12/ 7/75	60,000	55,625	1216.76	3710	341.32 x10 ⁶	4.295 x10 ⁶
2/28/76	64,055	61,734	972.01	2963	272.59 x10 ⁶	3.091 x10 ⁶
5/16/76	59,990	56,514	661.36	2016	184.572x10 ⁶	2.286 x10 ⁶
8/17/76	62,763	60,589	376.88	1084	99.73 x10 ⁶	1.15 x10 ⁶
10/ /76	68,164	62,815	801.99	2308	212.336x10 ⁶	<u>2.37 x10⁶</u>
					AVERAGE - 2.244 x10 ⁶	

Propane gas with pancake type brooders. Propane @32.8¢/gallon.

SECTION FIVE: TASK FOUR

SOCIOECONOMIC IMPACT ASSESSMENT OF GEOTHERMAL ENERGY DEVELOPMENT AND DIRECT HEAT UTILIZATION APPLICATIONS

5.1 INTRODUCTION

The primary objectives of socioeconomic impact assessments are to facilitate decision-making processes in public policy formation and, to a limited extent, to provide background data prior to inception of development programs. A secondary function of impact assessments is to improve the design and administration of policies in order to mitigate negative impacts and increase benefits.

Assessment could entail an entire range of analytical operations of research design and methodology, including identification, selection, and measurement of impacts, and data analysis using standard methodology of the social and economic sciences. Employment of each of these above modes must be commensurate with the objectives, scale and budgets of a particular project.

The developed portion of The Geysers geothermal field with a current electrical generating capacity of approximately 500 MW is in Sonoma County, contiguous with Lake County. Although the known geothermal area extends eastward into Lake County, geothermal development has encountered resistance from a portion of the public in Lake County. No electric power generating facilities exist as yet, although Lake County has been the subject of intensive exploration.

Pacific Gas and Electric Company's electric power generating Unit #13, with a capacity of 135 MW, is currently under construction with a planned date of operation of July 1979. This will be the first geothermal power plant in Lake County. A second power plant in Lake County with a capacity of 110 MW is planned for operation by May 1981, and is currently undergoing various agency and government licensing requirements.

A significant part of resistance to geothermal development stems from those communities of Lake County which are in the vicinity of the developed parts of The Geysers geothermal field, due to air and noise pollution generated by the older

Geysers power plants. These residents live within 4 miles of The Geysers power plant locations. The projected power plants in Lake County are to be constructed, with current abatement technology to be employed, to greatly reduce or altogether eliminate air pollution.

Public opinion in Lake County is highly divergent with regard to the exploration and development of geothermal energy. Land owners, the construction industry and general steam suppliers for electric power generation tend to be biased for development, whereas part of the population which is primarily concerned with retirement, agriculture, recreational activities and preservation of the environment is biased against development. Repeated public hearings on geothermal development have been prolonged and costly to potential developers. Yet, despite the partly negative image of geothermal energy, in one survey of Lake County, the majority of the residents were in favor of geothermal development, provided that potential negative environmental impacts would be minimized, and that economic benefits to the county would be maximized.

5.1.1 Scope of the Socioeconomic Assessment Task

The objectives of this study are to describe the social and economic milieu in which development is proceeding, to define impacts related to overall geothermal development, and to identify nonelectric applications of geothermal energy. These direct heat applications should be compatible with the perceived values of the various sectors, with present life styles and social behavior of the residents, with the economic demands placed upon county resources, and with energy needs of the county as well as with the broader social context of energy requirements of the state and country.

The socioeconomic component of the study includes: a demographic profile of the county, an economic profile of the county, socioeconomic effects of development, and aggregate social effects. The following aspects have been considered in regard to geothermal development in general, and to specific applications where possible:

- 1) The impact that geothermal development would have on the county in terms of revenues and economic development.
- 2) The relative beneficial or detrimental effects on sectors of the population, including considerations of the economic well-being and quality of life of the current residents.

3) Differential benefits accruing to various sectors of the population and the economy.

4) Local and regional effects versus statewide or national needs for development of this particular energy source.

The current socioeconomic profile of Lake County reveals that the county has the lowest median income in the state, and a disproportionate share of welfare for a population whose median age is 47 years. The limited agricultural activities in Lake County are now declining in value. In the past, Lake County has relied heavily on agriculture and tourism as a base for its economy. Of major concern to the citizens of Lake County is the effect any development will have on these two important sectors. However, agriculture and tourism constitute an unstable base for the economy of Lake County. Revenues from agricultural production vary widely due to weather conditions, crop failures, shortages, rising production costs, and market conditions. Tourist revenues fluctuate yearly, as was the case during the energy shortage of 1973-1974. Nationwide economic conditions and weather have a major impact on tourism. Growing competition from other tourist areas has further impact on the county's tourist industry.

The following six sites were identified in the original proposal (see Figure 2.2):

Site 1: Sulphur Bank - High Valley - Borax Lake

Site 2: Thurstone Lake - Mt. Konocti

Site 3: Collayomi Valley - Middletown

Site 4: High Valley Creek - Cobb - Glenbrook

Site 5: Alternate Site - Calistoga, Napa County

Site 6: Alternate Site - The Geysers, Sonoma County

The first four sites are in Lake County; the two alternate sites lie within Napa and Sonoma Counties. The primary focus of the data and analysis is Lake County, with some profiling for Napa and Sonoma Counties. The intent of the original proposal was to continue in subsequent phases with site-specific socioeconomic assessments after identification of particular sites and applications. The cost analysis of these assessment studies has to be made in terms of optimizing the tradeoffs in scale, focus, in-depth analysis, data acquisition, methodology and presentation of the results.

5.1.2 Data Sources and Acquisition

The field efforts of the socioeconomic assessment task were directed towards the assembling of socioeconomic impact data, information and opinions related to development of direct heat use applications of geothermal fluids. The acquisition process from both primary and secondary sources proceeded along six modalities: 1) acquisition of publications; 2) contact with local agencies; 3) contact with local organizations and enterprises; 4) interviews; 5) site visits; and 6) computer data retrieval.

Publications and documents obtained from governmental agencies and organizations are compiled in the bibliography for this task. Reliance upon these secondary sources is high, since no funding has been allocated to data acquisition from sample surveys, a primary source of data. The agencies contacted for source material and information are listed in Appendix I. The organizations and private and semi-private organizations contacted are also listed in the Appendix. Site visits and census data retrieval from computer data banks supplement the other material.

One source of primary information was that of selected interviews. The purpose of these interviews was to obtain a better understanding of the needs, plans and public opinions of Lake County residents, developers, and planners concerning geothermal development. Persons interviewed were asked for an opinion on nonelectrical applications of geothermal fluids and those in particular which would best fit into a framework of future planning and realization of goals for the overall prosperity of Lake County. Other interviews were held with technical staff of operating companies and Pacific Gas and Electric in order to obtain some insights into the possible modes of cooperation for the execution of any suggested applications.

A list of county representatives and technical staff with whom interviews and discussions were held is provided in Appendix I.

5.2 DEMOGRAPHIC CHARACTERISTICS

Demographic, social and economic profiles of Lake County with some comparative profiling for Napa and Sonoma Counties are provided as baseline data and as a descriptive setting for the development of geothermal energy. Included in this section are demographic and socioeconomic characteristics, population trends and demographic components. The economic status and profile of Lake County are provided in Section 5.3.

5.2.1 Age and Sex Characteristics

Age and sex characteristics of the population can be summarized by a population pyramid sometimes called the "Tree of Ages", which presents characteristics of a population and its structure at one point in time. Percentages presented on this scale are compiled by age categories for male and female separately. As revealed by these pyramids, impacts on population by forces such as in-migration, out-migration, birth rates, death rates, economic depressions or epidemics leave their mark on the demographic structure of a population.

The age-sex pyramids for the three counties, Lake, Sonoma and Napa, are presented in Figures 5.1, 5.2 and 5.3. Lake County, Figure 5.1, reveals an age-sex structure that is not pyramidal, but reflects a bimodal distribution where there has been a disproportionate reduction in the number of those in the productive age groups and a heavy concentration for the ages of 5 to 19 and 50 to 70. This is a strikingly different pattern from the age-sex pyramids displayed by Sonoma County and Napa County. Comparative population pyramids are presented for California and the United States (Figures 5.4 and 5.5). The California and United States pyramids approximate what is designated as 'slow growth' models of population. These figures are based on 1970 census data.

One common descriptive measure of a population is the median age, defining the 50% mark for a population. This number can be calculated from the data displayed in each of the population pyramids, and is indicated below each distribution for male and female. For Lake County, the median age of males is shown as 46, and the median age for females is shown as 48. For Sonoma County the median age is 30; for Napa County the median age is 32. But as can be seen, the median age does not provide information regarding many important variations in the internal structure of the population. Thus, preferred measures which can be used to describe the structure of a population are: (1) the dependency ratio, (2) percent population dependent, and (3) the sex ratio.

The Dependency Ratio is a measure of how many people are dependent upon the economically active sector. The Dependency Ratio is defined by the following formula:

$$\text{(Dependency Ratio)} = \frac{\begin{array}{c} \text{(No. of persons)} \\ \text{(aged 0-14)} \end{array} + \begin{array}{c} \text{(No. of persons)} \\ \text{(aged 65+)} \end{array}}{\begin{array}{c} \text{(No. of persons aged 15-64)} \end{array}} \times 100$$

The Dependency Ratio depends upon the relative proportion of the number of children in the population, plus the number of aged relative to the number of people of working age. A dominant component in the Dependency Ratio is the proportion of children in the population which in turn, depends upon fertility levels.

Table 5-I shows the Dependency Ratio and the component numbers from which it is calculated for Lake, Napa and Sonoma Counties, for the State of California and the United States. The Dependency Ratio for Lake is 77; for Napa, 63; for Sonoma, 68; for the State of California, 58; and for the United States, 62.

The Percent Population Dependent is an indicator which gives the percent of the population that is dependent, out of the total population. These numbers are provided in Table 5-I and show a percentage of the population dependent for Lake County as 43%, for Napa, 39%, for Sonoma, 40%, for the State of California, 37%, and for the United States, 38%. It would be of interest to calculate these indicators for a time sequence for each of these populations. Time series data could be examined for discerning the national and county-wide time trends of these indicators.

The Sex Ratio is another measure of demographic structure. It is the number of males per one hundred females in the population. In general, more male babies are born than female babies, causing the Sex Ratio at birth to range between 104 and 107, but gradually decreasing with age due to differential mortality rates. The Sex Ratios for Lake, Sonoma and Napa Counties, the State of California and the United States are provided in Table 5-I. It is interesting to note that in this indicator Lake and Sonoma County more nearly approximate the figures for the United States. Napa County presents a much higher sex ratio than the counties of Lake and Sonoma. These ratios are affected as much by economic factors as by demographic ones; higher ratios could reflect a more economically active population or a more economically active area. In other words, the causes for these differential Sex Ratios have to be sought in phenomena other than attrition with age.

5.2.2 Race, Ethnic and Minority Characteristics

According to the 1970 census, 96.9% of the population of Lake County is white, 0.2% is Black, 0.1% is Japanese, 0.1% is Filipino, 1.7% is American Indian, 4.5% is Spanish American and 0.9% is classified as other. Lake County has 7.6% minority population with a rank of 52 on this variable for California

counties. This is not the complementary figure of 96.9 for whites because Spanish Americans are also counted in the racial categories as white, Black, or other races.

5.2.3 Population Trends and Demographic Components.

Population projections and trends can be derived from five demographic components, defined as macro-indicators for a geographic area, which are interrelated as follows:

$$P_0 + \Delta t = P_0 + (\text{Birth Rate} - \text{Death Rate}) + (\text{In-migration Rate} - \text{Out-migration Rate})$$

where P_0 = Population at time zero.

$P_0 + \Delta t$ = Population at time zero plus a discrete period of time.

Population trends are based upon these five demographic components: population at a given time, birth rate, death rate, in-migration and out-migration rates. The discussion covers geographic distribution, past population changes, current population numbers, and the other components.

5.2.3.1 Geographic Distribution of the Population

Lake County's population is classified as 30% urban and 70% rural. Overall population density for the county is 15.5 persons per square mile in contrast to the California average of 127.6 persons per square mile (U.S. Census, 1970). The population statistics drawn from the census relate only to those who reside in Lake County permanently. The actual number of people in the area fluctuates seasonally with tourism, with heaviest concentrations during the summer months. The areas in which the permanent population resides also are the areas most attractive for tourism.

The population has been mainly distributed around Clear Lake. The pattern of settlement is displayed in Figure 5.6, which shows the population outlining the boundaries of the lake, with other concentrations at Kelseyville, Cobb and Middletown. Population numbers for the year 1975 are provided on the map. The county is divided jurisdictionally into five supervisorial districts. The county seat at Lakeport is the only incorporated city. Thus, the major concentration of population and recreational activity is within the Clear Lake Basin. Until now, the geothermal exploration and prospecting

activity has been concentrated in the lower southwestern area of the county.

5.2.3.2 Past and Current Population Numbers

A time-series graph for the population of Lake County from 1860 to 1970 is presented in Figure 5.7. Population numbers plus percent change from each period is presented in Table 5-II. There has been an increase of 20% in the population between the years 1950 and 1960. For the period 1960 to 1970 the percent change in population was 42%, which represents very high population growth rate.

The population projections in Figure 5.8 are based solely upon a demographic model usually described as a cohort component or cohort survival mode. The word "cohort" refers to a group of persons with a common birth year or span of birth years.

The basic components of a demographic model of population projection are a base population differentiated by age and sex groups, and assumed future rates of mortality, fertility, and migration. For the projections in this report, mortality rates are assumed fairly constant, since historical trends in California exhibit such a pattern. Fertility rate assumptions, from highest to lowest, are designated C, D, and E with rates of 2.8, 2.5 and 2.1 respectively. For a zero growth population, the rate would be 2.11 births per woman. Migration rates are harder to estimate. Total state migration projections used 100,000 persons per year as a base. The model designation D-100 is for fertility level D and 100,000 net migrants. Net migration levels of zero and 150,000 for a minimum and maximum are represented in series E-0, D-150 and C-150. The Lake County projections are civilian as there is no assumed military population at any future date. All projections are made as of July 1st, of their respective years.

Based on these demographic models, the projections for Lake County are presented in Figure 5.8. These projections may prove to be conservative over the next five years, given the fact of the heavy in-migration to Lake County. The county is one of the fastest growing counties in terms of population in the State of California today, but these projections show a maximum growth in population for the county of only 29,000 by 1980.

5.2.3.3 Birth Rates and Death Rates

Birth rates and death rates could be calculated from the statistics provided in Table 5-III. The number of live births and deaths for the three counties, Lake, Napa and Sonoma, and the State of California are provided for a three year period, from 1972, 1973 and 1974. These are based on Vital Statistics of California. Lake County displays a disproportionate number of deaths over live births, as expected, given the bimodal nature of the population age distribution. However, the birth-rate death-rate component of the population change equation is not the determining one for prediction of population projections for the county.

5.2.3.4 In-migration and Out-migration

Lake County is one of the fastest growing counties in California. The advantages of rural, small town living, coupled with an unpolluted environment, have attracted many younger couples, as well as people planning retirement, to the county. The disadvantages of a potentially reduced income do not outweigh the other attractions for people seeking a certain environment. Some civic leaders attribute the growth to an influx of both younger and retired people who are seeking a relatively crime-free environment. It is thought that the young families who have immigrated into the county are not necessarily returnees. The pattern of returnees has been that of those born in Lake County, who leave for a major urban point during their productive years, and eventually return. The stream of younger people has consisted of those who have left urban areas and come to this rural, relaxed atmosphere for three reasons: (1) it costs less to live here, (2) one can buy land at a reasonable price, and (3) one can attempt to be partially self-sustaining. There are exceptions to the above, and the patterns of in- and out-migration should be more fully delineated.

5.2.4 Educational Profile of the County

Educational attainments for persons 25 years old and over of both sexes for Lake County, according to 1970 Census figures, show the following: 32% of the population are high school graduates (a ranking of 35 out of 58 in the state comparisons), 11.2% have some college (a ranking of 54 in the state comparisons), and 7.2% are college graduates (a ranking of 53 in the state comparisons). The median number of years of schooling for Lake County is 12.0. Although this statistic is within the small distribution range for all counties from 10.7 to 12.9, the county has one of the lowest rankings, 51 out of

58. This indicates a population of comparatively little formal education as well as the potential type of available labor for a relocating industry.

5.2.5 Occupational Distribution and Structure

Occupational distribution of employed persons, aged 16 years and over for Lake County, 1970 data, is presented in Figure 5.9. The labor force has been differentiated according to male and female and according to twelve occupational categories. The total number of persons in the active labor force is indicated at about 5,800. The modal categories for males employed are: category 5, craftsmen, foremen and kindred workers, at approximately 22%, and category 2, managers and administrators, except farm administrators, at 15%. These two are followed by the next level of modal categories: category 11, service workers (except private households), at 11%; and category 1, professional and technical workers, at 9%. For the female employed population, the two modal categories are: category 4, clerical and kindred workers, at approximately 31%, and category 11, service workers (except private households), at 28%. The comparative occupational distribution of employed persons aged 16 years and over is provided for California, 1970 in Figure 5.10.

The occupational structure of Lake County can be examined within the context of the national structure (Labor Market Newsletter, E.D.D.). The national trend has been that of a steady increase in the proportion of white collar jobs--professional, technical and managerial jobs, sales jobs, and clerical jobs. During the later part of the 1970's, a continuation in the rapid growth in these white collar occupations is expected; a slower-than-average growth of blue collar occupations, a faster-than-average growth among service workers, and a general decline of farm workers in most areas are also foreseen. It is expected that by 1980, white collar jobs will account for more than one-half of all employed workers in the United States.

Based on Employment Development Department figures for the four categories of (1) white collar workers, (2) service occupations, (3) blue collar workers, and (4) farmers and farm workers, the following occupational distribution structure for Lake County was compiled. In 1970, 43% of the employed residents, both male and female, were white collar workers, a lower percentage than the statewide figure of 54%. The absence of a highly diversified industrial configuration within Lake County limits the need for workers in these positions. Lake County is characterized by a natural-resource-based economy where tourism,

agriculture, logging and related wood products manufacturing are major sources of employment. The largest group of white collar workers is in the clerical occupations, comprising 14% of the employed residents of the county, as compared to the statewide number of 20%.

Service occupations, the fastest growing occupational sector, account for 19% of the employed persons in Lake County, which is higher than the statewide figure of 11%. Usually a densely populated area is essential for thriving service industries; yet, Lake County is sparsely populated, with service workers comprising the largest single occupational group within the county, primarily because of tourism in the area. Nationally, this occupational group is expected to increase by about 35% between 1970 and 1980, as well as in Lake County. Factors contributing to the growth of employment in services are the planned expansion of summer and winter recreation facilities and other tourism attractions, and the rising demand for hospital and other medical care.

The blue collar workers include craftsmen, semi-skilled workers and laborers, who make up 29% of the total employment in Lake County. An increase in employment of blue-collar workers is dependent upon activity in the construction industry, not only in Lake County but in surrounding areas as well. The nonfarm laborer (casual labor type) is included in this group and represents 6% of total employment, slightly above the statewide figure of 4%.

Farmers and farm workers comprise 9% of the total employment in Lake County, compared to 2% of California's total employment. Farm labor employment is seasonal, rising during the peak harvest months.

In general, many job opportunities in the county are subject to extreme seasonal variations. Lumber industry, tourism, agricultural and related food processing employment reach a peak during the summer and autumn, and decline during the winter months, causing considerable, although temporary unemployment. Although employment growth and creation of new jobs are key indicators of future job opportunities, more jobs are created from replacement requirements as workers withdraw from the labor force because of death, retirement or other factors.

5.3 ECONOMIC CONDITION AND PERSPECTIVE OF LAKE COUNTY

5.3.1 Employment and Unemployment

Lake County, relying on agriculture and tourism, has a very unstable employment pattern. The summer and fall months have historically been the peak employment times while the winter months have brought unemployment rates as high as 21% (see Figure 5.11). Tourist activity in summer and autumn harvesting provide short-term employment for thousands of residents. Figure 5.11 shows the monthly unemployment rates for Lake County and California from January 1970 through December 1976.

The trough of Lake County's unemployment cycle rested at 2.7% in September 1970. Each successive year has witnessed a rising trough until 1976's September unemployment rate of 8%, which is considered high for a peak employment month. Complementary to this trend is a rising unemployment rate during the winter off season: in February 1970, the rate was 12.5% and increased each year with February 1975 showing a rate of 21.3%.

These trends indicate some of Lake County's major economic problems due to its reliance on two cyclical sectors. Mechanization within the agriculture industry has steadily reduced employment in that sector. Weather conditions, such as the present drought and frequent frost, can further reduce employment.

Table 5-IV illustrates Lake County's employment by industry and sex in 1970. Services and wholesale and retail trade account for 47% of the county's employment. Agriculture, forestry, mining, construction and manufacturing provide only 29.5% of the employment. Of all employed females, 80.3% are in services, public administration, or wholesale and retail trades. Light industrial activity in the county is lacking.

Some statistics from the 1970 U.S Census are illuminating for a profiling of Lake County's economy. Manufacturing employed only 5.1% of the working population, as compared to 21.6% for the state. Only 55.1% of the males over age 16 are in the labor force, giving Lake County the lowest rate in the state for that category. In contrast, participation rates in the overall labor force for males aged 14-17 are among the highest in the state. Males and females between the ages of 45-64 exhibit the lowest labor force participation rates of any county in the state, 67.4% for males and 33.5% for females. This can be expected since, as noted above, Lake County is a

place to which older persons immigrate for retirement. The overall pattern indicates very low participation rates in the labor force of Lake County for almost all age groups other than the 14-17 age group of males. The primary reason for low participation rates is again the lack of industrial activity to provide direct jobs and provide indirect spillover employment opportunities.

Perhaps the most critical statistic in the 1970 Census data is the non-worker-to-worker ratio in Lake County. This provides an economic indicator much like the demographic dependency ratios described above (Section 5.2.1). Specifically, Lake County's ratio of 2.01 to 1 means that for every person working, there are two persons not working and ultimately dependent upon an employed person for support. Statewide this ratio was only 1.37 to 1 in 1970. Out-migration of persons of working age has contributed to the increased non-worker-to-worker ratio.

Labor force activity could be expected to be increased. In 1970, 134 of 372 experienced unemployed males over age 16 were draftsmen, foremen and kindred workers; 82 others were operative, including transport. Together, these groups comprised 58% of the experienced, unemployed males in 1970. These absolute numbers are not large but the population base is small, and even small industries employing 6-20 people are objects of attention and concern in the county. It is conceivable that many of these individuals could find employment in a developing resource industry, which requires individuals of such skills, among many others. Whether this could have long term impacts on the county's unemployment problems would depend on the various locales and modes of recruitment selected by the geothermal industry.

5.3.2 Income

Based on 1970 U.S. Census data, Lake County had the lowest median income in the state of California: \$6,551 compared to \$10,732 statewide. Furthermore, 17.7% of all families in the county, the highest percentage of any county in the state, received an income below poverty level, \$3,000 (as compared to 8% for the state).

Figure 5.12 shows the percent distribution of family income for Lake County and California. Almost 40% of the families in the county earn less than \$5,000; statewide this figure is 17%. Only 10.8% of the families in the county earned over \$15,000, the lowest such percentage in the state for which the average was 26.7%. Figures 5.13 and 5.14, showing family

income in Sonoma and Napa Counties, are included for comparison. It should be noted that even though both counties are adjacent to Lake and share interests in regard to geothermal development, their median and mean incomes more closely parallel the state average, reflecting a much different demographic and economic base.

The trend for per capita personal income growth for Lake, Napa and Sonoma Counties and for the State of California for the years 1965 through 1973 is provided in Table 5-V. For Lake County, per capita income increased from 2,494 in 1965 to 4,180 in 1973, but it did not maintain its ratio of 0.76 to state figures.

Personal income by source for the years 1969 to 1973 for Lake County and comparative figures for California are provided in Table 5-VI. The same figures in terms of percentage distribution of sources of personal income are provided in Table 5-VII. In 1973, transfer payments constituted 28% of the sources of personal income for Lake County compared to the state-wide figure of 12%. Wages and salaries constituted 33% of the sources for the county, whereas wages and salaries constituted 64% of the sources of personal income state-wide.

These statistics showing low income in Lake County might appear to reflect the growing number of persons on fixed income, especially retired people on social security. However, even for those persons employed, the median earnings are approximately two-thirds to three-quarters of the state median figures (see Table 5-VIII).

5.3.3 Population Growth

The steady growth of Lake County's population has been mainly attributed to the influx of persons of retirement age. Developers have continued to concentrate on construction of retirement communities. Subdivisions have increased steadily to provide room for small-lot, mobile-home oriented settlement. The trend is toward an increase in the number of persons that have selected the county as a vacation spot with possible plans for future retirement there.

Such population growth, however, provides limited economic benefit for the county. Retired persons living on fixed incomes have low consumption patterns and reduced economic activity. Persons who have vacation homes in the county are only part-time residents, and provide only sporadic economic boosts. On the other hand, the core of economically active persons in Lake County, specifically those persons aged 16-45, has declined.

Between 1960-1970, the population of Lake County increased 42.4%, from 13,9000 to 19,800. For that period, the components of the change for Lake County have been a natural decrease of 700 and a net-migration of 6,600 persons (California Statistical Abstract, 1975). These figures are indicative of a population with a median age of 47, the influx of retirement age persons and of a higher than average death rate. Should this type of growth pattern continue, Lake County faces the problem of how to expand its economic base to accommodate the needs of a growing population characterized by limited economic activity.

5.3.4 Education

The public school system consists of seven school districts: four unified districts, two elementary districts and one union high school district. School enrollments have increased from 3,799 in 1966 to 4,856 in 1975. The enrollment increase of 6.9% in 1975 was the highest percentage increase for enrollment throughout the state (Table 5-IX). School enrollment by district for 1975 is presented in Table 5-X. The contribution of geothermal development in a particular school district, the Middletown Unified School District, is presented in Section 5.4.

5.3.5 Housing

The total number of housing units in Lake County is 15,294 permanent units and approximately 3,000 trailer and mobile home units, according to Department of Finance figures for January 1976 (see Table 5-XI). According to the Housing Element of the General Plan (1971) over 55% of the housing units of that year were second homes. The most unique feature of the housing profile for Lake County is the large proportion of mobile homes, which carries with it economic implications for the county.

Much of the elderly population live in mobile homes, and thus pay property taxes on the lots only. Such limited taxes are not necessarily low for individuals on fixed incomes. Yet, mobile home owners have contributed proportionately less to the overall county revenues, while deriving benefits on an equal basis to all other taxpayers. After long hearings, the Board of Supervisors in January 1977 passed a resolution that was to become an ordinance which would have required all new mobile homes to be installed on permanent foundations and be taxed as real property. The resolution was defeated by a citizens' initiative. Currently, the tax inequity still exists. The registration fees are based on the value of the mobile home,

but the rate is only slightly different from that of car fees. Mobile home owners pay registration and license fees to the state, and most of that money does not come back to the county. As the mobile homes get older, an even smaller percentage comes back. For older mobile homes, the county receives only 15-20% of the fees.

5.3.6 Agriculture

Agriculture is the primary contributor to economic activity in Lake County, with gross sales of \$20 million in 1975. Table 5-XII provides figures for the annual gross value of agricultural production for the years 1964 through 1975. A decrease of 5-8% annually is indicated between the years 1973 and 1975.

Net profits are considerably less now, as compared to past years, due to inflationary costs of farm production. Rising costs for farm production, coupled with lower prices paid for products, has reduced the demand for farm property. County taxes on farm property continue to be high, based on high prices paid during 1973 for land and improved property. Live-stock producers are confronted with higher feed costs as well.

Bartlett pear production dominates the agriculture industry in Lake County. While field crops, livestock and poultry constitute a part of total agricultural production, approximately 60% of the gross revenues is derived from Bartlett pear sales (see Table 5-XIII, Sector Contribution to Total Agricultural Production in Lake County, 1974-1975). According to the Lake County Chamber of Commerce, there are about 250 pear orchards in Lake County. The county leads the state in total acreage devoted to this crop, with 8,890 acres in 1969. Pear production is the largest single industry in the county, with revenues of \$11 million in 1975. About half of the pear crop is sold fresh to markets with the other half going to canneries in Sacramento and San Jose.

Employment in the pear industry reaches a peak of about 6,700 employees during harvest, when approximately 1,265 persons work in the pear sheds and 5,490 work in the fields. However, during the off-season, employment falls to 22 persons in the sheds and 266 in the fields.

Table 5-XIII shows a breakdown of agricultural revenues by source for 1974 and 1975. For 1975, pears provided 56% of the total agricultural production. Walnuts are second in importance, providing revenues of \$2.6 million or 13%. Livestock

and poultry generate another 13% as do field crops. The remaining 5% comes from wine grapes, eggs and a few other products. Increasing acreage has been converted to grape production, but this industry will apparently be slow to achieve major importance.

5.3.7 Recreation and Tourism

Clear Lake is regarded as Lake County's major recreational attraction. The lake's attractiveness as a resort and recreational area has steadily fallen, partly due to lack of development but mostly due to competition from Lake Tahoe and ski resorts in the winter, and from beaches and mountains in the summer. Changing patterns of recreation and development of other resort areas have steadily eroded the tourist industry of the Clear Lake region.

Tourism is not an unmitigated boon as an economic activity. On one hand, it is considered a profitable industry, with organizations like the Lake County Chamber of Commerce taking steps to attract more tourists from the San Francisco Bay Area, San Jose and the Sacramento Valley through an aggressive advertising program. On the other hand, the county experiences an annual boom-bust cycle as a result of this activity.

5.3.8 Finance

Because of its rural nature, low personal income, and lack of overall development, Lake County has been forced to rely heavily on governmental support to meet its budget requirements. A rising number of persons are on some form of government assistance program (see Table 5-VII). The unemployment office of Lake County handles an ever increasing number of assistance cases.

A breakdown of the sources of county revenues for the fiscal years 1974-1975 is presented in Table 5-XIV. For those years, governmental aid has provided about half the total needed revenue. Property taxes provide about another one-quarter and other taxes add another 10% of needed monies. The remaining 15% is raised through six other sources shown in Table 5-XIV.

A further breakdown of governmental aid to Lake County shows 12% originating from State Public Assistance programs, 12% from highway users taxes, 16% from Federal Public Assistance programs, 13% from Federal Revenue Sharing, and 12% from State and Federal Public Assistance Administration in 1974-1975. Even though governmental aid has declined as a percentage

contribution to the county budget, in absolute numbers aid has increased 10% from 1974 to 1977. Part of this increase is due to the cost of living adjustments to welfare payments, but the fact remains that no relief is in sight for the county's high reliance on federal and state aid.

An analysis of Lake County's budget requirements for the fiscal years 1974-1977 is presented in Table 5-XV. The category of public assistance makes up about 30% of the budget. Aid to families with dependent children (AFDC) is by far the largest sub-category, comprising over 50% of total assistance, \$2,144,880 in the budget for fiscal year 1976-1977. General county expenditures account for about another 30% of the budget with \$3,338,261 appropriated for 1976-1977. Major sub-categories include capital projects, office salaries, property management and revenue sharing. Public Protection has witnessed the greatest increase in expenditures since 1974, from 13.1% of the budget to 20.6% of the budget in 1976-1977. Public highways and facilities expenditures comprise another 12-14% of the budget with the road department the major recipient. The remaining budget units of health and sanitation, education, recreational facilities, and reserves account for about 10% of the budget.

5.4 ECONOMIC IMPACT OF GEOTHERMAL DEVELOPMENT IN LAKE COUNTY

This section focuses on three areas of impact of geothermal development:

1. Impact on the economy of Lake County and selected sectors.
2. Impact on county revenues and tax base of Lake County.
3. Impact on landowners.

5.4.1 Impact of Geothermal Energy on the Economy of Lake County and Selected Sectors

Our current estimates of the potential of geothermal power generation capacity in Lake County are between 400 MW and 1,200 MW. The total thermal energy potential is estimated at much more. By 1990, it is likely that several hundred MW of electrical power will be on stream in the county. Assuming an ultimate capacity of 1,000 MW of electricity generated, and assuming a current cost of 2.5 cents per kWH, the total value

of produced geothermal energy per year would be in the neighborhood of 200 million (in constant 1977 dollars). This figure exceeds the total value of agricultural production and monies generated by the tourist industry for the year 1975. Geothermal energy is likely therefore to overshadow agricultural production as one of the major commodities exported from the county by the mid or late 1990's by a very large margin.

Since exploration into the other potential uses of geothermal energy is the subject of this report, the above estimates for value of the resource are, if anything, conservative in nature. Other sources of revenue, besides the sale of electrical energy, are expected from any number of the direct heat applications, if the economic feasibility for such agricultural and industrial processes can be demonstrated and encouraged.

Rational geothermal resource development is considered a potential solution to the county's economic problems by many of the county's government officials and by a segment of its residents. If the development of geothermal energy were to result in agro-industrial expansion within the county, some of the more immediate and obvious economic problems, such as the inability of the county to provide an optimum level of essential services, and the seasonal nature of employment, resulting in high unemployment rates, may be relieved. Diversification of the county's sources of revenue, which are currently dependent primarily upon agriculture and tourism, would provide a cushion for the periodic shocks which the county receives in annual "boom-bust" cycles which are dependent upon changes in agricultural product prices, product yields, and the tourist season. With the introduction of alternate employment opportunities, the seasonal variations in unemployment rates could be softened.

5.4.1.1 Technical Labor Force

According to Pacific Gas and Electric Company figures, an estimated 640 people are working in jobs directly involved in geothermal development in the Sonoma-Lake County region. The number includes Pacific Gas and Electric Company's maintenance crews, operating crews and construction personnel, and the steam supplier's drilling, maintenance, administrative and construction workers. The growth rate in employment in the geothermal industry is about 4% per year. By 1981, the employment level for the region is expected to be 740 in the industry (Mahoney and Bangert, 1977).

Based on the assumption that the above development of geothermal resources would take place by the year 2000, Lake County could witness an increase in the technical labor force of more than 1,000 technical personnel, to operate and maintain the envisioned power plants and geothermal fields, and to maintain any of the direct-heat enterprises. The distribution of the labor force required for maintenance of the power plants and ancillary geothermal fields is different and of a lesser intensity per capital dollar outlay than that required for direct-heat enterprises. The demand for labor in the construction phases of power plants would be approximately one to two persons per MW installed capacity for three years (the construction period). The demand for labor would be approximately one person per eight MW capacity to operate and maintain the plant. At present, about 70 individuals are employed by Pacific Gas and Electric, operating a 500 MW complex of geothermal power plants. Maintenance of the steam field provides additional permanent employment to another 25 people.

The impact on the regional labor force in The Geysers-Clear Lake area in terms of direct creation of employment opportunities would be minimal. Secondary impacts have been identified as the additional manhours in support and regulation of the industry, such as employment in manufacturing materials and implementing government regulations. These are not necessarily associated with increased economic activity in the locale of development (Mahoney and Bangert, 1977). Of greater importance would be the secondary impact of service industries to support the growth in geothermal operations.

5.4.1.2 Pacific Gas and Electric Company and Other Utility Districts

A major beneficiary of development would be Pacific Gas and Electric Company or other utilities districts, whose returns are regulated by law at about 6-8% of gross revenue. (See Section 5.4.2 for revenues generated). Some communities which desire to develop their own electrical supply from geothermal energy have organized into the Northern California Power Association. This is a consortium of twelve cities which, among other activities, have combined to lease and develop the geothermal resource for the supply of their electrical power needs from The Geysers-Clear Lake development. Lake County itself is contemplating forming a utility district for its own electric power needs.

5.4.2 Impact on Lake County Revenues and Tax Base

The property tax base for Lake County has historically contributed about 30-35% of the county budget requirements (see Table 5-XVII). Presently, reappraisals of single family residences have caused a big jump in assessed valuation. Reassessments of land leased for geothermal activity have also resulted in an increase in taxes. However, due to a rapidly increasing county budget, the general county tax rate has also been increasing.

Also, property sales have accelerated, resulting in increased property values. Thousands of subdivision units were approved for retirement development and vacation homes. This change in land use, combined with the switch of agricultural land to recreational uses, has further increased the tax base.

The impact that development in any one area has on surrounding areas is not readily determined. To some degree, it depends on their development potential. However, a person owning land in the midst of geothermal activity who does not want to lease will most likely not have to pay more taxes due to increased valuation. Geothermal development in an area is closely watched by the assessor and the property is reappraised when exploratory results are known. The leases themselves have relatively little impact on land value. Land use is the main criterion in determining the tax level.

The assessed value of geothermal land is based on its income-producing capabilities. Assuming that a power plant is to be constructed and its generating capacity is known, the percent contribution of each well is easily calculated. However, there is a time lag between the time the resource is found and the time that it is used in the power plant. Therefore, a present discounted value of the land is arrived at for future income streams, which is used for the reappraisal. Land which is leased for development but has not undergone any exploration activity is not reassessed until results of the exploratory activity are known.

Overall tax rates within the county vary widely, from a low of \$7.45 per hundred to a high of \$12.00 per hundred for 1976-1977. According to the assessor, this wide differential has been closing. The tax rate is based upon "assessed valuation," which is 1/4 of the actual value. The general county rate is \$2.69 per hundred of assessed valuation. The remaining portion of the overall rate is based on the various budgetary requirements of individual districts and each district's total valuation. These include school tax and other taxes.

To date, geothermal activity has been in low tax-rate areas, and concentrated in the Middletown School District, which is the locale of the site area of Pacific Gas and Electric's Unit 13.

Recently, geothermal resource companies have obtained many leases on Bureau of Land Management (BLM) land within the county. When use of these lands transfers from the government to private hands, the land may be locally taxed. This activity has increased the tax base and the lessor is responsible for taxes to the county. A summary of the county revenues received from geothermal activity since 1972, was obtained from the county tax assessor, Mr. Verdon L. Strong. The year of 1972 is the first year with increased valuation directly attributed to such activity. In 1976-1977, revenues from geothermal activity (private wells and BLM leases) comprised 2.5% of the total county revenue from property taxes. This has increased from 0.03% in 1972-1973 (Table 5-XVIII).

The county tax assessor predicts that geothermal development will greatly reduce the tax rate for the county. Based on a projected assessed value of almost \$12 million for Pacific Gas and Electric Company's power plant Unit 13, the area of development, Middletown district, could reduce its tax rate by almost 50%. The current total assessed valuation in the district is \$22 million for 1976-1977. Table 5-XVI presents the component funds and rates for this school district. The total assessed valuation of property in this district was \$22 million in 1976-1977. The projected assessed valuation of Unit 13 for tax purposes is \$12 million. Based on these figures, the tax assessor predicts that the Middletown district can reduce its tax rate and still provide its needed revenue. He also predicts that areas further away from development will be able to reduce their tax rates by approximately 10% due to the added value of the plant to the total county tax base. Geothermal development could eventually reduce the tax rate for the entire county, based on the assumption of no expansion in county or district services.

The assessor believes that the Lakeport area can reduce its rate by 18% and still generate the same revenue as in 1976-1977. However, all these reductions are dependent upon an expenditure freeze. If budgets increase, the assumed tax reductions will be smaller.

According to the county tax assessor, geothermal development solely for electric power generation may further induce the growth of the old-age retirement community. Electric power

generation would result in increased county revenues, an expanding government but no major increase in economic activity. Therefore, no positions are created for persons of working age but the increased revenues could be spent by thus providing additional services for the retired community.

Data from 1970 through 1977 may provide some basis for predicting tax benefit distribution and courses of future action by the Board of Supervisors. During this period, the total assessed valuation of property in Lake County rose 64%, from \$97 million to \$159 million (see Table 5-XVII). However, due to an 81% increase in the county budget requirements, the general county tax rate rose 15%. Were this trend to continue, benefits accruing to the county would be realized solely through an increase in social services rather than directly through lower taxes.

Geothermal development in Lake County is likely to have a major impact on the tax structure: as land is leased for geothermal exploration it is reassessed by the county tax assessor to reflect its increased value. Each reassessment results in an increase in the county-wide tax base. An analysis of the revenues received by Lake County from geothermal activity since 1972 is presented in Table 5-XVIII.

County revenues will increase significantly over the next decade due to geothermal activity. The question of whether geothermal development would result in a reduction of the county property taxes or whether the increased revenues would be offset by expanding county government and provision of services is a dynamic, evolving issue for the county.

5.4.3 Other Tax Benefits

Other tax benefits to state and federal governments are derived from electric power generation. These are at fixed statutory rates paid by Pacific Gas and Electric Company. Based on a gross income of \$27 million per year per 110 MW electrical power generating module (assuming an 80% load factor and a sale rate of 3.5¢ per kWh), a power plant such as the one projected at the site of Unit 13 (135 MW) could produce about \$33 million of gross income. The computation of taxable income of utilities is in compliance with federal and state income laws. The federal government receives 48% of taxable income. The State of California receives 9% of the taxable income which remains after the deduction of the federal income tax.

Pacific Gas and Electric also pays franchise taxes to counties and cities for the privilege of doing business. In

1976, according to Pacific Gas and Electric Company numbers, these amounted to nearly \$16 million, of which \$466,000 was paid to Lake and Sonoma counties and cities.

5.4.4 Impact on Landowners

Landowners could be among the prime beneficiaries of geothermal resource leasing and development. The amount of return to the landowner is based on a multiplicity of factors not entirely in his control. The three major factors are: 1) the quality and size of the resources; 2) the timing of exploration and development; and 3) the terms of the lease agreement. The projected gains from the lease must be balanced against projected loss. Essentially, the determination is one of evaluating whether the new land use for geothermal is profitable (see Andersen and Wallace, 1976).

Substantial financial losses from environmental damage and unfavorable tax treatment are also possible. Geothermal development can reduce the yield of crops and increase costs of crop protection.

Another aspect of return to landowners is that the timing and extent of geothermal activities can reduce the value of land for residential, recreational and other developments. Even though some negative impacts would occur, however, lease fees and royalties to private landowners could dwarf all other aspects of current and potential land use. The total revenue from a lease is based upon: 1) rental payment; 2) bonus bid (a sum paid upon contract signature); and 3) royalties. In areas of unknown geothermal potential, geothermal lessees have offered landowners about \$1 per acre per year plus 10% royalty on steam sales revenue. Royalties start when steam is actually sold, at which time lease fees (rental) normally stops. In some cases, annual rent is not paid; in other cases, net royalty revenues to the landowner may be reduced by tax payments and other expenses. In areas of high geothermal potential, landowners have bargained for lease fees of \$20 to \$100 per acre and 8 to 19% of the gross steam sales revenue (see Finn, 1973). On the average, landowners receive about one-eighth of the gross value of steam produced in this region. It is likely that their share of the gross income would be about 2.4 million dollars per 110 MW module. A large percentage of that income will revert to federal, state and county governments as personal income taxes.

The net return to a landowner from a geothermal lease can be calculated from a net change in annual income by accounting for increased revenue less increased costs. Change in

revenue can be calculated from bonuses, rental fees, royalties, crop damage compensation or other compensatory payments, and miscellaneous revenue. Change in costs can be calculated from taxes, penalties, management expenses, legal fees, damage to crops or other effects on land use productivity (see Andersen and Wallace, 1976). Calculations of projected net return contain wide margins of risk in both revenues and cost components.

5.5 SOCIAL AND ECONOMIC FACTORS RELATED TO GEOTHERMAL RESOURCE DEVELOPMENT

5.5.1 Identification of Goals of the County in Terms of the Well-being and Quality of Life of its Population

An overall planning exercise has been carried out by several quasi-governmental and citizens' groups in the county. Notably, the Lake County Coordinating Council for Overall Economic Development, comprised of several committees, has defined development goals in its report (Overall Economic Development Plan, 1975-1976). The problems identified as needing immediate attention are:

1. Persistent unemployment
2. Abatement of the Clear Lake gnat problems
3. Pollution of Clear Lake waters and control of algae growth
4. Development of multi-purpose water projects
5. Housing the office of the county superintendent of schools

Area goals and action programs as defined by the various committees of the Lake County Coordinating Council for Overall Economic Development (1976) may be summarized as follows:

1. Attraction of new light industry to offset unemployment and to relieve tax burden on agriculture
2. Completion of precise zoning of Lake County's lands according to the general plan
3. Importation of water from the Eel River through Clear Lake to supplement Lake County's growing water needs

4. Development of transportation facilities directly related to agriculture, industry, recreation and senior citizens
5. Development of geothermal energy potential
6. Management of Clear Lake bottom- and rim-lands
7. Upgrading of recreational and tourism facilities, particularly parks
8. Further development of a favorable governmental climate attractive to industry, agriculture, recreation and senior citizens
9. Continued improvement of health care facilities
10. Area beautification which would make Lake County more attractive to tourists, to light industry and to retirees
11. Now that Lake County has become part of the Mendocino and Yuba community college districts, it is hoped that adult vocational education courses will enable adult workers to become trained in skills which will lead to steady employment.

Identification of sensitive impact effects of geothermal development is important. Any development which affected the above goals adversely would be met with opposition. On the other hand, applications of geothermal development which contribute to the achievement of stated goals or amelioration of recognized problems could gain support from any number of sectors, including those identified as anti-geothermal development.

5.5.2 Social Effects at the Individual and Family Level in the County

At the most basic level, beneficial or adverse social effects from a development plan derive from the project's success or failure to meet the social needs of the individual and family. In considering the differential socioeconomic impact of development, one useful approach can be that of the hierarchy of human needs as set forth by Maslow (1954). Human needs can be organized into a hierarchy in which one level must be satisfied before the person can consider the next. These levels of needs range from basic survival and physiological needs, to needs of security and self-sufficiency, to social or

group identity needs, to esteem, and finally, to needs of personal growth and self-actualization.

It is thus important to identify individuals and families whose needs are at the base level of the hierarchy, because they could well be the most important beneficiaries of a development program. On the other hand, they would be less able to cope with any adversity caused by a particular development program than others on the different levels of the hierarchy. These individuals or families may be identified either by certain demographic characteristics or by economic condition. In fact, it would be a valuable planning exercise for Lake County to assess the form or manner in which these groups, such as the elderly, the young, the unemployed and families on welfare, would be affected by geothermal development. Whether the effects would be felt indirectly through social services or directly through some type of job opportunity would be determined by the particular combination of applications.

Priorities and guidelines for social and economic development are delineated in the county planning documents and are continually evolving. Some guidelines specifically address the level of individual and family needs. The implementation of these programs will have profound effects on the satisfaction of these needs at most levels of existence.

One cannot assume that all individuals and families will react in the same way to any economic development. One aspect to be considered would be determination of how the development plans are related to needs. Attitudes vary with membership in different groups, and with experiences, goals and personal views about life. Thus, any project plan should have baseline attitudinal data in order to acquire some foreknowledge of differential responses and perceived benefits of any given application of direct heat utilization and/or development.

5.5.3 Group and Community Perspective of Social Effects

At this level, social effects could be identified either on a county-wide or a site specific level. Identification of aspects of geothermal development and concomitant social impacts could be organized as follows:

1. How geothermal development would differentially affect groups and institutions of the community
2. How development would affect the standard of living

3. How development would affect quality and diversity of services
4. How development would affect the formal and informal structure of community groups
5. How development would affect the general composition and character of the future community during and after development

A number of social concerns may be identified at this level, five of which are particularly relevant:

1. Opportunities available to people enabling them to participate in the social life and evolving economy of their communities
2. Stability and enhancement of community values and norms. The concern here is how positive, negative or drastic will be the changes resulting from the development in view of present-day norms and values.
3. The manner in which a predominantly agricultural, rural and environmentally oriented community, with its associated values, will be affected by an entirely new set of values introduced by any increase in urban-dominated economic activities. This has been a constant concern of the Lake County Energy Council.
4. The impact on the out-migration of the young and the in-migration of both the young and the elderly of the new job opportunities.
5. Impact of development on major institutions which provide critical services, such as education, health, crime protection, public assistance and transportation.

5.5.4 Area Socioeconomic Effects - Lake County

Based on the predicted high potential of geothermal energy, the implementation of current development plans could make the County of Lake a growth and development center, serving as a centralized place for mini-industrial agricultural processing and marketing, providing services and job opportunities. The effect thus would not only be localized but would reinforce the development of a string of service centers and communities, eventually leading to a stronger economic base for the entire county.

Shifts from the economic base of agriculture and tourism plus governmental assistance to that of industrial and agro-industrial would take place as a consequence of a major development of the geothermal resource. Different types of jobs would require new skills which will attract new inhabitants. New populations can radically alter demands, both in a negative and a positive sense: negatively, by straining capacities of housing, education, water supply and health services if such development proceeds rapidly, and positively by serving as an impetus for increased supply of these same services. One positive potential outcome is that a significant population increase generated by new employment opportunities is likely to have the secondary impact of establishing new and improved transportation and communication networks.

Furthermore, the planning process itself has its own secondary effect. Local groups like the Lake County Energy Council and the Geothermal Energy Association, aware that changes are in fact coming, have been stimulated to make their own contribution to development plans. On the other hand, a delay in development, coming in the wake of rising expectations, may have serious social and economic costs during protracted periods of uncertainty. Some note should also be taken of the political milieu in which local and regional leaders and planners must operate, as the plans for development and their implementation crystallize. Geothermal energy development is one of the dominant political issues in Lake County.

5.5.5 Contributions to the Regional Viability of the County

Contributions to the regional viability of Lake County that development of the geothermal resource would make are integrally tied to questions of orientation and autonomy of county units. One aspect of the geothermal resource development in Lake County is a pending conflict between county and state agencies over who regulates the development of the resource. In the past, the California Public Utilities Commission has been the agency to approve the construction of proposed power plants. Future geothermal plant construction will fall under the jurisdiction of the California State Energy Research Commission. It is likely that Lake County will encounter some conflict with the newly established California State Energy Commission over control and regulation of its geothermal resources. The State Energy Commission is chartered to assist the development of geothermal resources throughout the state. Lake County is viewed as unduly cautious in its review and approval process of exploration and development.

Decisions, policies and programs of the county, although they must conform to the perceived needs and values of various sectors in the county, are increasingly formulated in centralized, regional or state offices outside the county. They may also be guided more by their relationship to extra-community systems than by their relations to perceived local community needs only. Indeed, a new regional advisory board has been formed consisting of four counties, Lake, Napa, Sonoma and Mendocino, for the purposes of coordinating and regulating geothermal development activity in the region and of managing a planned development of the resource. That regional body was set up at the initiative of Lake County.

5.5.6 Economic Sectors and Community Groups Identified For or Against Development

This section provides an identification of groups which are for or against development of geothermal energy. The distinction and placement of these groups and sectors is not readily drawn on all issues. However, the following sectors are identified as pro-geothermal development:

1. Geothermal Energy Association of Lake County
2. the geothermal industry, including steam suppliers, oil companies, and developers
3. businesses that supply the geothermal industry
4. land owners with geothermal leases
5. some members of the County Board of Supervisors
6. selected local and regional governmental agencies
7. the financial community
8. utility companies
9. the new research community engaged in geothermal research and consulting
10. Federal government agencies (i.e. ERDA)
11. national laboratories engaged in geothermal research

Other sectors identified as negative or hesitant about the development of geothermal energy and likely to vocalize their views and opposition to unmitigated development are:

1. Lake County Energy Council
2. environmentalist groups
3. groups of homeowners near the geothermal installations
4. residents of the county who perceive little benefits to the area and yet feel threatened by a potential disruption
5. regional or local organizations who perceive little benefits to the immediate locale
6. some local and regional agencies which deal with protection of the physical, chemical and biological environment

5.5.6.1 Lake County Energy Council

One spokesman for community concerns is Peter Windrem, the attorney for the Lake County Energy Council, a well-organized and active citizens' group with a membership of approximately 3,000.

The Lake County Energy Council views, articulated by Windrem in an interview, are that geothermal energy is needed as part of an overall energy development program of the United States, but that strict regulation is essential. Developers must recognize the areas of sensitivity indigenous to the places of development. Lake County is a recreational, agricultural county with certain attributes that will be threatened by geothermal energy. Of primary importance are the air quality, water quality and overall scenic beauty of the area. Using the power plant development in the Sonoma Geysers area as an example, the Energy Council sees all of these attributes as being threatened should a similar facility be constructed in Lake County.

To prevent abuse during development by the geothermal resource companies and Pacific Gas & Electric, the Energy Council supports full-scale investigations of the total impact of development before the initial stages are begun. To achieve this, in March 1977 the Energy Council brought suit challenging the Environmental Impact Report (EIR) for the Thurstone Lake geothermal drilling proposal by the Union Oil Company. The Energy Council complaint was based on the allegation that the EIR for drilling was incomplete since it failed to consider the impact of full-scale development. At the end of June 1977 the

suit was dismissed on a legal technicality relating to the requirements that the environmental report should include the impact of full field development. As stated by Judge MacFarland (quoted in the Clear Lake Observer, June 23, 1977):

To suggest...that the environmental impact report in the instant case relative to exploration should contain information at this time relative to commercial development and production is to require the respondent (Lake County) to present its theoretical estimates as well as its speculative opinions and hypothesis as to production and development... [if the Council's] sole basis for the attack of the existing environmental impact report relative to the exploratory activities of Union Oil, is its failure to include information on commercial development and production. Then the petitioner's action must fail, since such factual information is not and cannot be available to the respondent until the completion of the exploratory drilling program heretofore authorized.

The question of when full field development should be considered in geothermal impact reports in Lake County is fundamental to the controversy between the county and the Energy Council. The Energy Council's case on appeal involving Magma Energy exploration at the base of Mt. Konocti, which also involves this question, was recently decided in favor of Magma and the county (Clear Lake Observer, June 23, 1977).

When questioned about nonelectrical applications of geothermal fluids, Windrem thought that such applications were of minor importance compared to the energy that would be generated by power plants. At this time of national crisis, decisions for use of geothermal fluids are not solely up to the county, but must be coordinated with overall national policy. He stated that a county of 20,000 persons can utilize only a small amount of the fluids produced by the steam suppliers for nonelectric uses. All the problems previously cited regarding power generation must be dealt with also in conjunction with nonelectric uses.

A major concern of the Lake County Energy Council relates to an overall energy program. Mr. Windrem of the Energy Council believes that development of geothermal energy for power will only expand an already wasteful national consumption of electricity. He questioned the motives of Pacific Gas and Electric and the oil companies and was fearful that the geothermal resource companies were interested only in the revenues

from electric power generation, without regard to benefits for the local population. A different outlook would emerge should every new megawatt of electricity produced from geothermal fluids result in an equal reduction in megawatts from an oil fired plant. This would result in decreased oil consumption and would benefit the economy, rather than simply increase electricity consumption.

One reason for distrust of the oil companies has been the oil companies' continued fight against all restrictions proposed by concerned groups. Another point made by Windrem is the rising property tax rates in the county. He is fearful of expanding government due to increased revenues from development. He would like to see across-the-board decreases in resident property taxes when county revenues rise, but he doubts this will be the case.

Windrem does not believe that in-migration of retirement-oriented people creates any major problem for Lake County's economy even though most of these persons live on fixed incomes. His opinion was that younger people are also coming to Lake County to escape the urban environment. This is an additional reason for preservation of the natural attractiveness of the county. On the other hand, if geothermal development can be molded into an acceptable framework it can be successfully developed in Lake County.

The stated hazards which are the concern of the county and the Energy Council are the air pollution, noise pollution, effect on water quality, seismic effects, visual impacts, and alteration of the weather in the Clear Lake Basin. The Lake County Energy Council has stated that there must be advanced technology which will eliminate these hazards. Developers have reduced noise considerably and now have the technology to control hydrogen sulfide emissions. The Energy Council views their own continuous input into the development as essential because: 1) developers tend to create and implement technological advances only when pressured to do so; and 2) some developers fail to show sensitivity to the aesthetic, recreational, residential and spiritual value of the places where they propose to drill.

These are the views of a very active, vocal citizens group, well-informed about the environmental impacts of geothermal development. It is important to note that oil companies and developers have a different perspective with regard to environmental constants. Iain Jameison of Thermogenics, Inc. feels that many of the environmental constraints which the companies follow in the course of drilling, exploration and

development are essentially in the interests of preservation of the environment as well as economic interest of the developer. Alterations and improvements of the physical environment such as grading, seeding of the sites, precautions against landslides, etc., are important to the developer as well, so as to make his facility free of environmental hazards in order to assure a continuous operation.

5.5.6.2 Geothermal Association of Lake County

Another group, the Geothermal Energy Association of Lake County, takes a strong pro-geothermal development stance. It has a membership of approximately 4,500 paying members. In an interview with Jess Combs, the president of the Geothermal Energy Association, in March 1977, the organization was described as being composed of various property owners who are interested in eventual income from development. Farmers and laborers who are not property owners attend the meetings of the association as well, although the primary interest of these members in the association would be in potential future employment.

The association does not have any statistics or numbers from developers about the projected impact on employment, but the general feeling is that geothermal energy development would have a positive impact on the creation of employment opportunities. The view expressed was that with the predicted development of the power plants in Lake County, Pacific Gas & Electric will have more people employed and secondary impacts of geothermal energy development would create additional permanent employment opportunities. Pacific Gas & Electric is viewed as being well aware of the high unemployment in the county and as willing to help in alleviating the problem. The Geysers field has various types of secondary activities going on with the potential of creating additional employment opportunities. Construction work, and work provided for unskilled and semi-skilled laborers, could be generated by geothermal development activities.

The Geothermal Association's view of the Lake County Energy Council is that the Energy Council is extremely anti-geothermal and would like to stop all development now. However, both the Association and the Energy Council are concerned about what agencies or persons are going to influence and determine policy decisions regarding development. The Association's opinion is that there are numerous unknowns, and it is best to proceed with development, since forecasting and projecting are at best guesswork, whereas there are some real, tangible benefits that are to be realized with development.

The Geothermal Association calls itself a middle of the road group, although it is viewed as extremely pro-geothermal by the Lake County Energy Council. Members of the Association see themselves as "wanting things to happen when they get to a certain point." They too are concerned with air quality, environmental constraints, and regulation of development, and have backed the Air Pollution Control District on many issues. But they also want to realize some of the benefits of geothermal development without delays and have organized speakers and educational campaigns for their members. They feel they should be doing more about communicating the pros and cons of geothermal energy development through civic organizations, Chamber of Commerce, schools and throughout the county.

The Geothermal Association has discussed various types of nonelectric applications, including crop protection with warm waters during the very critical cycle in the county during pear and grape growing seasons. They have discussed the feasibility of hydroponics, space heating for homes, schools, and the heating of swimming pools. The stance of the association is that it is in favor of developments by private business and private enterprise, and that they really do not like to see "the government" going into development. A potential increase in taxes is an explosive issue in the county, and it is felt that geothermal development could reduce the impact. The fundamental issue for the county, however, is the political issue of whether people in Lake County want industrialization or not. In regard to the effect on Clear Lake, the view is that geothermal energy development would not adversely affect Clear Lake or tourism. Any pollution by emissions of hydrogen sulfide is being adequately dealt with by Pacific Gas & Electric. In regard to delays due to environmental reviews, the view is that hundreds of thousands of dollars are being paid out in lease money in the county, and that there is much land that has been leased for 5 to 6 years without being drilled. There is a general identification with the interests of the geothermal companies and other developers; delays are viewed as detrimental incurring high costs with high risks. There is an appreciation of the roles that the geothermal development companies and lease money play in county economics.

The Geothermal Association's position on two issues: 1) environmental challenges in The Geysers steam field; and 2) importance to Lake County of maintaining local control of geothermal exploration and development, was reviewed before the California Geothermal Task Force, May 2, 1977 by Muriel Jordan, secretary of the Geothermal Association. Her testimony as summarized in the SUN, May 24 and 28, 1977 indicates with clarity the Association's position:

[Lake County is] an ideal environment, and our association is dedicated to preserving those natural attributes which make the county an agricultural and recreational center in northern California. We also strongly support orderly and intelligent development of geothermal resources in The Geysers region, of which Lake County is a major part.

You've all heard a lot during these hearings about hydrogen sulfide, or H_2S . Hydrogen sulfide.... is not a health problem in The Geysers geothermal resource area. Thousands of visitors have toured The Geysers since generating operations began in 1960. Workers there have recorded many hundreds of thousands of man-hours in direct proximity to wells and power plants. Our Geothermal Association members have painstakingly scoured the record and failed to uncover a single incident where exposure to H_2S at The Geysers has resulted in documented harm to an individual.

Existing generating units are being equipped with systems designed to reduce emissions by 90%. Cost for new units is about \$3 million. Abatement equipment will be an integral part of the engineering design for Unit 13 (the largest single unit in the world, located in Lake County) and beyond. Abatement applied between the well head and turbine has provide 98% effective in an experimental mode.

[This] could very well signal the end of the H_2S controversy. Or could it? Experience strongly indicates otherwise. Our association can produce sworn affidavits that when the natural fumeroles, now mostly plugged, were flowing freely, sulfur odor was there, long before there was any drilling in the area.

Geothermal Association for Lake County believes that the Air Resources Board and local air pollution control districts must adopt and stick to sane procedures in which all parties can be confident. They must not vacillate and temporize makeshift rules which increase paper work, bureaucratic delay and unreasonable permit conditions. We'd also like to see an end to the tactic of using additional studies to avoid the decisions to which the public is entitled.

Our members feel The Geysers should be in the Guinness Book of Records as the most overstudied energy project in the world. To date millions of dollars have been spent on various environmental investigations. A case in point is an \$800,000 air quality monitoring study paid for by Pacific Gas & Electric and steam developers and performed by Stanford Research Institute...We now are being told that further airshed mapping is required. Geothermal Association for Lake County devoutly hopes that this Task Force will make recommendations which will spare the public of this blitzkrieg of ink, paper, and costly duplication.

Is it not possible to professionalize the consulting industry so that we achieve more...performance and accountability? Is it not possible to....eliminate.... studies whose sole conclusions seem to call for more studies? Now the solid waste management board, an organization without demonstrable experience in [the area of geothermal drilling sumps], proposes to impose its own requirements. Our Geothermal Association regards this as nothing more than an unnecessary new layer of regulation at needless public expense.

Although we recognize failures and shortcomings at the local level....we are unalterably committed to full protection for local....geothermal development. We would strongly resist any system which sacrificed the interests of local citizens to an all encompassing state authority. I would recommend the Task Force tour The Geysers area and receive on the spot information from industry, local and interested public.

5.5.6.3 Summary of a Public Hearing: Proponents and Opponents of Geothermal Resource Development

A final description of pro- and anti- geothermal groups is well documented in a report on a public hearing on a use permit application for McCulloch Oil Co. on property bordering the Cobb Valley by the Lake County Planning Commission on June 16, 1977 (Clear Lake Observer, June 16, 1977):

Final draft of the environmental impact report prepared for the application to drill one exploratory well and one confirming well on the site was certified by the commission as complete. A use permit for a third well will remain pending.

Opponents and proponents of the exploratory project followed what have become predictable paths during the course of geothermal use permit hearings. Opponents to the issuance of the use permit cited the detrimental environmental impact from air and noise pollution and the heavy industrialization of the Cobb Valley which is now used primarily for residential, resort and recreation uses.

Proponents were largely landowners in the area who pointed out that they are paying taxes on lands that cannot produce income. They are hopeful that geothermal development will change this picture for them.

Mary Jadiker, speaking on behalf of the Energy Council, pointed out that, in deciding upon the use permit for McCulloch and similar geothermal projects, the commission was deciding the future economic and population growth pattern for Lake County. What will be the results when 20 to 40 power plants and their attendant well fields are producing in Lake County? How will the county cope with this? she asked. She rebuked the notion that development is coming to the county through altruistic motives of developers who wish to provide new energy sources for the nation. The development of geothermal resource is profitable and that is the principal reason why these people are before you, she said. She noted that the known geothermal resource area comprised the southern half of the county and most of the lands were under lease. The notion that the resource must be exploited, ... regardless of where it is, [is] not valid, she averred.

She refuted the argument that if the county does not allow geothermal proliferation, especially in sensitive areas of the county, the state or federal government will come in and take over. When, she added, have the people ever had anything to say about the geothermal question at the local level? Industry is doing the planning for Lake County and environmental considerations are not being addressed. Planning, she said, is more than responding to industry's requests. An over-all approach is needed and this kind of planning is not being done. Geothermal is a heavy industry. Are we ready to commit Cobb Valley to heavy industrialization? she asked. Is it right to introduce a development that will not

be compatible with existing land uses? she continued. This will slow up residential development, she stated.

Commissioner Jim Renfro saw the impact of future subdivision development in the Cobb Valley as being potentially as severe as geothermal industrialization. Jadiker replied that in her opinion the impact would not be the same. Renfro retorted that he has seen pollution from people destroying an area.

Muriel Jordan, president of the Geothermal Association of Lake County, said her group supported the use permit application. She stated that she owned property opposite to the proposed site and predicted that the area would either go geothermal or into subdivisions.

Hamilton Hess of the Sierra Club and a property owner at Anderson Springs, pointed out that the county had already committed the Cobb Valley to residential uses and was obliged now to protect it from heavy industrialization. He called upon the commission to turn down the use permit as it had denied permits for Mt. Konocti and Borax Lake.

The views of the two most active community groups on the issue of geothermal development, as cited above, provide the polar points for a classification of pro- and anti-development stances on a scale that indicates the range and possibilities of attitudes, opinions, interests, and community action in regard to geothermal development.

5.6 SOCIOECONOMIC IMPACT OF NONELECTRIC USES OF GEOTHERMAL ENERGY

The harnessing and direct application of geothermal energy for industrial and agricultural purposes is the subject of numerous research and development projects. Up to now, emphasis has been on the exploration and technical aspects of the heat source and geothermal fluids. Most published studies on economically feasible applications as well as demonstration facilities concentrate on temperatures, volume of fluids, competitive costing of other forms of energy, design of the system including production, distribution, heating and waste discharge, cost breakdowns for the wells, design and construction engineering, and production and energy needs related to the particular application (see References, Section 7). The

reports, for the most part, however, fail to mention any of the human resources required to design, construct, and operate these systems.

The latter parameter, of required human resources to operate the systems, is one of the most significant factors for the local population and economy. The price of geothermal fluids increases rapidly with the transmission distance; a plant site must therefore be chosen as close as possible to the energy source.

In this section, a comparative scale of revenues is discussed and two examples are presented which indicate the range of skills of labor required to run several different operations. These are rough estimates. It is recommended that for any site specific application that the manpower and types of skills required for a particular operation be as carefully considered as the engineering and technological parameters.

5.6.1 Comparative Scale of Revenues of Electric Power Generation Versus Direct Heat Applications

Based on the assumption that development of geothermal electrical power is likely to be of the order of 1,000 MW of electrical power by the year 2000 in Lake County, a total taxable revenue of about \$200 million per year would be generated at that time. Direct heat energy applications in the agricultural or industrial processing may boost the above figures by 5-10%. The electrical power generation would always be the dominant product of the geothermal resource in Lake County. This is mainly due to the predicted high quality of the geothermal reservoir, and the fact that comparable energy requirements for any conceivable direct heat applications are one order of magnitude lower than those for electrical power production.

This scale differential between revenues to the steam supplier to Pacific Gas & Electric's power plants and revenues from sale of energy for direct heat applications is a primary factor contributing to the low interest in these applications displayed by the exploration companies up to now.

The revenues to the federal, state and county governments will vary with the operation. Various forms of taxation will be drawn from the operation, including property taxes, gross receipts taxes, federal and state income taxes and payroll taxes. According to the Lake County tax assessor, any land to be used for nonelectrical applications will have to be reassessed based upon its income-producing capabilities.

The assessed value of a direct heat use would be small compared to an electrical power generating plant. On the other hand, some direct heat operations are labor intensive and would provide employment opportunities. A few examples are provided. These are by no means definitive analyses of the labor required; they merely indicate comparative spectra of manpower.

5.6.2 Greenhouse Operations

Greenhouse operations are labor intensive relative to capital investment and are recommended to help smooth both seasonal and chronic unemployment rates. Moreover, these operations are considered highly acceptable for the county. The number of hired workers for one type of greenhouse operation of growing cut flowers under 5,570 sq m (60,000 sq ft) on 0.01 sq km (2½ acres) of land is estimated at 990 man-hours for initial preparation of beds and planting, and 1,500 man-hours for cultivation of plants over a 120-day period. Hired workers are estimated at 5 for start-up construction, 2 for initial growth period and 3 for regular production. These estimates for labor may be quite different for other types of greenhouse operations (see Section 3).

Despite what appears to be the small number of employable positions, such as 5-15 people for a given module, the industrial base of Lake County is of such small scale that even a process that creates 10-12 jobs would be of significant impact. Thus for a specific product from a greenhouse operation, an analysis of the integration of the labor demands with the local and regional needs should be addressed with the same care as the marketing, economics and other engineering design parameters. In the greenhouse applications, the labor intensity factor could be readily underestimated. It is to be noted that many "ma-and-pa" greenhouse operations in California, stimulated by a promotion scheme out of Arizona, have failed; mainly because they did not have the technology for running a profitable operation, but also because the labor intensity factor was underestimated (Matherson, 1977, pers. comm.).

5.6.3 District Heating Example

The following is an approximate spread of types of labor required for a \$10 million project of district heating installation for both the design and construction phase and the operation. This example is patterned after a district heating system designed to heat condominiums, commercial buildings, and swimming pools and to melt snow. The system supplies 35 MW thermal heat transmitted over approximately 60,000 m (200,000 ft) of piping. (This information was obtained from the Ben Holt Co., 1977, pers. comm.)

\$10 Million District Heating Project

<u>Occupational Distribution and Skills</u>	<u>Design & Construction Phase</u>		<u>Operation Phase</u>
	<u>Months</u>	<u>Man Years</u>	
<u>Managerial:</u>			
Project Manager	12	1	1
<u>Engineering:</u>			
(6 listed @ 6 mo)	6		
	6		
	6		
	6	3 (office)	1
	6		
	6		
Construction Engineer	12	2 (site)	1
Construction Clerk	12		
Technicians (3)	12 (site)		
	6 (office)	6	
Blue collar (38)	12		
Unskilled (20)	12	58	4

The number of man years for this particular space heating project can be calculated as follows for (1) Construction management, (2) Design and Engineering, and (3) Construction labor. Construction management is displayed in the above table. Design and engineering manhours (MH) are computed by rule of thumb as follows:

Design & Engineering Manhours = (0.06) (\$10 million) = \$600,000

MH = $\frac{\$600,000}{\$25/\text{MH}}$ = 24,000 MH = 139 man months
= 12 man years

Construction Labor manhours are computed as:

Construction Labor $\cong$ (0.3) (Capital Cost) = (0.03)(\$10 million)
= \$3 million

MH = $\frac{\$3 \text{ million}}{\$25/\text{MH}}$ = 120,000 MH = 694 man months
= 58 man years

During the design and construction phase, a maximum of 3 jobs could be created locally. It is likely that the managerial, engineering and technical staff will come from outside the county. The information on direct costs such as construction, number of people employed, type of skills and wages, and taxes to federal, state and local agencies could be readily compiled for a given engineering design and module. Secondary impacts can be inferred from economic multiplier effects in terms of the same parameters indicated as primary effects.

Compared to greenhouse operations, it is readily seen that this direct heat application of geothermal energy requires a minimum of labor with only 6 permanent jobs created for a \$10 million project. The impact on the economy during the construction phase could, however, be significant, with the building of roads, drilling, and the demand for some of the materials and supplies distributed locally. Jobs in the service areas would be expanded to support the increased economic activity. Rational planning, however, would dictate avoiding a localized boom-bust cycle generated by construction.

5.7 IDENTIFICATION OF DIRECT HEAT APPLICATIONS OF GEOTHERMAL ENERGY FOR LAKE COUNTY BASED ON SELECTED INTERVIEWS

A summary of views regarding development of direct heat applications of geothermal energy is presented as derived from several interviews with county representatives. Time and budget for the socioeconomic task has not allowed the incorporation of much of the information, expressions of opinion, and comments on development and level of acceptance of various applications. Moreover, these interviews have not been a complete sampling of county officials, opinion leaders, and key functionaries on the issue of geothermal development. Appendix I lists the names of interviewees. The economic feasibility of many of these projects is not clearly evidenced and would require appropriate engineering and economic feasibility studies in the particular utilization technology of the applications, besides a marketing study if a product processing application is involved.

5.7.1 Bartlett Pear Industry

Based on the fact that the pear industry is the leading agricultural product, any direct heat application which would contribute to its economic marketability would be welcomed. Cost/benefit ratios for soil warming are not very favorable. But, if there were the possibility of a combined cycle in a pear-packing shed, designed from the outset to make use of

geothermal energy canning operations, a dehydration process and a refrigeration application, application of low-cost heat could be very beneficial. There are certain disadvantages to the present pear-packing sheds, because the present operations are a considerable distance from the known geothermal resource. Pears require subfreezing temperatures for a period of about four months. The packers in the county commonly refrigerate huge warehouses - on the order of 30,000 cu m - to -1°C (1 million cu ft - to 30°F) during the hottest part of the season. Currently they use ammonia plants for the most part, all electrically driven. Power requirements are one of the highest costs in the process.

On the other hand, the basic problem with the pear industry is industry-wide and not specific to Lake County. Currently, there is an oversupply of pears on the market. Helping production or processing of pears in Lake County does not solve the overall economic problem even though it could increase the competitiveness of the Lake County pear growers group. The pear industry has been declining over the past ten years, and canners and packers are inclined to eventually get out of the business.

Yet, in the long range, the likelihood of relieving some of the production costs by a reduction in the diesel requirements for heating the orchards or refrigeration must be considered in terms of its potential positive impact on the local economy.

5.7.2 Application Related to Walnut Production and Drying

Walnuts are the second largest agricultural product in the county and because of soil, climate, elevation and exposure are of high grade. For good yields, irrigation is required although dry land walnut farming has been common. Walnuts are not a protected crop and there is no association of growers. Walnut growers are loosely organized, and therefore their profitable production is intensely competitive.

Walnuts do not require much refrigeration and processing beyond the initial drying. They do require a considerable amount of heat to dry, which suggests an application. Moreover, the packaging of walnuts could be part of the combined process.

5.7.3 Recreation and Tourism

Clear Lake is considered Lake County's greatest recreational asset. Thus, the improvement of the water quality of

the lake and control of the algae growth would be most desirable applications.

Recreation and tourism which includes different types of tourism such as hot spas, scientific tourism and naturalistic tourism are also desirable.

5.7.4 Other Applications

Other areas identified as direct heat applications which could be considered are:

- 1) Greenhouses, all types
- 2) Direct agricultural applications such as soil warming and frost protection
- 3) The interruption of the life-cycle of the Clear Lake gnat, which makes parts of lower Clear Lake uninhabitable at certain times of the year
- 4) Space heating, which is cyclical use, but which could be economical, for the areas of Clear Lake Highlands, Clear Lake Park
- 5) Sewage and waste water treatment using low temperature heat
- 6) Processing of pulp and chip products of the knobcone pine
- 7) Small-scale processing which uses local craftsmen and skilled labor.

In general, there is sentiment for geoheat applications that deal with some of the economic needs of the county and the population in a direct manner. The technical or economic viability is important, but the situation is such that some way of dealing with the chronic unemployment is important, although rapid industrialization on a large scale is not considered desirable. The county would like small modest operations that employ 10-20 people, taking advantage of the low wages paid a craftsman locally and utilizing the inexpensive geothermal heat.

5.8 CONCLUSIONS AND RECOMMENDATIONS

The social and economic profile of the County of Lake has been presented, with examination of some parameters of existing structures, which included population characteristics and projections, and economic profiling. The prominent characteristics of the population are its bimodal age distribution, with a heavy concentration in the age group of 50-70 years, its high percentage classification as white (97%) and its low percentage of median years of schooling (only 11% with some college).

In terms of economic characteristics, the county's median income was \$6,551 in 1970, the lowest in the state. Job opportunities in the county are subject to extreme seasonal variations and unemployment can reach a peak of 19% during the winter months. Lake County relies primarily on agriculture and tourism for its commercial base, both being highly unstable sources of employment and income. Ten to twenty years hence the sale of geothermal energy per year would be approximately \$200 million (in constant 1977 dollars); this figure exceeds the combined value of agricultural production and monies generated by the tourist industry.

Coupled with this economically depressed portrait of the county, is the increasing influx of people, both of retirement age and younger families. Intense economic activity in lot sales and subdivisions, coupled with high annual increases in the school enrollment over the last 10 years, attest to the other side of the picture which might present the county in a burgeoning growth pattern.

Rational development of the geothermal resource is considered a potential solution to the county's economic problems by many of the county's officials and various sectors of its residents. County regulation of development could (1) minimize negative aspects of development, (2) improve land use planning, and (3) stimulate direct heat applications. Development of the resource can be viewed as a positive force contributing to these goals as well as contributing to the tax revenues and creating economic opportunities.

Geothermal development is likely to have a major impact on the county's tax structure, as land and improvements are reassessed. However, the question of whether geothermal development would result in a reduction of county tax rates, as opposed to using the monies for providing needed services, has not been determined, although these are critical issues in a county where nearly a third of the population relies on transfer payments (semi-fixed income) as a source of personal income.

One consideration for the county would be the manner in which a predominantly agricultural, rural and environmentally - oriented community with its associated values of "least government is the best government" will be affected by an entirely new type of more urban-related activities that geothermal development is likely to entail. These divergent interests operate outside of the county as well. The rural agricultural environment may be vulnerable to pressures of the long-term energy needs of metropolitan areas.

Aside from the concerns in conforming to federal and state regulations requiring environmental impact reports, county officials view the objective as shaping geothermal resource exploitation within two prominent values: those of development and those of environmental protection. There is considerable disagreement about the particular stance of the county government. Proponents of geothermal development view the environmental review process and local control over permitting as generating costly delays, while investments in land, leases and exploration are rendered marginal as delays increase the cost of such development. Opponents of development view the county government as so "pro-geothermal" as to approve eventually almost any geothermal development.

The review process for opponents of geothermal development is viewed as a reactive process to requests for drilling and exploration. A rational geothermal development plan, within a framework of an overall development plan, as complicated as it may be, is the eventual goal of the county. Many parameters shaping the demand for geothermal energy are beyond the jurisdiction of Lake County. This latter point of regional or state energy requirements and regulations is a focus of frustration for county officials under pressure "to do something" about the control of geothermal development.

The issues of control and regulation of the geothermal resource by centralized planning at the national, regional or state level versus local, district or county level are the underlying themes of development. Yet, this is the same problem which has and will continually plague the geothermal resource industry, that of overlapping jurisdictions with respect to acquisition of rights to geothermal resources, exploration, drilling, development production and ultimate utilization. Federal, state, county and local governments have all been involved in regulation of private, state and federal lands.

If Lake County decides to establish its own utility for the production of electrical power to utilize locally developed geothermal energy, it might be able to attract light industry.

This requires enticement of the industrial user who would have to evaluate the cost savings in energy and labor as opposed to distance from raw material and markets. On the other hand, certain agricultural processes could be comprised of several complete systems of feed growing, feed processing, livestock and meat processing.

In this study of the potential socioeconomic impact of geothermal resource development and direct heat applications, we do not purport to set priorities for development, because these must be determined within the context of goals and overall development plans of the county. We have tried to point out various aspects of development, including benefits and public reaction to perceived threats to the environment and to its way of life. Some nonelectric applications have been identified, but detailed feasibility studies are needed to establish cost/benefit trade-offs for a particular use.

Social and economic impacts of direct heat applications have not been studied intensively nor are they well documented. There are many aspects relating to geothermal development which require more complete delineation. These are identified as follows:

- 1) tax laws governing geothermal development
- 2) characteristics and economic realities of the elderly minority in Lake County
- 3) site specific socioeconomic impact assessment.

The tax laws governing geothermal development are not well defined. An integral part of any analysis of geothermal project is how the applications are incorporated into an area's tax base. The effects of any development within Lake County are predicted to be substantial. An analysis of these effects would be of significance for decision makers and planners. Meetings with Lake County's Planning Commission, Board of Supervisors, and Tax Assessor are necessary, as is a thorough study of governmental plans for taxation of geothermal projects. Various uses of geothermal fluids will fall into different categories of taxation. Each application suggested in this report needs to be considered under a general overview of the tax benefits which would accrue to the county should the applications be implemented. Such an analysis, even in general terms, is recommended for the next phase of the project.

Investigation into the characteristics and economic realities of an "old-age" minority within a population should be an

integral part of a follow-up project. The effect of this population on the county's economy, growth, tax structure, future planning and development is necessary in order to plan for concomitant demands for services.

Some interesting crosscurrents in public opinion and economic realities are to be noted, and although these have not been thoroughly investigated they indicate the complexity of the issues. These are:

1. Local attitudes, both young and old, seem to reflect the position of "I'm here, but let's prevent others from coming, and ruining it," a decidedly anti-growth sentiment. Yet, recent subdivision activity spurred growth in the construction industry and other service areas.
2. The increase in private taxes due to the increased assessment of property from geothermal activity is paid to a large degree (indirectly) by the developers under the lease agreement.
3. The impact from alternative uses of geothermal energy is not well defined at this stage, but is regarded as much better than electric power generation for the county residents.
4. Fears that regional, state and national demands for energy are likely to overwhelm the county are countered by expectations of the expected tax boon, stemming from electric power generation.

In the assessment of the socioeconomic impact of geothermal energy development and nonelectric applications in Lake County, we have encountered a number of questions which need to be answered before an overall development plan of geothermal energy is formulated. Among these questions are the following:

1. Will aggregate energy needs of the United States and California supersede the particular local needs of the county.
2. What ultimate trade-offs are county residents willing to make, given the known impact of geothermal development.
3. Will nonelectric applications of geothermal fluids be incorporated into an overall development plan, quite independent of electric power generation.

4. Can electric power plants be constructed in such a way as to blend into the "natural" environment of Lake County, a quality highly respected by its inhabitants.
5. How feasible is the idea of Lake County generating its own power by creating a county utility district, enabling the county to reduce electricity rates; what are the costs and benefits of such an initiative, and how would it be viewed by Pacific Gas & Electric, by the state, and by the residents.

The objective of the socioeconomic task in Phase Zero has been to provide a broad view of the socioeconomic milieu relevant to the development of geothermal energy. An overall view of Lake County's economy as well as a demographic profile has illustrated the various sectors, needs, and trends for the county. Attitudes of the various interest groups have been integrated into this report as well. These are some of the parameters to be considered under an overall geothermal development program.

APPENDIX I

Government Agencies Contacted

1. Lake County Planning Department
2. Lake County Planning Commission, Lakeport, California
3. Lake County Chamber of Commerce, Lakeport, California
4. Employment Development Department, Lakeport
5. Agriculture Commission, Lakeport
6. Office of Lake County Auditor, Lakeport
7. Office of Farm Advisor, Lakeport
8. California Division of Oil and Gas, Sacramento, California
9. Department of Health, State of California, Sacramento
10. City of Calistoga

Organizations Contacted

1. Lake County Energy Council, Lakeport
2. Geothermal Association of Lake County, Lakeport
3. Farm Bureau, Lakeport
4. Lake County Chamber of Commerce, Lakeport

Private and Semi-Private Enterprises Contacted

1. Geothermal Development Service, Lakeport
2. Clearlake Observer, Clearlake Highlands
3. Aminoil, Inc., Division of Geothermal Operations, Santa Rosa

4. Pacific Gas and Electric Company, Geysers Geothermal Power Group, San Francisco
5. Thermogenics, Inc., Santa Rosa
6. Union Oil Company, Geothermal Operations, Santa Rosa

Interviews and Discussions were held with

Don Johnson - Director, Lake County Planning Department, Lakeport

Larry Vollintine - Lake County Planning Department, Lakeport

Jess Combs - President, Geothermal Association of Lake County, Lakeport

Peter Windrem - Attorney, Lake County Energy Council, Lakeport

Mary Jadiker - Citizen representative and member, Lake County Energy Council, Lakeport

John Jago - Native and life-time resident of Lake County, Lakeport

Verdon L. Strong - Director, Lake County Planning Department, Lakeport

Bonnie Jean Hanchett - Editor, Clearlake Observer, Clearlake Highlands

Marion Geobles - Lake County Chamber of Commerce, Lakeport

Carl Wall - Employment Development Department, Lakeport

George Frye - Division Engineer, Geothermal Operations, Aminoil, Inc., Santa Rosa

Larry Krumland - Senior engineer, Mechanical & Nuclear Engineering Department, Geysers Geothermal Power Project Groups, Pacific Gas and Electric Company, San Francisco

Dave Barton - Senior mechanical engineer, Mechanical and Nuclear Engineering Department, Geysers Geothermal Power Project Group, Pacific Gas and Electric Company, San Francisco

Iain Jamieson - Geologist, Thermogenics, Inc., Santa Rosa

Francis Smigley - City engineer, City of Calistoga (together with Dr. James A. Neilson)

Warren Smith - Environmental engineer, Geothermal Operations, Union Oil, Santa Rosa

Dick Lindwall - Economist, Geothermal Division, Union Oil Company, Los Angeles

Gregory Ross - Geothermal Division, Union Oil Company, Los Angeles

Dr. Carel Otte - Vice president, Geothermal Division, Union Oil Company, Los Angeles

George Goldman - Extension economist, University of California, Berkeley, Agricultural Extension

Oleh Weres - Physical chemist, Lawrence Berkeley Laboratory, Berkeley

Harry Moritz - Geothermal coordinator, Bureau of Land Management, Ukiah, California

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LAKE COUNTY

AGE - SEX PYRAMID

1970

Population 9,536

10,012

Median Age 46.4

47.5

Figure 5.1 Percent Distribution of the Population by Five-Year Age Groups and Sex, Lake County, 1970

Based on data from: Table 35, 1970 United States Census, California General Population Characteristics

SONOMA COUNTY

AGE - SEX PYRAMID

1970

Population 99,362

105,523

Median Age 28.6

31.0

Figure 5.2 Percent Distribution of the Population by Five-Year Age Groups and Sex, Sonoma County, 1970

Based on data from: Table 35, 1970 United States Census, California General Population Characteristics

NAPA COUNTY

AGE - SEX PYRAMID

1970

Population 39,188

39,952

Median Age 31.7

32.8

Figure 5.3 Percent Distribution of the Population by Five-Year Age Groups and Sex, Napa County, 1970

Based on data from: Table 35, 1970 United States Census, California General Population Characteristics

CALIFORNIA

AGE - SEX PYRAMID

1970

Population 9,816,685

10,136,449

Median Age 27.0

29.1

Figure 5.4 Percent Distribution of the Population by Five-Year Age Groups and Sex, California, 1970

Based on data from: Table 20, 1970 United States Census, California

UNITED STATES

AGE - SEX PYRAMID

1970

Population 98,912,192

104,299,734

Median Age 26.8

29.3

Figure 5.5 Percent Distribution of the Population by Five-Year Age Groups and Sex, United States, 1970

Based on data from: Table 54, United States Census, General Population Characteristics

Figure 5.6 Location of the
Population Centers in Lake
County, Based Upon 1975
Numbers

Figure 5.7 Trend of Population Growth of Lake County, 1860 to 1970

Based on data from: Lake County Chamber of Commerce (compiled by Marion Geoble),
based on U.S. Census data

Figure 5.8 Population Projections for Lake County, July 1, 1975 through July 1, 2020
(Based on California Department of Finance Data, June 1974)

Based on data from : Table 122, 1970 United States Census, California Social and Economic Characteristics

Figure 5.10 Occupational Distribution of Employed Persons, Age 16 Years and Older For Twelve Categories by Sex for California, 1970

Based on data from : Table 54, 1970 United States Census, California Social and Economic Characteristics

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Figure 5.11 Time Series of Monthly Unemployment Rates, 1970-1975
for Lake County and California

Based on data from: California Employment Development Department

Figure 5.12 Comparative Percent Distribution of Family Income for Lake County and California, 1970

Based on data from: 1970 U.S. Census

TABLE 5-I

DEPENDENCY RATIO, PERCENTAGE OF POPULATION DEPENDENT, AND
SEX RATIO FOR LAKE, NAPA AND SONOMA COUNTIES, CALIFORNIA
AND THE UNITED STATES, 1970

POPULATION	LAKE	NAPA	SONOMA	CALIFORNIA*	UNITED STATES*
Total	19,548	79,140	204,885	19,953	203,212
Age 0-14	3,992	20,002	56,266	5,524	57,900
Age 15-64	11,060	48,514	122,274	12,628	125,246
Age 65+	4,496	10,624	26,345	1,801	20,066
Dependency Ratio	76.7	63.1	67.6	58.0	62.2
% Population Dependent ²	43.4	38.7	40.3	36.7	38.4
Sex Ratio ³	95.25	98.09	94.16	96.84	94.83

$$1. \frac{(0-14) + (65+)}{(15-64)}$$

$$2. \frac{(0-14) + (65+)}{\text{Total Population}}$$

$$3. \frac{\text{Males}}{\text{Females}} \times 100$$

* Population in thousands

Source: 1970 United States Census

TABLE 5-II
POPULATION OF LAKE COUNTY AND PERCENT
CHANGE IN POPULATION 1860 TO 1970

<u>Year</u>	<u>Population</u>	<u>Percent Change</u>
1860	1000 (est)	
1870	3078	+208%
1880	6643	+116%
1890	7210	+8.5%
1900	6017	-16.5%
1910	5226	-13.1%
1920	5402	+3.4%
1930	7166	+32.6%
1940	8069	+12.6%
1950	11,481	+42.3%
1960	13,786	+20.1%
1970	19,548	+41.8%

Source: Lake County Chamber of Commerce - (Compiled by
Marion Geoble) Based on U.S. Census Data.

TABLE 5-III

DEMOGRAPHIC CHARACTERISTICS FOR LAKE, NAPA, SONOMA COUNTIES
AND THE STATE OF CALIFORNIA, 1972-1974
(by place of residence)

		Live Births	Deaths	Births- Deaths	Fetal Deaths	Total	Infant Deaths by Age	
							Neo-Natal	1-11 Months
California	1972	306,375	170,026	136,349	3,147	4,877	3,467	1,410
	1973	297,834	172,798	125,036	3,039	4,351	3,065	1,286
	1974	311,668	170,475	141,193	3,163	4,274	2,959	1,315
Lake	1972	211	394	-183	6	3	1	2
	1973	211	382	-171	1	2	1	1
	1974	251	413	-162	1	3	1	2
Napa	1972	1,000	978	22	16	17	9	8
	1973	963	987	-24	9	10	7	3
	1974	1,038	1,004	34	9	14	10	4
Sonoma	1972	3,195	2,428	767	28	56	36	20
	1973	3,170	2,423	747	31	41	29	12
	1974	3,250	2,352	898	32	39	28	11

Source: Vital Statistics of California, 1972-1973-1974.
State of California, Department of Health.

TABLE 5-IV
EMPLOYMENT BY INDUSTRY AND SEX FOR PERSONS AGED 16 AND OVER,
LAKE COUNTY, 1970.

INDUSTRY	MALE TOTAL	%	FEMALE TOTAL	%	BOTH SEXES TOTAL	%
Agricultural, Forestry & Fisheries	611	16.7	74	3.5	685	11.8
Mining	62	1.7	0	0	62	1.1
Construction	632	17.3	33	1.6	665	11.5
Manufacturing	244	6.7	51	2.4	295	5.1
Public Utilities	306	8.4	97	4.5	403	6.9
Wholesale & Retail Trade	681	18.6	564	26.3	1245	21.5
Finance, Insurance & Real Estate	128	3.5	166	7.7	294	5.1
Services	645	17.7	826	38.6	1471	25.4
Public Administration	343	9.4	330	15.4	673	11.6
Total, All Industries	3652	100%	2141	100%	5793	100%

Source: Manpower Information for Affirmative Action Programs,
Lake County Employment Development Department, Division
of Employment Data & Research, November 1975

TABLE 5-V

PER CAPITA PERSONAL INCOME FOR LAKE, NAPA, SONOMA COUNTIES
AND THE STATE OF CALIFORNIA, 1965-1974

YEAR	LAKE	NAPA	SONOMA	CALIFORNIA
1965	2,494	3,030	3,024	3,266
1966	2,614	3,254	3,171	3,464
1967	2,729	3,453	3,308	3,663
1968	3,132	3,801	3,629	3,979
1969	3,346	3,999	3,849	4,241
1970	3,545	4,259	4,147	4,489
1971	3,710	4,488	4,371	4,711
1972	3,797	4,621	4,582	5,043
1973	4,180	5,067	4,920	5,491
1974	4,494	5,599	5,286	6,041

Source: Department of Finance, Sacramento, California

TABLE 5-VI

PERSONAL INCOME BY SOURCE, CALIFORNIA AND LAKE COUNTY,
1969-1973, IN DOLLARS

Source	CALIFORNIA (in millions)					LAKE COUNTY (in thousands)				
	1969	1970	1971	1972	1973*	1969	1970	1971	1972	1972*
Wages and Salaries	53,958	56,815	58,971	64,534	75,753	20,995	21,751	25,051	26,378	33,035
Other Labor Income	2,950	3,184	3,541	3,877	4,432	945	960	1,225	1,274	1,441
Proprietors Income	6,753	6,709	7,034	7,119	8,526	9,331	8,414	9,524	10,644	15,623
Property Income	11,389	12,172	12,964	14,148	15,879	12,621	10,915	16,814	17,890	23,000
Transfer Payments	8,142	9,945	11,608	12,421	13,792	13,909	16,942	20,067	22,596	27,817
TOTAL	\$ 83,192	88,825	94,118	102,099	118,382	57,801	58,982	72,681	78,782	100,906

Source: *-California Statistical Abstract, 1975.
California County Falt Book, 1974

TABLE 5-VII

SECTOR CONTRIBUTION TO PERSONAL INCOME FOR LAKE COUNTY AND
THE STATE OF CALIFORNIA 1969-1973, IN PERCENTAGES

CALIFORNIA	1969	1970	1971	1972	1973
Wages + Salaries	65%	64%	63%	63%	64%
Other Labor Income	3%	4%	4%	4%	4%
Proprietors Income	8%	7%	7%	7%	7%
Property Income	14%	14%	14%	14%	13%
Transfer Payments	10%	11%	12%	12%	12%

LAKE COUNTY

Wages + Salaries	36%	37%	34%	33%	33%
Other Labor Income	2%	2%	2%	2%	1%
Proprietors Income	16%	14%	13%	13%	15%
Property Income	22%	18%	23%	23%	23%
Transfer Payments	24%	29%	28%	29%	28%

Source: California Statistical Abstract, 1975.
California County Fact Book, 1974.

TABLE 5-VIII

MEDIAN EARNINGS OF PERSONS IN THE EXPERIENCED CIVILIAN
LABOR FORCE FOR SELECTED OCCUPATIONAL GROUPS, LAKE COUNTY
AND THE STATE OF CALIFORNIA, 1969

	<u>Lake County</u>	<u>California</u>
Male, 16 and over with earnings	\$6,356	\$8,520
Professional, Managerial and Kindred Workers	9,200	12,095
Craftsmen, Foremen and Kindred Workers	6,858	9,103
Operatives, including Transport	5,500	7,380
Laborers, except Farm	5,405	5,655
Farmers and Farm Managers	3,867	6,810
Farm Laborers and Foremen	3,750	3,777
Female, 16 and over with earnings	2,410	4,237
Clerical and Kindred Workers	3,602	4,838

Source: United States Census, 1970, California
General Social and Economic Characteristics

TABLE 5-IX

TOTAL FALL ENROLLMENTS IN LAKE COUNTY SCHOOLS
1966-1975

Year	Elementary Grades K-8	High School Grades 9-12	Lake County Total	% Change from previous year
1966	2622	1177	3799	
1967	2559	1261	3820	+0.5%
1968	2585	1206	3791	-0.7%
1969	2699	1294	3993	+5.3%
1970	2868	1374	4242	+6.2%
1971	2938	1430	4368	+3.0%
1972	2941	1434	4375	+0.2%
1973	2903	1389	4292	-1.9%
1974	3025	1519	4544	+5.9%
1975	3251	1605	4856	+6.9%

Source: Lake County Overall Economic Development Plan for 1975-1976
Lake County Coordinating Council for Overall Economic
Development

TABLE 5-X

SCHOOL ENROLLMENT BY DISTRICT AND GRADE, LAKE COUNTY
SCHOOL DISTRICTS OCTOBER, 1975

District	Elementary K-6	Grades 7-8	High 9-12	Total Enrolment
Konocti Unified	738	293	506	1537
Lakeport Unified	620	178	450	1248
Kelseyville Unified	406	140	242	788
Middletown Unified	220	75	121	416
Upper Lake Union	249	83	---	332
Upper Lake Union High	---	---	266	266
Lucerne Elementary	123	55	---	178
Special Classes	71		20	91
County Totals	3251		1605	4856

Source: Lake County Overall Economic Development Plan for 1975-76
Lake County Coordinating Council for Overall Economic
Development

TABLE 5-XI

POPULATION AND HOUSING ESTIMATES FOR LAKE COUNTY, 1975-1976

	1-1-75		1-1-76	
	<u>Lakeport</u>	<u>Total County</u>	<u>Lakeport</u>	<u>Total County</u>
Total Population	3816	24,637	3758	25,300
Household Pop.	3654	24,251	3622	24,938
Persons in Group Quarters	162	386	136	362
Persons per Household	2.707	2.466	2.663	2.421
Housing Units	1468	14,659	1475	15,294
Households	1350	9836	1360	10,280
Vacant Households	118	4823	115	4899
Percent Vacant	8.04	32.90	7.80	32.78
Mobile Homes	118	2590	112	3053
Mobile Homes Population	260	4850	190	5565
Persons per Mobile Home	2.203	1.873	1.696	1.823

Source: Department of Finance, Sacramento, California.

TABLE 5-XII

GROSS VALUE OF AGRICULTURAL PRODUCTION FOR LAKE
COUNTY, 1964-1975

1975	\$19,589,910
1974	\$21,257,840
1973	\$22,155,400
1972	\$15,231,200
1971	\$12,991,950
1970	\$10,778,209
1969	\$15,416,420
1968	\$16,795,050
1967	\$13,028,070
1966	\$13,697,900
1965	\$ 9,128,330
1964	\$10,831,910

Source: Agricultural Crop Report, Lake County, 1975.
Department of Food and Agriculture.

TABLE 5-XIII

SECTOR CONTRIBUTION TO TOTAL AGRICULTURAL PRODUCTION IN LAKE
COUNTY, 1974-1975

	1974	1975
Fruit & Crops		
Grand Total	15,239,335	14,378,335
Barlett Pears	13,503,520	11,010,840
Walnuts	1,280,025	2,622,710
Wine Grapes	356,955	657,320
Others	98,835	87,465
Field Crops		
Grand Total	2,531,250	2,461,595
Pasture	990,400	1,081,300
Hay	1,071,835	1,017,820
Safflower	103,500	107,600
Grain	94,225	106,690
Others	271,290	148,185
Livestock & Poultry		
Grand Total	3,229,040	2,482,055
Cattle & Calves	2,907,710	2,201,640
Sheep & Lambs	78,095	92,640
Hogs	31,155	87,705
Horse	193,750	85,275
Others	18,330	14,795
Livestock & Poultry Products		
Grand Total	258,215	267,925
Eggs	219,575	236,330
Others	38,640	31,595
Total Agricultural Production	\$21,257,840	\$19,589,910

Source: Agricultural Crop Report, Lake County 1975
Department of Food and Agriculture

TABLE 5-XIV
ANALYSIS OF REVENUES BY SOURCE, LAKE COUNTY, 1974-1977

SOURCE	1974-1975		1975-1976		1976-1977	
	Revenues (in thousands)	% of Total Rev.	Revenues (in thousands)	% of Total Rev.	Revenues (in thousands)	% of Total Rev.
1. Taxes (except current property)	906	10%	1,124	11%	1,157	9%
2. Licenses and permits	110	1%	153	1.5	140	1
3. Fines and Penalties	174	2	150	1.5	148	1
4. Revenues from use of money and property	223	2	180	2	166	1
5. Aid from Government Agencies	5,102	56	5,207	52	5,655	46
6. Charges for current services	370	4	469	5	575	5
7. Other Revenues (includes sales of fixed assets)	100	1	134	1	95	1
8. Previous balances available	-	-	-	-	926	7
9. Current Property Tax	2,107	24	2,522	26	3,567	29
TOTAL REVENUES	9,092	-	9,939	-	12,429	-

SOURCE: Lake County Auditors Office

TABLE 5-XV

LAKE COUNTY BUDGET REQUIREMENTS- FISCAL YEARS 1974-1977

BUDGET UNIT	1974-1975		1975-1976		Adopted 1976-1977	
	Expenditures (in thousands)	% of Total Budget	Expend. (in thou- sands)	% of Total Budget	Expend. (in thou- sands)	% of Total Budget
1) General (salaries, construction, manage- ment, etc.)	2,786	30.6	3,206	32.3	3,338	26.9
2) Public Protection (judicial, police, planning)	1,192	13.1	1,456	14.6	2,557	20.6
3) Public Highways and Facilities	1,261	13.9	1,400	14.1	1,489	12.0
4) Health and Sanitation	458	5.0	509	5.1	610	4.9
5) Public Assistance	3,067	33.7	3,009	30.3	3,840	30.9
6) Education (library, Board of Education Salaries)	218	2.4	239	2.4	223	1.8
7) Recreational Facilities	111	1.2	119	1.2	175	1.4
8) Reserves					197	1.5
Total Budget	\$ 9,092		\$9,939		\$12,429	

Totals may not add due to rounding

Source: Lake County Auditors Office

TABLE 5-XVI

MIDDLETOWN SCHOOL DISTRICT
TAX RATES FOR FISCAL YEAR 1976-1977

TRA	Title	Fund	Fund Name	Land	Land&Imp.	Net	TRA
062 008	101	101	General County			2.230	062 008
	101	103	Road			.230	
	101	105	Advertising			.040	
	101	121	Animal Control			.030	
	101	131	Fish & Game			.010	
	101	152	Contingency			.050	
	102	125	County Free Library			.100	
	304	516	Middletown Unified Gen			2.640	
	307	562	Yuba Community College			.800	
	311	550	Spt Schl-Optg			.140	
	311	582	Educable Mentally Rtrd.			.010	
	311	583	Trainable Mentally Rtrd.			.020	
	311	584	Physically Handicapped			.020	
	311	586	Equalization Aid Offset			.060	
	311	587	Spt. Sch. Cap. Outlay			.040	
	311	588	Regional Occupation Program			.030	
	312	518	Middletown Unif. Bonds 58/61/71			.220	
	510	200	Lake Co Flood-General			.080	
	558	304	Middletown Cemetery Dist.			.070	
	587	357	Middletown Fire Prot Dist.			.400	
	591	371	Lake County Mosquito Abate			.230	
	592	905	Redbud Hospital Operating			.240	
	592	906	Redbud Hospital-Bonds			.110	
	751	331	Eastlake Resource Cons	.010			
			Tax Rate Area 062 008 Totals	.010	.000	7.800	

TABLE 5-XVII

TIME SERIES ANALYSIS OF LAKE COUNTY'S PROPERTY TAX BASE AND
REVENUES, 1960-1977

<u>Year</u>	<u>Total Tax Base¹ (Assessed Value)</u>	<u>General County Tax Rate²</u>	<u>County Revenue from Property Tax³</u>	<u>County Budget Requirement</u>	<u>Contribution of Property Tax Revenues of County Budget</u>
1960-61	\$ 35,694,920	\$2.41	\$ 860,247	\$2,493,670	34.4%
1961-62	38,969,985	2.32	904,101	3,343,809	27.0
1962-63	43,588,905	2.18	950,238	2,886,890	32.9
1963-64	46,127,270	2.24	1,033,250	3,138,173	32.9
1964-65	49,116,020	2.57	1,262,281	3,652,428	34.5
1965-66	52,046,960	2.54	1,321,992	4,397,545	30.0
1966-67	56,925,450	2.53	1,440,214	4,311,254	33.4
1967-68	76,740,510	1.90	1,548,069	4,768,288	30.5
1968-69	81,926,310	2.31	1,892,509	5,329,050	35.5
1969-70	85,853,443	2.30	1,974,629	6,171,384	31.9
1970-71	97,037,304	2.28	2,212,450	6,855,505	32.2
1971-72	102,399,244	2.27	2,324,463	7,828,417	29.6
1972-73	111,911,890	2.32	2,596,356	9,244,381	28.0
1973-74	118,154,600	2.32	2,741,186	8,759,838	31.2
1974-75	124,519,850	2.41	3,000,938	9,092,670	32.3
1975-76	140,827,135	2.49	3,506,590	11,293,494	31.0
1976-77	159,286,870	2.69	4,284,816	12,429,493	34.5

1. Assessed value of land, improvements and personal property.

2. Per \$ 100 of assessed value

3. Gross revenues prior to any reimburseable exemptions.

Source: Lake County Tax Assessor.

TABLE 5-XVIII

TAX REVENUES RECEIVED DIRECTLY FROM GEOTHERMAL ACTIVITY,*
LAKE COUNTY, 1972-1977

GENERAL COUNTY REVENUES	<u>YEAR</u>				
	1972-73	1973-74	1974-75	1975-76	1976-77
Assessed Value of Geothermal Activity	\$35,000	\$383,750	\$836,480	\$2,607,050	\$3,917,250
General County Tax Rate	2.32	2.32	2.41	2.49	2.69
Geothermal Revenue	\$812	\$8,903	\$20,159	\$64,915	\$105,374
General County Total Tax Revenue	\$2,596,356	\$2,741,186	\$3,000,928	\$3,506,596	\$4,284,816
% Contribution of Geothermal Activity to County Revenue	0.03%	0.3%	0.6%	1.8%	2.5%
<u>MIDDLETOWN DISTRICT</u>					
Assessed Value of Geothermal Activity	\$35,000	\$383,750	\$836,480	\$2,607,050	\$3,917,250
District Tax Rate	6.60	6.63	6.64	6.75	7.80**
Total Geothermal Revenue	\$2,310	\$25,442	\$55,542	\$175,975	\$305,545

*Incremental assessment of property from geothermal wells or leases on B.L.M. land. Assessment made directly from geothermal activity.

**7.80 = 2.69 + $\frac{\text{School Tax}}{\text{Special District}}$ for Middletown School District (see Table 5 -XVI)

SECTION SIX: TASK FIVE

ENGINEERING: COST OF GEOTHERMAL HEAT DELIVERED AT A UTILIZATION SITE

6.1 INTRODUCTION

Preliminary estimates of the cost of heat delivered to a utilization site from geothermal wells show that heat can be delivered economically, the degree of attractiveness depending on conditions specific to each case. The diversity of factors involved makes it difficult to draw general conclusions based on a few cost estimates. Therefore, a method is presented here that permits the step-by-step development of a budget type cost of heat delivered to a utilization site from a typical well producing 90,720 kg (200,000 lb)/hour of hot brine. In Section 6.2 an outline of each of the steps in the procedure is presented; then, in the next section, an example is worked using a standard worksheet. In Section 6.4 a justification is made of the procedure, and in the final section the results obtained by applying the method in six typical cases and two minimum capital cost cases are discussed and some conclusions drawn.

6.2 COST ESTIMATE PROCEDURE

The procedure to obtain cost of heat delivered has been broken down into three steps; the estimate of cost of heat delivery, the estimate of total heat delivered, and the estimate of the cost of heat delivered. It will be helpful to refer to Table 6-XXI (a typical worksheet) in order to follow the discussion below.

6.2.1 Cost of Heat Delivery

The cost of heat delivery is a function of total capital cost and total operating and maintenance (O and M) cost. The costs of installing (capital cost) and operating the heat delivery facility, consisting of wells, pump, and pipeline, have been combined into three groups; wells, surface installation, and pumping power costs.

6.2.1.1 Wells

The total well capital (completed) cost is the sum of the costs of the production well and the injection well (if any), plus the dry well allowance. The average cost of a completed production well is dependent on its depth. Figure 6.1 represents this relationship, where the cost of the completed well is plotted on the left side (Y-axis) scale as a function of depth.

The injection well cost is also dependent. It is suggested that, for lack of better information, the cost of the injection well be assumed equal to that of the production well. An allowance should be made for intended production wells which turn out dry. It is recommended that 16.67% of the cost of a production well be allocated to cover for dry hole occurrences.

The total O and M cost for the wells is equal to the sum of the well maintenance costs and the cost of field supervision (labor). The yearly maintenance costs associated with the wells have been estimated equal to 10% of their capital cost. These costs have been prorated to an hourly charge and are shown, opposite to the corresponding capital cost, on the right side (Y-axis) scale in Figure 6.1. Field labor has been estimated for maximum and minimum supervision. A prorated cost of \$0.1957/operating hour, equivalent to half an hour supervision every operating day, is considered a minimum for each set of wells (one production and one injection well). However, in the case of an isolated well set, a man might be hired to monitor the operation of the field installation (including pipeline) for eight hours every operating day, in which case a prorated cost of \$2.7397/operating hour should be used.

6.2.1.2 Surface Installation

The surface installation capital cost is the sum of the pump and motor, and pipeline costs.

Pump and motor installation costs have been developed based on verbal budget-type quotations of deep well pumps. In Figure 6.2, the cost of the pump and motor (equipment cost) has been plotted as a function of pump setting depth (equivalent to the length of the discharge column of the pump) and pumping power cost (in \$/operating hour). To obtain the installed cost of the pump and motor, the equipment cost should be multiplied by a factor of four. Since the cost of installation will vary depending on setting depth, an addition should be made to the installed cost. This correction is listed in Table 6-III as a function of setting depth.

Installed, insulated pipeline costs have been developed as a function of brine temperature (the number of expansion loops required per given length increases with fluid temperature), pipeline diameter (15.2 or 20.3 cm [6 or 8 in.] nominal pipe size), and type of installation (below or aboveground). The costs are presented in Table 6-IV through 6-VII. Normally, only supply lines would be insulated while return lines would be coated (protected) only. It has been estimated that the installed cost of the return uninsulated pipeline should be only about 75% of the cost of the corresponding insulated pipeline.

The yearly operating and maintenance costs for the surface installation have been assumed equivalent to 4% of the installed cost of the facilities. In Figure 6.2, below the cost of the pump and motor scale (X-axis) there is a scale from which the corresponding O and M cost can be read. The pump setting depth cost addition can be obtained from Table 6-III. The O and M cost for the pipeline has been tabulated in parenthesis just below the corresponding installed cost in Tables 6-IV through 6-VII. In case of uninsulated (return) pipelines, 75% of the tabulated O and M cost should be used.

6.2.1.3 Pumping Power

The total pumping power cost is the sum of the power costs resulting from supplying, utilizing, returning, and injecting the brine. The pumping power costs are tabulated in Tables 6-I and 6-II, as a function of pipe nominal size 15.2 and 20.3 cm (6 and 8 in. in diameter), total static head (difference in elevation between the pumping water level down inside the well and the maximum pipeline elevation above the wellhead location), brine temperature (the number of expansion loops required for a given pipeline length increases with fluid temperature), and distance along the pipeline route (length).

The total capital cost is obtained by adding the well and the surface installation costs. The total O and M cost in prorated dollars per operating hour is obtained by adding the wells and surface installation O and M costs to the total pumping power cost. In Figures 6.3 and 6.4 the cost of heat delivery in dollars per operating hour is plotted as a function of the total capital cost and the total O and M cost. Figure 6.3 covers the low (\$20,000-150,000) range of capital costs. Figure 6.4 covers the high (\$90,000-7,000,000) range of capital costs.

6.2.2 Heat Delivered

The total heat delivered is determined by the difference between the heat available in the brine and the heat losses sustained in the supply pipeline. The heat available is listed in Table 6-VIII as a function of brine temperature at the inlet of the pipeline and the spent (used) brine temperature. The heat losses are shown in Tables 6-IX and 6-X as function of the pipe size 15.2 and 20.3 cm (6 and 8 in.), the temperature at which the brine enters the pipeline, and the distance from the source to the utilization site along the pipeline route.

6.2.3 Cost of Heat Delivered

The cost of heat delivered, in \$/BTU is obtained by dividing the cost of heat delivery, in \$/operating hour, into the total heat delivered, in BTU/operating hour. In addition, estimation of the equivalent cost of a barrel of fuel oil is recommended in order to appreciate the competitiveness of the heat delivery system.

6.3 EXAMPLE

The following case has been chosen to demonstrate the procedure:

- A. The wells (production and injection with a flow rate of 90,720 kg (200,000 lb)/hour) are 910 m (3,000 ft) deep.
- B. A minimum field supervision will be required.
- C. The brine at wellhead is at 149°C (300°F).
- D. The spent brine is returned at 71°C (160°F).
- E. The utilization site is 4.8 km (3 mi) away from both the production and the injection wells.
- F. Due to the considerable distance, the 20.3-cm (8-in.) pipe will be used to transport the brine in order to minimize power consumption. Another estimate could be made utilizing a 15.2-cm (6-in.) pipeline, thus permitting an optimization.
- G. For environmental considerations, the pipeline will be installed underground.

- H. The pump setting depth will be assumed to be 61 m (200 ft).
- I. The maximum elevation of the supply and return pipelines above the production and injection wellhead levels is 20 m (100 ft).
- J. The pressure drop at the utilization point is 3.0 kg/sq cm (42.5 psi), equivalent to 30 m (100 ft) of head (caused by control valves, heat exchangers, etc.).
- K. In addition to the static head at the inlet to the injection well, 30 m (100 ft) more of head are required to pump the brine back into the ground.

Table 6-XI is the worksheet prepared to obtain the cost of the heat delivered under the above conditions. Below is the step-by-step procedure followed to obtain this cost.

6.3.1 Well Costs

6.3.1.1 Capital (Installed) Costs

The costs of the production and the injection wells were read from the left side (Y-axis) scale in Figure 6.1. Since the cost of the production well is \$150,000, the dry hole allowance is \$25,000 ($\$150,000 \times 0.1667$).

6.3.1.2 Operating and Maintenance Costs

The prorated hourly production and injection well expenses were read from the right side (Y-axis) scale in Figure 6.1. The cost of field labor is \$0.1957/operating hour, which corresponds to a minimum of supervision.

6.3.2 Surface Installation and Pumping Power Costs

6.3.2.1 Pump and Motor

To obtain the installed cost of the pump and motor, the required pumping power cost must be established for the system. The power cost to operate 20.3-xm (8-in.) pipeline transporting 90,720 kg/hr (200,000 lb)/hour of brine is obtained from Table 6-II. Since the supply line will transfer brine at 149°C (300°F) (brine temperatures are listed on the extreme left hand side of the table) under a total static head of 91 m (300 ft) (61 m [200 ft] corresponding to the pumping water level inside

the well plus 30 m (100 ft) corresponding to the maximum elevation of the pipeline above the wellhead level), the power cost for the 4.8-km (3-mi) run to the utilization site is \$1.4/operating hour. The power required to pump the brine through the utilization site will be added, for convenience, to the power required to pump the brine back to the injection well. The return pipeline carries brine at 71°C (160°F) under a total static head of 61 m (200 ft). Due to the maximum elevation above the wellhead, 30 m (100 ft) are provided by the recovery of the head in the supply line (closed loop system). Therefore, only the 30 m (100 ft) of equivalent head due to the 3.0 kg sq km (42.5 psi) pressure drop at the utilization point and the 30 m (100 ft) of additional injection head have to be provided by the pump. The line loss incorporated in the pumping power cost values shown in Table 6-I and 6-II does not give credit for the siphoning which could be used advantageously in transporting sub-cooled liquids between points at different elevations. Table 6-II shows that the 4.8-km (3-mi) return line pumping cost is \$1.1/operating hour. These two power costs are tabulated and totaled in the appropriate section of the operating and maintenance cost column in Table 6-XI. The total, \$2.5/operating hour, is used to determine in Figure 6.2 the cost of the pump and motor (equipment cost) required by the system. In this case, for a setting depth of 61 m (200 ft) the cost of equipment is \$16,500. The installed cost is four times this value or \$66,000 as shown on the appropriate line in Table 6-XI.

The corresponding O and M cost is read from the bottom (X-axis) scale in Figure 6.2 and again written in the appropriate column in Table 6-XI. For the \$16,500 pump and motor the O and M cost is \$0.3350/operating hour. The installed cost additions to capital and O and M costs are obtained from the Table 6-III. For a 61 m (200 ft) setting, the corresponding values are \$1,000 and \$0.0051/operating hour.

6.3.2.2 Pipeline Costs

The capital and O and M costs of the 4.8 km (3mi) insulated supply pipeline carrying 149°C (300°F) brine are obtained from Table 6-V under the column for an 20.3 cm (8 in.) line installed below ground. The pipeline costs \$958,440 and its maintenance cost is equivalent to \$4.8627/operating hour. The costs of the 4.8 km (3 mi) return line carrying 71°C (160°F) brine is obtained from Table 6-VII under the appropriate column. The corresponding costs are \$907,470 and \$4.6041/operating hour. However, since these are costs for an insulated pipeline and there is no need to reduce heat losses in the return line, the above costs should be multiplied by 0.75 to reflect the

savings in insulation. The adjusted costs are shown in Table 6-XI.

6.3.3 Total Capital Cost

The total capital cost of the system is equal to the sum of total well and surface installation costs. The total O and M cost of the system is equal to the sum of well and surface installation O and M costs plus the pumping power cost.

6.3.4 Heat Delivery Cost

The cost of heat delivery in \$/operating hour is obtained from Figure 6.4, and is a function of the total system capital cost and total O and M cost. From this graph a cost of heat delivery of \$123.5/operating hour is obtained.

6.3.5 Heat Delivered

The heat available per operating hour was read from Table 6-VIII for a brine temperature of 149°C (300°F) and a spent brine temperature of 71°C (160°F). It is 28,340,000 BTU/operating hour. The heat loss from an insulated 4.8 km (3 mi) long, 20.3 cm (8 in.) in diameter pipeline carrying 149°C (300°F) is 1,555,000 BTU/operating hour. This value was read from Table 6-X. The total heat delivered is the difference between the heat available and the heat loss in the pipeline. Table 6-XI shows it is 26,785,000 BTU/operating hour.

6.3.6 Cost of Heat Delivered

The cost of heat delivered is estimated by dividing the cost of heat delivery in \$/operating hour, by the total heat delivered, in BTU/operating hour. Table 6-XI shows that the cost is \$4.61/million BTU.

6.3.7 Equivalent Cost of a Barrel of Fuel Oil

The average net heating value of a barrel 159 liters (42 gal) of fuel oil is 6,200,000 BTUs. Therefore, the equivalent cost of a barrel of fuel oil for this case is \$28.6 (\$4.61/million BTUs x 6.2 million BTUs/barrel).

6.4 JUSTIFICATION OF PROCEDURE

The heat delivery system considered in this study has a constant capacity of 90,720 kg (200,000 lb) of brine/operating hour. All capital costs are reported in dollars and represent expected installed costs at present.

The method developed is general in scope. The tables and figures have been prepared covering the variables and their range of values expected for this particular project. Even in situations where some of the variables take values outside these ranges, it is possible to determine with a minimum of effort the cost of heat delivered, either by judicious use of ratios or by supplying new values.

All maintenance and operating (O and M) costs were obtained by prorating the estimated yearly expenses to an hourly charge based on a 90% operating factor (7,884 hours out of 8,760 hours in a year). This factor accounts for unexpected shutdowns as well as a scheduled maintenance shutdown of the whole system once a year.

6.4.1 Well Costs

Capital costs obtained from Figure 1 represented expected average costs of drilling and completing wells in typical soils. Three known values were used to develop the cost curve; \$115/m (\$35/ft) for a 91 m (300 ft) (deep) well, \$164/m (\$50/ft) for a 910 m (3,000 ft) well, and \$328/m (\$100/ft) for a 1,830 m (6,000 ft) well. Since the purpose of the injection is to return the brine to the strata where it came from, to reduce possibilities of contamination, the injection well is expected to be as deep as the production well. Thus, it is recommended using the same cost for both wells.

The charge made for dry holes is based on an expectancy that, on the average, one out of six wells intended for production turns out dry. The equivalent charge is 16.67% of the cost of a production well. The well O and M costs were estimated based on the following expected yearly expenses.

6.4.1.1 Production Well Maintenance

The yearly expense has been assumed equal to 10% of the cost of the well, reflecting the operator's need to keep expenses under control and in proportion to the cost of the well. This expense covers the cost of removing and reinstalling the pump, the cost of "killing" the well and the cost of a yearly down-hole survey. Also included are the costs of remedial work or acidizing that might be incurred at intervals of several years but are amortized on a yearly basis. This maintenance expense has been prorated to a cost in \$/operating hour and can be read from Figure 6.1, directly opposite to the corresponding cost of the well.

6.4.1.2 Injection Well Maintenance

The yearly expense is expected to be proportional to the cost of the well. This expense, assumed to be equal to 10% of the cost of the well, covers the same type of costs incurred in a production well except for those associated with the production pump.

6.4.1.3 Dry Well Maintenance

Properly plugged dry wells should not cause maintenance expenses.

6.4.1.4 Field Labor

With minimum supervision, one person working eight hours a day could check once a day 14 sets of wells (production and injection), provided the wells are close to one another. However, if the wells are far apart and closer attention to the operation is desired, one person working eight hours a day could supervise the operation of one set of well and the pipeline. In both cases, the salary of a field supervisor has been estimated at \$12,000 a year. A sum of \$9,600 has been allocated to cover fringe benefits and general and administrative overhead costs. The minimum prorated O and M cost is \$0.1957/operating hour [$\$21,600 \div (14 \text{ well sets}) \div (7,884)$]. The maximum prorated O and M cost is \$2.7397/operating hour ($21,600 \div 7,884$).

6.4.2 Surface Installation Costs

6.4.2.1 Pump and Motor Costs

The costs of pumps were furnished by manufacturers having experience in geothermal well pumping. Two of the manufacturers, Gould and Peabody-Floway, have pumps operating in geothermal fields in Iceland. Peerless has had experience in the geothermal fields in Nevada and California. All three manufacturers provided base quotations for multi-stage deep-well pumps. The head developed by each stage and its cost were also supplied. The cost curves plotted in Figure 6.2 were developed using this information. Costs were estimated for pumps fitted with the required number of stages and driven by properly sized motors to meet the head requirements. The pump model selected for this study could handle the 90,720 kg (200,000 lb)/hour flow developing the full range of heads, up to a maximum of 410 m (1,350 ft). At this limiting condition, the pump would have 25 stages and would require a 200 HP motor. Costs are for

pumps with enclosed line shafts (to permit clean, cold water lubrication of shaft bearings), fitted with cast iron bowls and impellers and utilizing a 15.2 cm (6 in.) carbon steel discharge column. Pump costs were adjusted for different setting depths at a rate of \$124/m (\$37.7/ft) plus or minus the setting depth of the base quote 61 m ((200 ft). The motor prices were obtained from an up-to-date catalog of G.E. vertical motors fitted with nonreverse couplings (for pump protection). The motors are hollow shaft, 1,800 RPM, TEFC (totally enclosed fan cooled).

To obtain a relationship between total head and power requirements, an overall pump efficiency of 75% was used up to 55 brake horsepower (BHP). A 72% efficiency was used from 55 BHP up to 190 BHP. The latter efficiency reflects the need of a less efficient vertical can type booster pump beyond the 55 BHP requirement. Two of the three manufacturers contacted agree in this respect. The third one quoted a single vertical pump costing the same, at 55 BHP and over, as the combination of deep-well and vertical can booster pumps. The impeller efficiency of the single pump is expected to be in the range of 80%. The more conservative efficiency estimate was used because this is an impeller efficiency and does not include shaft bearing losses. The user of this procedure could simply ratio up or down the tabulated pumping power requirements (in \$/operating hour) shown in Tables 6-I and 6-II to account for different pump efficiencies. At the efficiency brake point (55 BHP) the pumping power cost is \$1.5/operating hour. An electric power cost of 36 mills/killowatt-hour was used.

The total head requirement is the sum of the velocity head spent as pressure drop in the pipeline (from the pump setting depth to the utilization site) and the total static head. The total static head is the difference in elevation between the pumping water level (assumed equal to the pump setting depth) and the maximum elevation of the pipeline on its route to the utilization site.

The velocity head requirements (due to line pressure drop) were estimated for the flow of 90,720 kg (200,000 lb)/hour of saturated water in the two pipe sizes, 15.2 and 20.3 cm (6 and 8 in.), that looked best suited for this job. Carbon steel, Schedule 40 pipe was selected because it could withstand the full range of operating conditions (temperature and pressure) expected in this study. The line pressure drop was obtained by multiplying the clean pipe pressure drop by 1.7 to account for fouling inside the line. This factor is not nearly as conservative as the C=120, which is equivalent to a pressure drop of only 71% of a C=100 estimate.

Since the line pressure drop for the same mass flow did not change more than 10% over the 200°C (400°F) range of brine temperatures studied, an average value in grams per sq cm/m (lb/sq in./100 ft) was selected for each pipe size; 1.87 g/sq cm/m (0.80 psi/100 ft) for 15.2 cm (6 in.) lines and 0.44 g/sq cm/m (0.19 psi/100 ft) for 20.3 cm (8 in.) lines. Nevertheless, the total head requirements for a given distance increase with brine temperature because the number of necessary expansion loops in the pipeline increases with fluid temperature. Therefore, Tables 6-I and 6-II show the total pumping cost as a function of brine temperature and also as a function of total static head in feet (and equivalent psi) and distance along the pipeline route from the source to the utilization site.

To obtain the total pumping power cost of the closed loop (brine supply and return) system, an estimate is required of the power to pump the brine through the utilization site and return leg of the pipeline, and to provide the head to inject brine back into the ground. The same cost tables can be used, being careful to read the power cost for the appropriate spent brine temperature. The static head column in these tables is now used to account for any head requirements in addition to the velocity head (line pressure drop). Thus, if the pressure drop on the brine side in the utilization site (due to heat exchangers, control valves, etc.) is 2.8 kg/sq km (40 psi) and there is the same ground elevation in the return as in the supply pipeline, the static head would be only 2.8 kg sq cm (40 psi) (equivalent to about 30 m [100 ft]). If there is also an injection head requirement of 3.2 kg sq cm (45 psi), the total static head is now 6.0 kg sq cm (85 psi) which is equivalent to about 61 m (200 ft). Interpolation makes it possible to estimate power costs for a wide range of head requirements.

For this study, complete static head interchangeability between ground elevation and well water level has been assumed because the results are within the accuracy desired. However, static head due to ground elevation occurs along the pipeline, but the well water level (pump setting depth) determines the length of the discharge column (the pipe run inside the injection well) affecting the line loss as well as the static head requirements. To obtain the pumping power cost estimates shown in Table 6.1 and 6.2, the following combinations of ground elevations and well water levels were used.

<u>Total Static Head Column in Tables 6-I and 6-II</u>		<u>Ground Elevation</u>	<u>Well Water Level (Pump Setting Depth)</u>		
30 m	(100 ft)	0 m	(0 ft)	30 m	(100 ft)
61 m	(200 ft)	30 m	(100 ft)	30 m	(100 ft)
91 m	(300 ft)	0 m	(0 ft)	91 m	(300 ft)
122 m	(400 ft)	30 m	(100 ft)	91 m	(300 ft)
183 m	(600 ft)	122 m	(400 ft)	61 m	(200 ft)
244 m	(800 ft)	152 m	(500 ft)	91 m	(300 ft)

The sum of supply, utilization and return pumping power costs determines the cost of the pump and motor (equipment only, installation not included). Figure 6.2 shows this relationship. Based on experience, the installed cost of the pump and motor is expected to be about four times the equipment cost. A final pump cost adjustment is necessary in order to account for additional labor required for deep pump settings. Table 6.3 shows these costs as a function of pump setting depth.

O and M costs for pump and motor are obtained directly from the lower scale (below the cost scale, on the X-axis) in Figure 6.2. The yearly expense corresponds to 4% of the installed cost of the pump and motor and has been prorated to an hourly charge. The O and M cost addition for installation of deep well pumps is shown in Table 6.3.

6.4.2.2 Pipeline Costs

Carbon steel, Grade B, Schedule 40 pipe was selected for this study because it can stand the flow of 200°C (400°F) brine up to a pressure of 70.3 kg/sq cm (gauge) (1,000 psig). The costs in dollars/meter (dollars/foot) of installed insulated pipeline used in this study are shown below.

	<u>15.2 cm (6 in.)</u>	<u>20.3 cm (8 in.)</u>
Aboveground	28	39
Below ground	43	53

These costs include the cost of a 5.1 cm (2 in.) insulation compatible with the surroundings (air or soil). For aboveground installation allowance has been made for anchors and supports every 67 m (220 ft) and pipe guides every 12 m (40 ft). For underground installation, trenching 0.6 m by 1.5 m (2 ft by 5 ft) deep has been assumed necessary.

To permit thermal expansion of the pipeline, the following schedule of expansion loops as a function of brine temperature has been used.

204°C (400°F) Brine	4.5 Loops/300 m (1,000 ft)
149°C (300°F) Brine	3.5 Loops/300 m (1,000 ft)
93°C (200°F) Brine	2.5 Loops/300 m (1,000 ft)
71-46°C (160-115°F) Brine	2.0 Loops/300 m (1,000 ft)

Each expansion loop consists of 4,900-long radius weld-end elbows and 4.9 m (16 ft) of pipe in each of the two sides perpendicular to the main axis of the pipeline. Pressure drop and cost estimates reflect this loop design.

The total costs of insulated pipeline as a function of brine temperature, pipe size, type of installation (above or below ground) and distance from source to utilization site are listed in Table 6-IV through 6-VII. In the case of the return (spent brine) pipeline, in addition to the lower fluid temperature, which requires less expansion loops, a credit can be taken for not needing insulation. It is estimated that an average of 25% of the cost of insulated pipeline can be saved. In all but one of the cases that have been worked as part of this study, a return line as long as the supply line has been assumed to be required.

Aside from buying bare pipe and subcontracting the insulation at the job site, at least one shop-insulated steel pipe is available and is sold under the Perma-Pipe trade name. Costs are comparable with the ones used in this study.

Asbestos cement pipe might prove economical for low temperature, low head brine distribution systems. The pipe is not only cheaper, but its manufacturers claim it has a nondegrading internal surface which would remain clean ($C=150$ instead of $C=100$ in the Williams and Hazen equation) throughout the life of the project. This property of the pipe would reduce the pumping power costs significantly. Although this characteristic has been demonstrated extensively in water lines, it is hard to predict what would happen if this pipe were to be exposed to geothermal brines. The cost of a 15.2 cm (6 in.) insulated pipe 5.1 cm (2 in.) insulation, including asbestos wall) installed underground was estimated at \$92/m (\$28/ft), which compares very favorably with the \$141/m (\$43/ft) used in this study. Typical of this type of pipe is Johns-Manville's Temp-Tite, an asbestos, epoxy-lined pipe. Further savings are possible with a Temp-Tite pipeline because it does not require expansion loops. At the pipe joints there is enough clearance to permit thermal expansion. The maximum recommended operating

fluid temperature is 99°C (210°F) at 9.1 kg/sq cm (gauge) (130 psig). At 93°C (200°F), a maximum operating pressure of 10.5 kg/sq cm (gauge) (150 psig) is allowed. Since the pipe is compatible with steel pipe installations it is possible to use Temp-Tite in the return line only. In any case, these restrictions in operating conditions will limit the utilization of this type of pipe in hot brine distribution systems.

6.4.3 Cost of Heat Delivery

The cost of heat delivery is a function of total capital cost and total O and M cost. The relationship has been plotted in Figures 6.3 and 6.4, and was established utilizing a Holt Company computer program that has been used extensively to evaluate economics of geothermal projects.

The economics program requires complete information on capital investment and operating expenses. Following is a detailed explanation of the components.

6.4.3.1 Capital Investment Components

Exploration and Land Acquisition Costs. These represent the money spent in geological and geophysical research, exploratory drilling, bonus payment and other costs involved with establishing the presence of an exploitable geothermal reservoir. These costs are incurred prior to the field development phase. No exploration and land acquisition costs have been considered in this study.

Well Drilling Costs. The cost of wells is estimated as described earlier in this report.

Working Capital. Working capital is required as of the start-up of the heat delivery system. This amount has been estimated equal to one month's expenses, and is returned at the termination of the project.

Capital Additions. An additional drilling cost is required to provide additional wells in the field to offset the effects of a declining reservoir. For this study, no additional drilling cost has been contemplated.

These capital investments are expected to return a profit commensurate with the risks involved in a geothermal venture. To account for the time value of money, the discounted-cash-flow method is used to determine the annual revenue requirements.

6.4.3.2 Expenses Incurred

The expenses incurred during the operation of a producing geothermal field fall into two classes: cash expenses and book expenses. The book expenses are not deducted from the revenues but are used in determining the taxable income for Federal and state income taxes.

Cash Expenses. These consist of operating and maintenance expenses, described earlier in this report, and royalty payment. The royalty, estimated at 12.5% of gross revenues, is paid to the owner of mineral rights of the land on which the production well is located.

Book Expenses. Book expenses include depreciation, intangible drilling expenses and depletion allowance. Depreciation for tax purposes is calculated by the sum-of-the-years digits method for a tax life of 15 years. This is the shortest period of time in which federal regulations permit a complete depreciation of this type of installation. Depreciation for book-keeping purposes is calculated by the sum-of-the-years digits method over the life of the project. In this case, 15 years is also the life of the project.

Intangible drilling expenses are deducted in the year incurred. Since most of the drilling activities occur before any taxable income is produced by the project, it is assumed that the producer can take advantage of this deduction elsewhere to the credit of the project. Although this deduction is currently in use in the oil industry, there is some question as to whether it will also be available for the geothermal industry. Therefore, no deduction has been made to revenues on account of this type of expense. The depletion allowance, similar to depreciation, could be as high as 22% of gross revenue. However, it has not been ruled applicable to geothermal in general. Therefore, it was not considered applicable to this study.

6.4.3.3 Taxation

Federal, state and local taxes will be paid by the project. The federal and state income taxes are paid according to the net taxable income. In this study, the federal and state income tax rates were assumed equal to 48% and 9%, respectively. A federal investment tax credit of 10% is deducted from the federal income tax. The credit is based on the tangible, depreciable assets of the project. The state and local real property taxes are generally charged according to the value of the real property. This is judged to be a function of the revenues produced by that property. Thus, these taxes are

usually a percentage of the gross revenues. They are treated as an ad valorem tax of 10% in this study. If the land is not owned by the heat delivery system operator, as no allowance has been made for acquiring the land, it can be assumed that the owner will not be willing to pay these taxes out of his own money. Therefore, in this project, these taxes have been deducted from the operating revenues.

6.4.3.4 Cash Flow

The cash flow consists of the sales revenues minus taxes and expenses not including depreciation. There is no annual capital addition to be subtracted from the cash flow. The cash flow is discounted at the desired rate of return to a present worth at the beginning of the heat delivery options. For this study a 15% rate of return has been used. The annual sales revenue is adjusted iteratively until the sum of the discounted cash flows equals the capital investment at the start of operations. The sales revenue then becomes the cost of heat delivery.

Under these economic conditions, the capital investment is completely paid out in an average of 5.5 years. For the very low capital cost cases the payout times varied between 4.6 and 6.0 years.

6.4.4 Total Heat Delivered

The total heat delivered is calculated as the difference between heat available and heat losses in the pipeline.

6.4.4.1 Heat Available

Heat available has been estimated utilizing the enthalpy values listed in the Keenan and Keyes tables for pure saturated water. For the relatively low pressures and temperatures expected in this study, liquid enthalpy corrections for pressures above saturation were ignored. The net maximum correction was estimated to be in the order of one BTU/pound of liquid. Table 6-VIII shows the heat available as a function of the temperature at which the brine enters the pipeline and the spent (return or used) brine temperature. The temperature range of the hot brine was extracted from the section "Potential Study Areas, Resource Status," included in the proposal prepared by Geonomics titled "Non-Electric Applications of Geothermal Energy in the Geysers/Clear Lake KGRA" (April, 1976). Temperatures range from 204°C (400°F) in Site 1 (at this temperature an economic feasibility study should be made for utilizing the brine in electric power generation) to 49°C (120°F) in Site 5.

Intermediate temperatures have been added to facilitate interpolation of heat available values. The temperatures of the spent brine were selected to permit the evaluation of each step of an integrated system of processes utilizing thermal energy at decreasing or cascading temperature levels. For example, a refrigeration plant could use heat available down to 93°C (200°F). At this point, space heating or a canning operation could utilize the heat available in the brine between 93°C and 71°C (200°F and 160°F). Greenhouse heating could utilize heat down to 54°C (130°F), and aquaculture or tree breeding could extract the remaining low temperature heat.

6.4.4.2 Heat (Pipeline) Losses

Heat losses from insulated pipes to the surroundings are proportional to the overall temperature difference between the brine and the surroundings, the surface conductances at the brine-pipe wall interface and at the insulation-surroundings interface, and the conductivities of the pipe wall and the insulation. The two interface conductances can be assumed constant since velocities of brine and air would not change significantly under normal operating conditions. The soil conditions affect the interface conductivity significantly. Moisture content could increase conductivity of dry soil almost by a factor of ten. This uncertainty is unfounded when it is realized that appropriate insulation (for which allowance has been made in the pipeline cost estimates) would reduce heat losses as effectively below ground as aboveground. Thus, it was considered unnecessary to make separate estimates of heat losses. The conductivities of the metal and the insulating material do not change significantly within the range of temperatures expected. Therefore, the heat loss becomes proportional to the overall temperature difference and was determined for an insulated pipe surrounded by still air at 16°C (60°F). Tables 6-IX and 6-X contain the heat losses estimated for an insulated pipeline as function of brine temperature and distance from the source to the utilization site (pipeline length). Table 6-IX values apply to a 15.2 cm (6 in.) pipeline covered with 5.1 cm (2 in.) of insulation. Table 6-X values apply to an 20.3 cm (8 in.) pipe covered with 5.1 cm (2 in.) of insulation. It is estimated that a 5.1 cm (2 in.) insulation reduces the pipeline heat losses to about 7% of the bare pipe heat losses. A 6.4 cm (2½ in.) insulation would make the 20.3 cm (8 in.) pipe losses almost identical to those expected in an equivalent 15.2 cm (6 in.) pipe with 5.1 cm (2 in.) insulation. The additional 1.3 cm (½ in.) insulation would increase by \$6.60/m (\$2/ft) the installed cost of the 20.3 cm (8 in.) pipe.

Accordinging to report 76-1 of the Oregon Institute of Technology, supply line heat losses can be reduced by 15% by installing (burying, in the particular case discussed in the report), both the supply and return lines next to one another. This possibility has not been taken into account in the estimation of heat losses, but the figures could be easily adjusted.

6.4.5 Cost of Heat Delivered

Cost of heat delivered is defined as the quotient of the cost of heat delivery divided by the total heat delivered.

6.4.6 Equivalent Cost of a Barrel of Fuel Oil

Utilizing the average net heating value of fuel oil (6,200,000 BTUs/barrel), an estimate of the equivalent cost of the barrel can be obtained. Since the price of fuel oil is readily available, the equivalent price becomes a reliable measure of the degree of competitiveness of the heat delivery system.

6.5 TYPICAL COSTS AND CONCLUSIONS

Six cases representing typical brine delivery systems were evaluated utilizing the cost of heat delivered procedure presented in this report. Cases 1 through 3 represent a high temperature brine system operating with a pump set 91 m (300 ft) inside a 610 m (2,000 ft) well and delivering heat 152, 762, and 1,610 m (500, 2,500, and 5,280 ft) away from the wells. The costs of heat delivered were obtained as shown in the corresponding Tables 6-XII through 6-XIV. Cases 4 through 6 represent a low temperature brine system operating with a pump set 30 m (100 ft) inside a 152 m (500 ft) well and delivering heat 152, 762, and 1,610 m (500, 2,500, and 5,280 ft) away from the wells. The costs of heat delivered were obtained as shown in the corresponding Tables 6-XV through 6-XVII.

The results have been tabulated in Table 6-XVIII and indicate that it is economically feasible to supply hot brine to a utilization site as far as one mile away from the geothermal well. Depending on the conditions of the brine, wells, and pipeline, this distance might increase or decrease. To check the competitiveness of the brine delivery system the equivalent cost of a barrel of fuel oil is shown below the corresponding cost of heat delivered. For utilization sites beyond one mile, it is expected that only high temperature brines (149°C [300°F] or higher) and/or large brine flow systems 1,500 liters/min (400 gal/min [gpm] or larger) would be competitive with the present day cost of fuel.

A typical example of the effect of flow (volume) on the cost of heat delivered is the comparison of the two minimum capital cost cases. Tables 6-XIX and 6-XX are the worksheets prepared for both cases. The costs are \$0.94 and \$0.24 for every million BTUs of heat delivered 152 m (500 ft) away from the production wellhead. The higher cost corresponds to the case with the lowest capital cost but making available for sale only 120 liters/min (60 gpm) of brine. The lower cost corresponds to the case with a 60% higher capital cost but delivering 1,570 liters/min (415 gpm) of brine, making available for sale almost seven times more heat at the utilization (sale) point. It follows that the flow rate of brine has a very significant effect on the cost of heat delivered.

The higher the temperature of the hot brine, the more efficient and more flexible become the energy utilization schemes; but there is no question that in order to improve significantly the economics of a particular system, an alternate system handling a large volume of brine might have to be considered, provided that there is a market ready to buy that extra energy on a continuous basis. Due to the diverse factors involved, it is not possible to make further generalizations. This is why an estimating procedure has been developed. The procedure provides a means of obtaining costs of heat delivered, thus permitting the quick determination of the feasibility of a system. The procedure could also be used to optimize a particular system.

Figure 6.1 Cost of a Completed Well and Its Maintenance Cost as a Function of Well Depth

Figure 6.2 Cost of Pump and Motor Maintenance as a Function of Pumping Power Cost

Figure 6.3 Cost of Heat Delivery as a Function of Total Capital Cost and Total Operating and Maintenance Cost

TOTAL OPERATING AND MAINTENANCE
COST IN \$/OPERATING HOUR

Figure 6.4 Cost of Heat Delivery as a Function of Total Capital Cost-and
Total Operating and Maintenance Cost

TOTAL OPERATING AND MAINTENANCE
COST IN \$/OPERATING HOUR

TABLE 6-I. PUMPING POWER COSTS IN \$/HR AS FUNCTION OF TOTAL STATIC HEAD,
PIPELINE LENGTH AND BRINE TEMPERATURE
PIPE NOMINAL SIZE: 6 INCHES

Total Static Head: Pumping Water Level Plus Maximum
Pipeline Elevation Above Well Head Location

PIPE NOMINAL SIZE: 6 INCHES

PRESSURE DROP FOR USED CARBON STEEL PIPE: 0.80 PSI/100 FEET

FLOW RATE: 200,000 POUNDS/HOUR

	TOTAL STATIC HEAD IN FEET (PSI)	DISTANCE ALONG PIPELINE ROUTE FROM SOURCE TO UTILIZATION SITE IN FEET OR MILES						
		200	1000	(1 MILE) 5280	2 MILES	3 MILES	5 MILES	10 MILES
BRINE AT 400°F	100(37)	0.4	0.5	0.9	1.5	2.0	3.1	5.8
	200(74)	0.7	0.8	1.3	1.8	2.4	3.5	6.2
	300(111)	1.1	1.2	1.7	2.2	2.8	3.9	6.6
	400(143)	1.5	1.6	2.0	2.6	3.1	4.2	6.9
	600(222)	2.3	2.4	2.8	3.4	3.9	5.0	7.7
	800(296)	3.0	3.1	3.6	4.1	4.7	5.8	9.5
BRINE AT 300°F	100(37.5)	0.4	0.5	0.9	1.3	1.8	2.8	5.2
	200(74)	0.7	0.8	1.2	1.7	2.2	3.2	5.6
	300(111)	1.1	1.2	1.6	2.1	2.6	3.6	6.0
	400(152)	1.5	1.6	2.0	2.5	2.9	3.9	6.4
	600(237)	2.3	2.4	2.8	3.3	3.7	4.7	7.1
	800(316)	3.0	3.1	3.5	4.0	4.5	5.5	7.9
BRINE AT 200°F	100(41.5)	0.4	0.5	0.8	1.3	1.6	2.6	4.8
	200(83)	0.7	0.8	1.1	1.6	2.0	2.9	5.1
	300(124)	1.1	1.2	1.6	2.0	2.4	3.3	5.5
	400(166)	1.5	1.6	1.9	2.4	2.8	3.7	5.9
	600(249)	2.3	2.4	2.7	3.1	3.6	4.5	6.7
	800(332)	3.0	3.1	3.5	3.7	4.1	5.2	7.4
BRINE RETURN 160°F - 115°F	100(42.5)	0.4	0.5	0.8	1.2	1.6	2.5	4.6
	200(85)	0.7	0.8	1.1	1.6	2.0	2.8	4.9
	300(123)	1.1	1.2	1.6	2.0	2.4	3.2	5.3
	400(170)	1.5	1.6	1.9	2.4	2.8	3.6	5.7
	600(255)	2.3	2.4	2.7	3.1	3.6	4.0	6.5
	800(340)	3.0	3.1	3.5	3.9	4.3	5.1	7.2

TABLE 6-II. PUMPING POWER COSTS \$/HR AS FUNCTION OF TOTAL STATIC HEAD, PIPELINE LENGTH AND BRINE TEMPERATURE
PIPE NOMINAL SIZE: 8 INCHES

Total Static Head: Pumping Water Level Plus Maximum Pipeline Elevation Above Well Head Location

PIPE NOMINAL SIZE : 8 INCHES
PRESSURE DROP FOR USED CARBON STEEL PIPE: 0.19 PSI/100 FEET
FLOW RATE : 200,000 POUNDS/HOUR

TOTAL STATIC HEAD IN FEET (PSI)	DISTANCE ALONG PIPELINE ROUTE FROM SOURCE TO UTILIZATION SITE IN FEET OR MILES						
		200 TO 1000 (MILE)	1.280 (2 MILES)	(3 MILES)	(5 MILES)	(10 MILES)	
BRINE AT 400°F	100 (37)	0.4	0.5	0.6	0.8	1.0	1.7
	200 (74)	0.7	0.8	1.0	1.1	1.4	2.1
	300 (111)	1.1	1.2	1.4	1.5	1.8	2.5
	400 (148)	1.5	1.6	1.7	1.9	2.2	2.8
	600 (222)	2.3	2.4	2.5	2.7	2.9	3.6
	800 (296)	3.0	3.1	3.3	3.4	3.7	4.4
BRINE AT 300°F	100 (37.5)	0.4	0.5	0.6	0.7	0.9	1.6
	200 (79)	0.7	0.8	1.0	1.1	1.3	1.9
	300 (119)	1.1	1.2	1.3	1.4	1.7	2.3
	400 (158)	1.5	1.6	1.7	1.8	2.1	2.7
	600 (237)	2.3	2.4	2.5	2.6	2.8	3.4
	800 (316)	3.0	3.1	3.3	3.4	3.6	4.2
BRINE AT 200°F	100 (41.5)	0.4	0.5	0.6	0.7	0.8	1.4
	200 (83)	0.7	0.8	0.9	1.1	1.3	1.8
	300 (124)	1.1	1.2	1.3	1.4	1.6	2.2
	400 (166)	1.5	1.6	1.7	1.8	2.0	2.6
	600 (249)	2.3	2.4	2.5	2.6	2.8	3.3
	800 (332)	3.0	3.1	3.2	3.3	3.5	4.1
BRINE BETWEEN 160°F - 115°F	100 (42.5)	0.4	0.5	0.6	0.7	0.8	1.3
	200 (85)	0.7	0.8	0.9	1.1	1.3	1.7
	300 (128)	1.1	1.2	1.3	1.4	1.6	2.1
	400 (170)	1.5	1.6	1.7	1.8	2.0	2.5
	600 (255)	2.3	2.4	2.5	2.6	2.8	3.2
	800 (340)	3.0	3.1	3.2	3.3	3.5	4.0

TABLE 6-III. INSTALLED PUMP COST ADDITIONS AS FUNCTION OF PUMP SETTING DEPTH.

<u>PUMP SETTING DEPTH IN FEET</u>	<u>INSTALLED COST ADDITION IN \$</u>	<u>EQUIVALENT O AND M ADDITION IN \$/HR</u>
100	500	0.0025
200	1,000	0.0051
300	1,500	0.0076
400	2,000	0.0102
500	2,500	0.0127

TABLE 6-IV. COST OF INSTALLED, INSULATED PIPELINE IN \$'S (MAINTENANCE COST, \$/HOUR) FOR PIPELINE CARRYING BRINE AT 400°F

DISTANCE FROM SOURCE TO UTILIZATION SITE IN FEET OR MILES	6 INCH LINE		8 INCH LINE	
	ABOVE GROUND	BELOW GROUND	ABOVE GROUND	BELOW GROUND
100 ft	3,350 (0.0170)	5,060 (0.0257)	4,660 (0.0237)	6,270 (0.0318)
200 ft	6,690 (0.034)	10,130 (0.0514)	9,330 (0.0473)	12,530 (0.0636)
300 ft	10,040 (0.0509)	15,190 (0.0771)	13,990 (0.0710)	18,800 (0.0754)
500 ft	16,730 (0.0849)	25,310 (0.1284)	23,320 (0.1183)	31,330 (0.1589)
1,000 ft	33,470 (0.1698)	50,630 (0.2569)	46,650 (0.2367)	62,650 (0.3179)
2,500 ft	83,670 (0.4245)	126,570 (0.6422)	116,610 (0.5916)	156,630 (0.7947)
5,280 ft (1 MILE)	176,710 (0.8965)	267,310 (1.3562)	246,290 (1.2496)	330,810 (1.6784)
(2 MILES)	353,420 (1.7931)	534,630 (2.7125)	492,580 (2.4991)	661,610 (3.3567)
(3 MILES)	530,130 (2.6896)	801,940 (4.0687)	738,860 (3.7487)	992,420 (5.0351)
(5 MILES)	883,540 (4.4827)	1,336,570 (6.7812)	1,231,440 (6.2478)	1,654,030 (8.3918)
(10 MILES)	1,767,080 (8.9654)	2,673,130 (13.5623)	2,462,880 (12.4956)	3,308,050 (16.7836)

INTERPOLATION POSSIBLE

TABLE 6-V. COST OF INSTALLED, INSULATED PIPELINE IN \$'S (MAINTENANCE COST, \$/HOUR) FOR PIPELINE CARRYING BRINE AT 300°F

DISTANCE FROM SOURCE TO UTILIZATION SITE IN FEET OR MILES	6 INCH LINE		8 INCH LINE	
	ABOVE GROUND	BELOW GROUND	ABOVE GROUND	BELOW GROUND
100 ft	3,230 (0.0164)	4,890 (0.0248)	4,490 (0.0228)	6,050 (0.0307)
200 ft.	6,450 (0.0327)	9,790 (0.0497)	8,990 (0.0456)	12,100 (0.0614)
300 ft.	9,630 (0.0491)	14,680 (0.0745)	13,480 (0.0684)	18,150 (0.0921)
500 ft	16,130 (0.0818)	24,470 (0.1241)	22,470 (0.1140)	30,250 (0.1535)
1,000 ft.	32,250 (0.1636)	48,930 (0.2483)	44,950 (0.2280)	60,510 (0.3070)
1 2,500 ft.	80,630 (0.4091)	122,330 (0.6207)	112,370 (0.5701)	151,270 (0.7675)
5,280 ft (1 MILE)	170,290 (0.8640)	258,360 (1.3108)	237,320 (1.2040)	319,480 (1.6209)
(2 MILES)	340,590 (1.7280)	516,730 (2.6216)	474,640 (2.4081)	638,960 (3.2418)
(3 MILES)	510,880 (2.5920)	775,090 (3.9325)	711,950 (3.6121)	958,440 (4.8627)
(5 MILES)	851,470 (4.3200)	1,291,820 (6.5541)	1,186,590 (6.0202)	1,597,400 (8.1045)
(10 MILES)	1,702,930 (8.6399)	2,583,640 (13.1082)	2,373,180 (12.0405)	3,194,800 (16.2090)

INTERPOLATION POSSIBLE

TABLE 6-VI. COST OF INSTALLED, INSULATED PIPELINE IN \$'S (MAINTENANCE COST, \$/HOUR) FOR PIPELINE CARRYING BRINE AT 200°F

DISTANCE FROM SOURCE, TO UTILIZATION SITE IN FEET OR MILES	6 INCH LINE		8 INCH LINE	
	ABOVE GROUND	BELOW GROUND	ABOVE GROUND	BELOW GROUND
100 ft	3,100 (0.0157)	4,720 (0.0240)	4,320 (0.0219)	5,840 (0.0296)
200 ft	6,210 (0.0315)	9,450 (0.0479)	8,650 (0.0439)	11,670 (0.0592)
300 ft	9,310 (0.0472)	14,170 (0.0719)	12,970 (0.0653)	17,510 (0.0888)
500 ft	15,520 (0.0787)	23,620 (0.1198)	21,620 (0.1097)	29,180 (0.1481)
1,000 ft	31,040 (0.1575)	47,240 (0.2397)	43,250 (0.2194)	58,360 (0.2961)
2,500 ft	77,590 (0.3937)	118,090 (0.5992)	108,120 (0.5485)	145,910 (0.7403)
5,280 ft (1 MILE)	163,880 (0.8314)	249,410 (1.2654)	228,350 (1.1585)	308,150 (1.5634)
(2 MILES)	327,760 (1.6629)	498,830 (2.5308)	456,690 (2.3171)	616,310 (3.1269)
(3 MILES)	491,630 (2.4943)	748,240 (3.7963)	685,040 (3.4756)	924,460 (4.6903)
(5 MILES)	819,390 (4.1572)	1,247,070 (6.3271)	1,141,730 (5.7927)	1,540,770 (7.8172)
(10 MILES)	1,638,780 (8.3145)	2,494,140 (12.6542)	2,283,470 (11.5853)	3,081,540 (15.6344)

INTERPOLATION POSSIBLE

TABLE 6-VII. COST OF INSTALLED, INSULATED PIPELINE IN \$'S (MAINTENANCE COST, \$/HOUR) FOR PIPELINE CARRYING BRINE AT 160°-115°F

DISTANCE FROM SOURCE TO UTILIZATION SITE IN FEET OR MILES	6 INCH LINE		8 INCH LINE	
	ABOVE GROUND	BELOW GROUND	ABOVE GROUND	BELOW GROUND
100 ft	3,040 (0.0154)	4,640 (0.0235)	4,240 (0.0215)	5,730 (0.0291)
200 ft	6,090 (0.0309)	9,280 (0.0471)	8,480 (0.0430)	11,460 (0.0581)
300 ft	9,130 (0.0463)	13,920 (0.0706)	12,720 (0.0645)	17,190 (0.0872)
500 ft	15,220 (0.0772)	23,195 (0.1177)	21,200 (0.1076)	28,650 (0.1453)
1,000 ft	30,430 0.1544	46,390 (0.2354)	42,400 (0.2151)	57,290 (0.2907)
2,000 ft	76,080 (0.3860)	115,980 (0.5884)	106,000 (0.5378)	143,230 (0.7267)
5,280 ft (1 MILE)	160,670 (0.8152)	232,310 (1.1786)	223,860 (1.1358)	302,490 (1.5347)
(2 MILES)	321,340 (1.6303)	489,880 (2.4854)	447,720 (2.2716)	604,980 (3.0694)
(3 MILES)	482,010 (2.4455)	734,820 (3.7281)	671,580 (3.4073)	907,470 (4.6041)
(5 MILES)	803,350 (4.0759)	1,224,700 (6.2136)	1,119,310 (5.6789)	1,512,460 (7.6735)
(10 MILES)	1,606,700 (8.1517)	2,449,390 (12.4272)	2,238,610 (11.3578)	3,024,910 (15.3471)

INTERPOLATION POSSIBLE

TABLE 6-VIII. HEAT AVAILABLE IN THOUSAND (10^3) BTU/HOUR
(WITHOUT HEAT LOSSES)

Flow : 200,000 POUNDS/HOUR

TEMPERATURE AT WHICH FLUID ENTERS PIPELINE, °F	SPENT (USED) PIPELINE TEMPERATURE, °F				
	200	160	130	115	100
400	41,396	49,416	55,414	58,403	61,400
350	30,728	38,748	44,746	47,740	50,732
300	20,320	28,340	34,338	37,332	40,324
250	10,078	18,118	24,116	27,110	30,102
200	—	8,020	14,018	17,012	20,004
160	—	—	5,993	8,992	11,984
130	—	—	—	2,994	5,986
115	—	—	—	—	2,992

TABLE 6-IX. HEAT LOSSES IN THOUSAND (10^3) BTU/HOUR USING 2" INSULATION ON 6" PIPELINE

Flow: 200,000 POUNDS/HOUR

TEMPERATURE AT WHICH BRINE ENTERS PIPELINE, OF	DISTANCE FROM SOURCE TO UTILIZATION SITE ALONG PIPELINE ROUTE IN FEET OR (MILES)										
	100 ft	200 ft	300 ft	500 ft	1,000 ft	2500 ft	(1 MILE) 5,280 ft	(2 MILES)	(3 MILES)	(5 MILES)	(10 MILES)
400	12	25	37	62	125	311	657	1,302	1,944	3,208	6,255
350	10	21	31	51	103	257	542	1,075	1,607	2,649	5,171
300	8	16	24	40	81	202	427	847	1,264	3,088	4,083
250	6	12	19	31	62	155	327	655	970	1,602	3,136
200	4	9	13	22	43	108	227	455	682	1,115	2,184
160	3	6	9	15	30	75	158	316	473	773	1,515
130	2	4	6	10	20	50	105	210	316	526	1,014
115	1	3	4	7	15	37	79	157	236	393	763

INTERPOLATION POSSIBLE

TABLE 6-X. HEAT LOSSES IN THOUSAND (10^3) BTU/HOUR USING 2" INSULATION ON 8" PIPELINE

Flow: 200,000 POUNDS/HOUR

TEMPERATURE
AT WHICH BRINE
ENTERS PIPELINE,
OF

DISTANCE FROM SOURCE TO UTILIZATION SITE ALONG
PIPELINE ROUTE IN FEET OR (MILES)

	100 ft	200 ft	300 ft	500 ft	1,000 ft	2,500 ft	(1 MILE) 5,280 ft	(2 MILES)	(3 MILES)	(5 MILES)	(10 MILES)
400	15	31	46	77	154	385	813	1,606	2,375	3,943	7,641
350	13	25	38	63	127	317	670	1,325	1,976	3,254	6,315
300	10	20	30	50	100	250	527	1,043	1,555	2,563	4,984
250	8	15	23	38	77	191	404	809	1,194	1,969	3,931
200	5	11	16	27	53	133	281	563	844	1,371	2,672
160	4	7	11	19	37	93	196	392	588	955	1,861
130	3	5	7	12	25	62	131	263	394	657	1,252
115	2	4	6	9	19	47	99	198	296	494	943

INTERPOLATION POSSIBLE

TABLE 6-XI. WORKING SHEET

CASE: EXAMPLE DISCUSSED IN SECTION II.

THE BEN HOLT CO.	CAPITAL (INSTALLED) COST IN \$	OPERATING AND MAINTENANCE COST IN \$/OPERATING HOUR
WELLS		
PRODUCTION WELL (FROM FIGURE 1)	150,000	1.9026
DRY (PRODUCTION) WELL ALLOWANCE	25,000	—
INJECTION WELL (FROM FIGURE 1)	150,000	1.9026
FIELD LABOR	—	0.1957
TOTAL	325,000	4.0009
SURFACE INSTALLATION		
PUMP AND MOTOR (FROM FIG. 2 EQUIPMENT COST X 4)	66,000	0.3350
PUMP SETTING DEPTH COST ADDITION FROM TABLE 3	1,000	0.0051
SUB TOTAL	67,000	0.3401
PIPELINE (FROM TABLES 5 AND 7)		
SUPPLY (INSULATED)	958,440	4.8627
RETURN (COATED ONLY)	680,600	3.4531
SUB TOTAL	1,639,040	8.3158
TOTAL	1,706,040	8.6559
PUMPING POWER COST (FROM TABLE 2)		
SUPPLY		1.4000
UTILIZATION AND RETURN		1.1000
TOTAL		2.5000
TOTAL (OVERALL)	2,031,040	15.1568
COST OF HEAT DELIVERY IN \$/OPERATING HOUR (FROM FIGURE 4)	123.5	
HEAT IN BTU/OPERATING HOUR		
AVAILABLE (FROM TABLE 8)	28,340,000	
PIPELINE LOSSES (FROM TABLE 10)	1,555,000	
TOTAL HEAT DELIVERED IN BTU/OPERATING HOUR	26,785,000	
COST OF HEAT DELIVERED IN \$/BTU		
COST OF HEAT DELIVERY / TOTAL HEAT DELIVERED	123.5 ÷ 26,785 = \$	4.61/MILLION BTU

TABLE 6-XII. WORKING SHEET CASE 1

CASE 1 300°F BRINE 130°F RETURN 6" 500 FEET GALVANIZED PIPELINE, EITHER WAY (BUCKED) 2000 FEET WELL 300 FEET PUMP SETTING 100 FEET PUMP SETTING UTILIZATION NO ADDITIONAL INFORMATION FOR MINIMUM FIELD SUPERVISION			CAPITAL (INSTALLED) COST IN \$	OPERATING AND MAINTENANCE COST IN \$/OPERATING HOUR
WELLS				
PRODUCTION WELL			85,000	1.0781
DRY (PRODUCTION) WELL ALLOWANCE			14,200	—
INJECTION WELL			85,000	1.0781
FIELD LABOR				0.1957
TOTAL			184,200	2.3519
SURFACE INSTALLATION				
PUMP AND MOTOR (EQUIPMENT COST X 4)			75,200	0.3815
PUMP SETTING DEPTH COST ADDITION			1,500	0.0076
SUB TOTAL			76,700	0.3891
PIPELINE (6 INCHES IN DIAMETER)				
SUPPLY (INSULATED)			24,470	0.1241
RETURN (COATED ONLY)			17,400	0.0833
SUB TOTAL			41,870	0.2124
TOTAL			118,570	0.6015
PUMPING POWER COST				
SUPPLY				1.55
UTILIZATION AND RETURN				0.45
TOTAL				2.00
TOTAL (OVERALL)			302,770	4.7534
COST OF HEAT DELIVERY IN \$/OPERATING HOUR			19.8	
HEAT				
AVAILABLE			34,338.000	
PIPELINE LOSSES			40.000	
TOTAL HEAT DELIVERED IN BTU/OPERATING HOUR			34,298.000	
COST OF HEAT DELIVERED				

TABLE 6-XIII. WORKING SHEET CASE 2

CASE 2 200°F LINE 120°F RETURN 6"-2500ft GREENSAND PIPING, EITHER WAY (BURIED) 2500 FEET WELL 300 FEET PUMP SETTING 100 FEET CIRCUIT ELEVATION 100 FEET HEAD AT UTILIZATION NO ADDITIONAL INFLECTION HEAD MINIMUM FLOW 500 GPM			CAPITAL (INSTALLED) COST IN \$	OPERATING AND MAINTENANCE COST IN \$/OPERATING HOUR
WELLS				
Production well			85,000	1.0781
Dry (Production) well allowance			14,200	—
Injection well			85,000	1.0781
Field labor			—	0.1957
TOTAL			184,200	2.3519
SURFACE INSTALLATION				
Pump and motor (equipment cost x 4)			80,000	0.4060
Pump setting depth cost addition			1,500	0.0076
SUBTOTAL			81,500	0.4136
PIPELINE (6 INCHES IN DIAMETER)				
Supply (insulated)			122,330	0.6207
Return (coated only)			86,990	0.4413
SUBTOTAL			209,320	1.0620
TOTAL			290,820	1.4756
PUMPING POWER COST				
Supply				1.8
Utilization and return				0.6
TOTAL				2.400
TOTAL (OVERALL)			475,020	6.2275
COST OF HEAT DELIVERY IN \$/OPERATING HOUR			31.0	
HEAT				
AVAILABLE			34,338,000	
PIPELINE LOSSES			202,000	
TOTAL HEAT DELIVERED IN BTU/OPERATING HOUR			34,136,000	
COST OF HEAT DELIVERED				
COST OF HEAT DELIVERY/TOTAL HEAT DELIVERED			$31 \div 34.136 = \$0.91/\text{million BTU}$	

TABLE 6-XIV. WORKING SHEET CASE 3

CASE 3 300°F IRINE
120°F RETURN
8" INCH CARBON STEEL PIPELINE, EITHER WAY (BURIED)
2000 FEET WELL
200 FEET PUMP SETTING
100 FEET GROUND ELEVATION
100 FEET HEAD AT UTILIZATION
NO ADDITIONAL INTERMEDIATE HEADS
MINIMUM FLOW 200 GPM

	CAPITAL (INSTALLED) COST IN \$	OPERATING AND MAINTENANCE COST IN \$/OPERATING HOUR
WELLS		
PRODUCTION WELL	85.000	1.0731
DRY (PRODUCTION) WELL ALLOWANCE	14.200	—
INJECTION WELL	85.000	1.0781
FIELD LABOR	—	0.1957
TOTAL	184.200	2.3519
SURFACE INSTALLATION		
PUMP AND MOTOR (EQUIPMENT COST x 4)	76.000	0.3860
PUMP SETTING DEPTH COST ADDITION	1.500	0.0076
SUB TOTAL	77.500	0.3936
PIPELINE (8 INCHES IN DIAMETER)		
SUPPLY (INSULATED)	319.480	1.6209
RETURN (COATED ONLY)	226.870	1.1510
SUB TOTAL	546.350	2.7719
TOTAL	623.850	3.1655
PUMPING POWER COST		
SUPPLY		1.6
UTILIZATION AND RETURN		0.5
TOTAL		2.1000
TOTAL (OVERALL)	908.050	7.6174
COST OF HEAT DELIVERY IN \$/OPERATING HOUR	50.0	
HEAT		
AVAILABLE	34.338.000	
PIPELINE LOSSES	527.000	
TOTAL HEAT DELIVERED IN BTU/OPERATING HOUR	33.811.000	
COST OF HEAT DELIVERED		
COST OF HEAT DELIVERY / TOTAL HEAT DELIVERED	$50 \div 33.811 = \$1.49/\text{MBTU}$	

TABLE 6-XV. WORKING SHEET CASE 4

CASE 4 170°F BRINE
115°F RETURN
6" - 500 FEET CARBON STEEL PIPELINE, EITHER WAY
(BURIED)
500 FEET WELL
100 FEET PUMP SETTING
NO GROUND ELEVATION
100 FEET HEAD AT UTILIZATION SITE
NO ADDITIONAL INJECTION HEAD
MINIMUM FIELD SUPERVISION

CAPITAL
(INSTALLED) COST
IN \$

OPERATING AND
MAINTENANCE COST
IN \$/OPERATING HOUR

WELLS		
Production well	20,000	0.2537
Dry (Production) well allowance	3,300	—
Injection well	20,000	0.2537
Field labor	—	0.1957
TOTAL	43,300	0.7021
SURFACE INSTALLATION		
Pump and motor (equipment cost x 4)	33,600	0.1705
Pump setting depth cost addition	500	0.0025
SUB TOTAL	34,100	0.1730
PIPELINE (6 INCHES IN DIAMETER)		
SUPPLY (INSULATED)	23,410	0.1188
RETURN (COATED ONLY)	17,400	0.0883
SUB TOTAL	40,810	0.2071
TOTAL	74,910	0.3801
PUMPING POWER COST		
SUPPLY		0.45
UTILIZATION AND RETURN		0.45
TOTAL		0.90
TOTAL (OVERALL)	119,210	1.9932
COST OF HEAT DELIVERY IN \$/OPERATING HOUR	7.2	
HEAT		
AVAILABLE	13,902,000	
PIPELINE LOSSES	18,500	
TOTAL HEAT DELIVERED IN BTU/OPERATING HOUR	12,983,500	
COST OF HEAT DELIVERED		
COST OF HEAT DELIVERY/TOTAL HEAT DELIVERED	$7.2 \div 12.9835 = \$0.55/\text{million BTU}$	

TABLE 6-XVI. WORKING SHEET CASE 5

CASE 5

180°F ZIRK
115°F RETURN
6"-2500 feet CAPEN STEEL PIPELINE, EITHER WEGY.
(BURIED)
500 FEET WELL
100 FEET PUMP SETTING
NO GEOPOND ELEVATION
100% LIT. W. AT UTILIZATION SITE
NO ADDITIONAL INJECTION NEED
MINIMUM FIELD CREATION

CAPITAL
(INSTALLED) COST
IN \$

OPERATING AND
MAINTENANCE COST
IN \$/OPERATING HOUR

		CAPITAL (INSTALLED) COST IN \$	OPERATING AND MAINTENANCE COST IN \$/OPERATING HOUR
WELLS			
Production well		20,000	0.2537
Dry (Production) well allowance		3,300	—
Injection well		20,000	0.2537
Field labor		—	0.1957
TOTAL		43,300	0.7031
SURFACE INSTALLATION			
Pump and motor (EQUIPMENT COST X 4)		38,000	0.1928
Pump setting depth cost addition		500	0.0025
SUB TOTAL		38,500	0.1953
PIPELINE (6 INCHES IN DIAMETER)			
Supply (INSULATED)		117,040	0.5938
Return (COATED ONLY)		86,990	0.4413
SUB TOTAL		204,030	1.0351
TOTAL		242,530	1.2304
PUMPING POWER COST			
Supply			0.65
Utilization and return			0.65
TOTAL			1.30
TOTAL (OVERALL)		285,330	3.2335
COST OF HEAT DELIVERY IN \$/OPERATING HOUR		16.6	
HEAT			
Available		13,902,000	
Pipeline losses		91,500	
TOTAL HEAT DELIVERED IN BTU/OPERATING HOUR		12,910,500	
COST OF HEAT DELIVERED			
COST OF HEAT DELIVERY / TOTAL HEAT DELIVERED		12,910,500	41.79 / BTU

TABLE 6-XVII. WORKING SHEET CASE 6

CASE 6. 180°F FINE
115°F RETURN

8" - 1 MILE CARBON STEEL PIPE, EITHER WAY (BURIED)

500 FT WELL
100 FEET PUMP SETTING
NO GROUND ELEVATION
100 FT HEAD AT UTILIZATION
NO ADDITIONAL INFECTION HEAD
MINIMUM FIELD SUPERVISION

CAPITAL
(INSTALLED) COST
IN \$

OPERATING AND
MAINTENANCE COST
IN \$/OPERATING HOUR

WELLS		
PRODUCTION WELL	20,000	0.2537
DRY (PRODUCTION) WELL ALLOWANCE	3,300	—
INFECTION WELL	20,000	0.2537
FIELD LABOR	—	0.1957
TOTAL	43,300	0.7031
SURFACE INSTALLATION		
PUMP AND MOTOR (EQUIPMENT COST x 4)	34,300	0.1766
PUMP SETTING DEPTH COST ADDITION	500	0.0025
	35,300	0.1791
SUB TOTAL		
PIPELINE (8 INCHES IN DIAMETER)		
SUPPLY (INSULATED)	305,320	1.5491
RETURN (COATED ONLY)	226,870	1.1510
SUB TOTAL	532,190	2.7001
TOTAL	567,490	2.8792
PUMPING POWER COST		
SUPPLY		0.5
UTILIZATION AND RETURN		0.5
TOTAL		1.0
TOTAL (OVERALL)	610,790	4.5823
COST OF HEAT DELIVERY IN \$/OPERATING HOUR	35.5	
HEAT		
AVAILABLE	13,002,000	
PIPELINE LOSSES	239,000	
TOTAL HEAT DELIVERED IN BTU/OPERATING HOUR	12,763,000	
COST OF HEAT DELIVERED		

TABLE 6-XVIII. COST OF HEAT DELIVERED AND EQUIVALENT COST OF A BARREL OF FUEL OIL AS A FUNCTION OF DISTANCE FROM SOURCE TO UTILIZATION SITE AND A LIST OF TYPICAL CONDITIONS

	DISTANCE FROM SOURCE TO UTILIZATION SITE		
	500 feet	2,500 feet	(1 MILE) 5,280 feet
200,000 POUNDS/HOUR 300°F BRINE 130°F RETURN 2,000 FEET WELL 300 FEET PUMP SETTING 100 FEET GROUND ELEVATION	CASE 1 \$ 0.58/10 ⁶ BTU \$ 3.6/BARREL	CASE 2 \$ 0.91/10 ⁶ BTU \$ 5.6/BARREL	CASE 3 \$ 1.43/10 ⁶ BTU \$ 9.2/BARREL
200,000 POUNDS/HOUR 180°F BRINE 115°F RETURN 500 FEET WELL 100 FEET PUMP SETTING NO GROUND ELEVATION	CASE 4 \$ 0.55/10 ⁶ BTU \$ 3.4/BARREL	CASE 5 \$ 1.29/10 ⁶ BTU \$ 8.0/BARREL	CASE 6 \$ 2.78/10 ⁶ BTU \$ 17.2/BARREL

TABLE 6-XIX. MINIMUM CAPITAL COST CASE - ASBESTOS CEMENT PIPELINE

MINIMUM CAPITAL COST CASE - ASBESTOS CEMENT PIPELINE - 60 GPM - 29,000 POUNDS/HOUR

200°F EXHIST 120°F RETURN 3" ASBESTOS CEMENT PIPELINE, ONE WAY (BURIED) 300 FEET WELL 100 FEET PUMP SETTING NO GROUND ELEVATION 154 FEET WELL AT UTILIZATION SITE NO INTERFLOWS NO FIELD SUPERVISION	CAPITAL (INSTALLED) COST IN \$	OPERATING AND MAINTENANCE COST IN \$/OPERATING HOUR
WELLS		
PRODUCTION WELL	10,500	0.1332
DRY (PRODUCTION) WELL ALLOWANCE	—	—
INJECTION WELL	—	—
FIELD LABOR	—	—
TOTAL	10,500	0.1332
SURFACE INSTALLATION		
PUMP AND MOTOR (EQUIPMENT COST X 4)	18,000	0.0913
PUMP SETTING DEPTH COST ADDITION	500	0.0025
SUB TOTAL	18,500	0.0939
PIPELINE (3 INCHES IN DIAMETER)		
SUPPLY (INSULATED)	12,500	0.0634
RETURN (COATED ONLY)	—	—
SUB TOTAL	12,500	0.0634
TOTAL	31,000	0.1573
PUMPING POWER COST		
SUPPLY		0.0639
UTILIZATION AND RETURN		0.0293
TOTAL		0.0926
TOTAL (OVERALL)	41,500	0.3831
COST OF HEAT DELIVERY IN \$/OPERATING HOUR	2.15	
HEAT		
AVAILABLE	2,317,000	
PIPELINE LOSSES	18,200	
TOTAL HEAT DELIVERED IN BTU/OPERATING HOUR	2,298,800	
COST OF HEAT DELIVERED		
COST OF HEAT DELIVERY/TOTAL HEAT DELIVERED	$2.15 \div 2.2988(10^6) = \$0.94/\text{MILLION BTU}$	

TABLE 6-XX. MINIMUM CAPITAL COST CASE - CARBON STEEL PIPELINE

MINIMUM CAPITAL COST CASE - CARBON STEEL PIPELINE - 415 GPM - 200,000 POUNDS/HOUR

200°F BRINE

120°F RETURN

6" - 500 FEET CARBON STEEL PIPELINE, ONE WAY (BURIED)

300 FEET WELL

100 FEET PUMP SETTING

NO GROUND ELEVATION

154 FEET HEAD AT UTILIZATION SITE

NO INJECTION

NO FIELD SUPERVISION

	CAPITAL (INSTALLED) COST IN \$	OPERATING AND MAINTENANCE COST IN \$/OPERATING HOUR
WELLS		
PRODUCTION WELL	10,500	0.1332
DRY (PRODUCTION) WELL ALLOWANCE	—	—
INJECTION WELL	—	—
FIELD LABOR	—	—
TOTAL	10,500	0.1332
SURFACE INSTALLATION		
PUMP AND MOTOR (EQUIPMENT COST X 4)	30,200	0.1530
PUMP SETTING DEPTH COST ADDITION	500	0.0025
SUB TOTAL	30,700	0.1555
PIPELINE (6 INCHES IN DIAMETER)		
SUPPLY (INSULATED)	23,620	0.1198
RETURN (COATED ONLY)	—	—
SUB TOTAL	23,620	0.1198
TOTAL	54,320	0.2753
PUMPING POWER COST		
SUPPLY + 20 PSI AT UTILIZATION		0.5900
UTILIZATION AND RETURN		—
TOTAL		0.5900
TOTAL (OVERALL)	64,320	0.9985
COST OF HEAT DELIVERY IN \$/OPERATING HOUR	3.9	
HEAT		
AVAILABLE	16,014,000	
PIPELINE LOSSES	22,000	
TOTAL HEAT DELIVERED IN BTU/OPERATING HOUR	15,992,000	
COST OF HEAT DELIVERED		
COST OF HEAT DELIVERY / TOTAL HEAT DELIVERED	$3.9 \div 15.992(10^6) = \$0.24/\text{million BTU}$	

TABLE 6-XXI. TYPICAL WORKSHEET

	CAPITAL (INSTALLED) COST IN \$	OPERATING AND MAINTENANCE COST IN \$/OPERATING HOUR
WELLS PRODUCTION WELL DRY (PRODUCTION) WELL ALLOWANCE INJECTION WELL FIELD LABOR TOTAL		
SURFACE INSTALLATION PUMP AND MOTOR (EQUIPMENT COST x 4) PUMP SETTING DEPTH COST ADDITION SUB TOTAL PIPELINE SUPPLY (INSULATED) RETURN (COATED ONLY) SUB TOTAL TOTAL		
PUMPING POWER COST SUPPLY UTILIZATION AND RETURN TOTAL		
TOTAL (OVERALL)		
COST OF HEAT DELIVERY IN \$/OPERATING HOUR		
HEAT AVAILABLE PIPELINE LOSSES TOTAL HEAT DELIVERED IN BTU/OPERATING HOUR		
COST OF HEAT DELIVERED IN \$/BTU COST OF HEAT DELIVERY / TOTAL HEAT DELIVERED		

SECTION SEVEN

SUMMARY AND RECOMMENDATIONS

Specific conclusions have been drawn and presented in Sections Two, Three, Four and Five for the various tasks.

The geotechnical assessment of the six sites shows that the opportunities for geoheat applications occur in practically all of the sites. However, site-constraints, such as lack of flat land in The Geysers steam field or limitation of transportation costs, limit the number of actual sites that can be developed for nonelectric agro-industrial uses. A number of areas near existing wells or hot springs have a proven potential for low-grade heat applications. Any near-term development would be directed to those sites first. Geotechnical exploration in areas where no hot springs exist and where no wells have been drilled will increase the number of sites where nonelectrical applications are feasible. Broad regions, where such exploration is likely to be fruitful, have been identified in this study.

It is a matter of policy for ERDA and county officials to decide whether geotechnical exploration on a lower scale than that practiced by the geothermal energy development companies, for achieving a more limited objective of discovering additional moderate-grade geothermal heat at a shallow depth, is to be pursued. The alternative is to seek fallout information from the activities of the geothermal steam companies, after the latter have carried out their work. That information could then be employed for planning of new nonelectric projects. The difference between the two approaches would be that of speed of development of nonelectric applications.

The agribusiness section of this study phase was based on evaluation of the problems of Lake County within the context of the agricultural economy of the region. Some examples of direct heat applications have been worked out, showing how they affect costs of production. The worked out example revolves around the utilization of steam and hot water at one specific site.

Ecological-environmental investigations of all six sites have been carried out. Potential environmental hazards have been evaluated, in the context of specific environments within

the county. The environmental studies provide background data for each of the sites and discuss the potential problems that must be considered in any large scale development of geothermal energy.

The socioeconomic section described the social and economic milieu in which geothermal development is taking place in Lake County. Any geothermal development program which alleviates or addresses the dominant issues, concerns and problems of the county and its residents--such as the persistent unemployment, pollution of Clear Lake waters, and exploitation of the natural resources of the area--must be given consideration. The geothermal development issue is a highly politicized one, because it touches on the daily lives of most of the residents of the region from here on.

The engineering phase of this study provides preliminary estimates of the cost of heat delivered to a utilization site from geothermal wells. Parametric engineering considerations have been given, which indicate the range of conditions under which transport of geothermal water for nonelectric uses is going to be economical. It shows that heat can be delivered economically, provided that the distance between the geothermal wells and the utilization site is small. The larger the distance, the greater the amount of hot brine that must be conducted, for cost of delivery to be kept reasonably low. Hence, best uses of geothermal heat in Lake County would be for those agro-industrial enterprises than can locate themselves within a few hundred meters (several hundred yards) of the producing wells. Detailed cost calculations including cost of wells drilled specifically for geoheat applications, surface installations and pumping costs are included, to provide estimates for the cost of delivered heat. These calculations show that with proper engineering, geothermal heat can be provided at a plant site with a very substantial cost saving, as compared to costs of energy from other sources.

Many different criteria may be employed in ranking different potential projects or investment opportunities in nonelectric applications of geothermal energy. In general terms, factors which will affect ranking of different projects include:

- 1) Factors which will materially benefit the largest number of inhabitants in the shortest possible time.
- 2) Factors which will increase profitable employment opportunities.

- 3) Activities which will generate additional taxable income.

Specifically, for Lake County these criteria for determination of direct heat applications might be augmented by:

- 4) Improving any aspect of producing or marketing agricultural products, thereby yielding a higher revenue to the agricultural economy of the county.
- 5) Assisting in the development of tourism.
- 6) Developing new industries which require low cost energy, which will help to alleviate the unemployment problem.

General economic factors, such as the effect of shortage of employment opportunities on quality of life, have not been investigated.

7.1 Recommended Prefeasibility and Feasibility Studies Related to Construction of Facilities for Nonelectric Applications of Geothermal Resource Utilization

Reference should be made to Section Three, Task Two, which provides an entire range of applications. Moreover, suggestions have been made throughout this report regarding areas where feasibility studies are necessary. In general, the studies suggested are classified according to the following categories:

- 1) Agribusiness Applications: Production of fish, poultry, hogs and agricultural products, including closed systems of feed growing and processing, livestock raising and meat processing. Problems of timing, marketing and transportation would be considered.
- 2) Agricultural Applications: Greenhouses. Growing of cut flowers and bulbs, fruits, and off-season vegetables. The feasibility study would have to include consideration of transportation and marketing needs, optimal utilization of the fluids and access to metropolitan centers.
- 3) Agro-industrial Processes: Include dehydration of vegetables, operation of a fertilizer and cattle-feed production plant, canning operations.

- 4) Special Application: Clear Lake algae harvesting and processing for protein for human and animal consumption.
- 5) Industrial Processes: What plans may be made for new industries which could be directed to the vicinity of the geothermal development. What industries use water at temperature levels of waste water from the geothermal plant.
- 6) Tourism: Facilities for tourism compatible with the type of tourist facilities involving therapeutic hot baths, viability and feasibility of construction of such facilities, costs and proposed development schedules (reference to Section Five, Task Four, above).
- 7) Detailed feasibility study of a particular application required to establish the distance to which geothermal heat may be transported for any nonelectric application. The cost of heat transmission depends upon the original temperature, the distance of transmission and the volume of fluid transmitted (reference to Section Six, Task Five, above).
- 8) Feasibility Study of a Geothermal-integrated Energy Park: An integrated multipurpose complex is envisioned, whereby a series of agricultural, industrial and service facility operations are constructed, so that discrete plateaus of successively lower grade heat are utilized in an integrated complex.

It is apparent that direct heat application projects produce comparatively small amounts of revenue for the steam supplier, and thus have not been included in any large scale development plans. It is equally apparent that these projects are considered to have direct benefit to the residents of the county. In contrast, electric power generation utilizing the geothermal resource is viewed by some as exploitation of another county resource which is exported for outside consumption, with little or no tangible benefits to the majority of residents and with a perceived threat of destroying certain aspects of the quality of life and environment.

Operators and developers have to pay for a continuing series of environmental reports which satisfy legal requirements. Although these EIRs do address various problems and aspects of development, those problems are dealt with in a

highly generalized manner. This is due to the numerous variables in the physical, chemical, biological and sociological environments which the report must consider. The nonelectric applications have been mentioned in a cursory manner in most such reports, but not examined in any depth.

The consideration of the funding for Phase One and Phase Two of the project has evolved in the course of the project, as a potential outcome of the the entire Phase Zero portion (see Figure 7.1). The following four sites have been identified in the course of Phase Zero:

- 1) High Valley Creek Area, site of the McCulloch Oil Corporation, Franciscan Well No. One, in Site No. 4.
- 2) Ford Flat Area, part of the Colloyomi Valley - Middletown Area in Site No. 4, adjacent to Aminoil's well, near the Pacific Gas and Electric Company's Unit 13 supply field.
- 3) City of Calistoga, Alternate Site No. 5.
- 4) A fourth site could be the subject of a feasibility study for the waste heat utilization of Pacific Gas and Electric's Power Plant #16. This unit is the second power plant scheduled for construction in Lake County; the plant with a capacity of 110 MW is planned to be operational by 1981.

We have submitted estimates and breakdown of the tasks for Phase One and Phase Two of the proposed followup project, as shown on the project work schedules below. The Calistoga site, Site No. 5, is a likely target for development. We recommend two sites in Lake County for immediate followup studies. Thus the projected Phase One and Phase Two work schedules are the development of applications on three sites, two in Lake County and one alternate site. The estimated amount for Phase One is \$395,000, which includes a budget for resource evaluation and some temperature gradient drilling. The estimated amount for Phase Two is \$1,535,000, which includes temperature gradient drilling and construction of facilities. The estimated work schedules also display the projected time frame for completion of the projects. Detailed cost estimates for the next phases will be submitted after the review of the final report.

Experience with other power plant siting suggests the advisability of assessing the concerns of the community based on a broad spectrum of interest in the early stages of development, in order to minimize dissatisfaction with development

in later stages. Continuing support by ERDA of the current project is not a panacea for unobstructed development. It is, however, a demonstration that a federal agency is willing to consider favorably certain projects which are beneficial to the communities and is willing to take some initiative with regard to concerns of local residents in developing the resource. By these measures the purely economic motive of development and the effect of regional needs overshadowing local needs are perceived to be mitigated.

Continuation of the project with the momentum of Phase Zero would greatly add to ERDA's stated goal of actualization of "near-term commercialization" projects. The realization of a major development in the area of direct heat applications for the county could be accomplished within the projected time constraints of 24 months (see Figures 7.3 and 7.4).

The recommendations are for a combination of agricultural and industrial studies which would be evaluated by detailed feasibility studies for:

- 1) utilization of the existing hydrothermal well sites in Lake County, California, which are not targeted for electric power production.
- 2) developing a diversified agricultural industry in Lake County which would provide a steady cash flow of income and expenditure by the industry and residents;
- 3) assessing the reduction of the county's high unemployment rates, which would relieve the social burden on county government, and increase county tax revenues;
- 4) assessing utilization of exhaust heat of geothermal power plants, perhaps for Unit No. 16, 110 MW unit to be operational in Lake County by 1981.
- 5) Assessing, in detail, ecological/environmental impacts of any large scale agribusiness development.

It would be of great importance for Lake County to extend the income producing seasons, thereby alleviating the chronic peaking-troughing labor unemployment which is associated with the relatively short agricultural and tourist seasons at present. Environmental improvement (such as elimination of pollution of Clear Lake) would improve the attraction of Clear Lake and concomittantly public acceptance of geothermal resource development.

These studies could well lead to one or more significant developments:

- 1) Harnessing potential-pollution elements such as hot water, steam, sulfur and other minerals to produce a clean, controlled-environmental-growth complex that utilizes some or all of those components.
- 2) Establishing demonstration centers for agricultural utilization of geothermal resources.
- 3) Developing a functional hydrothermal farm community, recreation and park area which would serve the dense population areas of Sacramento and the San Francisco Bay in a small way.
- 4) Producing a prototype "farming of the future" center which could be used for advanced experiments in food production.
- 5) Waste and sewage treatment: The problem of waste and sewage disposal cannot be readily solved without some novel, economical approach. The growing pollution of Clear Lake has already resulted in economic losses to the county (reduction in tourism to resorts surrounding the lake). Utilization of low-cost, low-enthalpy geothermal heat energy may turn out to be an economical method of sewage treatment that could result in environmental improvement. A preliminary examination of that possibility is recommended.

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Figure 7.1 General Project Plan - Lake County Project

Figure 7.2 Work Schedule - Lake County Project

Figure 7.3

GENERAL PROJECT PLAN - NON-ELECTRIC APPLICATIONS
CLEAR LAKE/GEYSERS AREA

CONTRACT NO.: EG-77-03-1326

PHASE 1

ESTIMATED
DOLLAR
AMOUNT