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DIRECT HEAT APPLICATIONS OF GEOTHERMAL ENERGY IN THE GEYSERS/CLEAR LAKE REGION: GEOTECHNICAL, ENVIRONMENTAL,SOCIOECONOMIC, AND ENGINEERING ASSESSMENTS AND AGRIBUSINESS APPLICATIONS

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The combined geotechnical, environmental, socioeconomic impact, and engineering study was undertaken to identify the different uses to which geothermal heat and fluids could be applied as a direct utilizations of resources or as heat utilization. The primary research objective was to determine optimal direct heat utilizations for agricultural and industrial uses, to determine optimal benefits, and to recommend the feasibility studies for the next phase of development and construction of facilities.

Optimal utilization of the resource for non-electric uses is determined by a multiplicity of interactive factors. 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. Environmental factors may militate against some development plans while favoring others. A still different consideration --needs of the local population--may tend to favor some agricultural or industrial processes while relegating others to a lower level of acceptance.

Six geothermal sites were identified in the Geyser/Clear Lake KGRA, four of which are located in Lake County, one in Sonoma County and one in Napa County. 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/Geysers, Sonoma Co.

The project was divided into five major tasks, each with the following rationales and research objectives:

o 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. This task was carried out by Geonomics.

o Agricultural and Industrial Applications: Assessment of the optimum agricultural enterprises (environmentally controlled growth or processing) which would be suitable at each of the four identified sites in Lake County. Low-enthalpy geothermal fluids from either exhaust of geothermal power plants or from low-base-temperature wells in the area are considered for a variety of agricultural and agribusiness processes. This task was carried out by Ag-West with Richard Matherson as task consultant.

o 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 for each of the six sites. This task was carried out by EcoView.

o 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 Co.

o Socioeconomic Assessment: Assessment of socioeconomic impact of development including social and economic profiles of Lake County, sources of revenues, plus principal problems in the social, economic, and political milieu unique to the area. This task was carried out by Geonomics.

The developed portion of the Geysers geothermal field is in Sonoma County, bordering Lake County (see Figure 1). It is likely that the high-quality, vapor-dominated reservoir extends into Lake County. Manisfestations 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 born the brunt of the undesirable air and noise pollution. On the other hand, 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, with appropriate regulation.

Lake County's resources have been largely 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 limited economic and employment opportunities. Non electric applications are commonly perceived as more directly beneficial to the residents.

GEOTECHNICAL ASSESSMENT

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.

Only limited geochemical or geophysical data have 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 are now available for setting up a geologic model. Here, the reservoir exists primarily within the greywackes the Franciscan Formation. Northward of the Collayomi fault the limited data at hand suggest that the reservoir apparently changes from the vapor-dominated type to the liquid-dominated type, within the younger volcanics present to the northeast. 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, manisfestations of the reservoir exist. However, due to self-sealing or other factors, such manisfestations are more often absent than present.

Several published geophysical studies have been conducted relating to regions of geothermal potential extending into Lake County. Taken together, they define a fairly consistent picture of a deep magma source beneath Mt. Hannah, where the near surface volcanic and thermal manisfestations tend to be centered. 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, follow by geoelectric, passive seismic techniques, and the drilling of temperature gradient and heat flow holes. The results of these published studies are presented in the report.

Wells drilled for various purposes which upon completion show the presence of thermal waters, may be used for nonelectric purposes, depending upon the applicability of the water to the specific use. Criteria needed to establish whether thermal waters are 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 constitutents 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.

Figure 1 presents a tentative classification of geothermal reservoirs in The Geysers/Clear Lake region for nonelectric uses. We have subdivided the region into four categories:

(1) an area where dry steam has already been encountered;

(2) an area where dry steam is likely to be encountered;

(3) areas where warm water of interest to nonelectric applications is likely to be encountered at shallow depth; and

(4) areas where warm water will probably be encountered at shallow dept, but present data at out disposal are not as conclusive as the data in the area designated as Likely Warm Water Reservoir.

AGRICULTURAL, AGRIBUSINESS, AND INDUSTRIAL APPLICATIONS AND ENVIRONMENTAL ASSESSMENT

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. Major factors affecting agriculture in Lake County are:

(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 poor highway transportation systems for trucks, and no railroad or commercial air freight service.

(e) Other than low-cost energy sources, Lake County lacks commercial agribusiness to attract industry.

(f) The county has limited amount of good soil

for farming and not much level land.

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

The Sulphur Bank Mine area once supported a cattle breeding ranch, and almond and walnut orchards. Some elements of each remain on a small scale. The mine itself is a large surface excavation covering some 50 acres. The most likely applications of geothermal energy in this area are: (a) local utility district for municipal operations, including electric power generation, space heating and cooling for homes and businesses, sewage and solid waste disposal, water supply treatment facility; (b) agribusiness operations, including greenhouse operations of vegetables and cut flowers, algae growing, harvesting, and processing, mushroom growing, aquaculture, and livestock feed production; (c) commercial operations, including lumber processing and curing, dehydration, cryogenic, pharmaceutical, and specialized food processing. Environmental factors to be considered are: aesthetics of the area, water quality maintenance and transportation planning to avoid congestion.

The High Valley area is a small valley, partially wind protected and subject to some frost in winter and early spring. The closest community is Clear Lake Oaks. The access road to High Valley is narrow, with a steep grade for trucks. The valley is generally under private ownership, primarily by livestock ranchers. When low cost geothermal energy is available, this area could be utilized for controlled environmental livestock and poultry operations. Potential also exsits for small green house operations.

The Borax Lake Area is close to one of the denser population concentrations surrounding Clear Lake. The towns of Clear Lake Park and ClearLake Highlands provide an opportunity to apply municipal space heating and cooling for its citizens as well as a potential for agribusiness, and industrial processing. Environmentally acceptable applications are: a utility district to generate and distribute electricity for local use; agribusiness operations particularly livestock feed,cut flowers, mushroom nursery stock, or food processing; poultry or livestock feeding coupled with shrimp or fish production, provided these are remote from recreational and residential areas.

Site No. 2, Thurston Lake/Mt. Konocti Area

The Thurstone Lake/Mt. Konocti area is of lessor importance for agricultural use as compared to other site locations. The trend of semi-rural and residential development in this area is likely to continue. Big Valley is largely alluvium, relatively flat or gently rolling hills, with rich soils. This is the largest single block of agricultural soils in the county. Pears, walnuts, some grapes, and irrigated pasture are the principal crops. The area between Mt. Konocti and Thrustone Lake supports some walnut orchards; but most land use is devoted to open space, cattle ranching and retirement dwellings. Several large lakeside resorts have been built near Mt. Konocti.

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 is fairly adequate for orchards, vineyards, and greenhouses. This valley has the potential of developing surface storage facilities for the runoff water from the Putah Creek watershed, just north of the valley. Availability of adequate fresh water in sufficient quantities is critical to major agricultural development complex. The area is the closest area in Lake County to the San Francisco/Bay Area market.

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

An area in High Valley Creek was selected as the most likely site for near-term development of demonstration complexes for nonelectrical uses. A general plan for an agriculturally-oriented enterprise 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 Corp. in developing a nonelectric geothermal demonstration center were also factors in selection of this site. Moreover, maximum daylight hours prevail in this area, an essential component of greenhouse or plant-type operations.

Alternative Site No. 5, City of Calistoga, Napa County

The City of Calistoga has experienced a severe water shortage since June 1976; various conservation measures have been enforced since that time. Calistoga's reservoirs and wells were at or near capacity during the high rainfall years of 1974 and 1975. Currently, geothermal water is being purified to minimum potable standards for human consumption to supplement the dwindling reservoir supplies.

The agricultural base is principally wine grapes of high quality. Several wineries are located in the immediate vicinity. Irrigation is not generally practiced on a large scale, but water is used to establish young grape vines and for vineyard frost protection. Much of the natural underground water sources contain levels boron well above the tolerance limits of grapes; hence, water holding ponds dot the valley to store run-off water from creeks. Undeveloped land zoned for commercial and industrial uses within the City of Calistoga appears to be sufficient to build and operate small processing applications.

Alternative Site No. 6, The Geysers Geothermal Field

The Geysers geothermal field is centerd along the Big Sulphur Creek Drainage System. It is a mountainous area with steep slopes, many of which are unstable. Landslides are common. Soils are generally rocky and this. Vegetation is largely brushland with many forests and grasslands. A few scattered residences are present along the river; but the region as a whole is open space with geothermal development superimposed. Because the terrain is so rough, the opportunity for non-electric uses will be largely limited to abandoned drill pads which may have supported one or two wells proven unproductive for electric power generation. Accessibility to the area is difficult.

The agricultral processes that are applicable to these areas and that lend themselves to the use of low-cost geothermal heat are analyzed in the report. These are:

(1) algae harvesting from Clear Lake recreational area

(2) development of an integrated agribusiness geothermal complex in Lake County; this complex is divided into three groups of potential applications:

a. power plant and distribution unit
b. agro-industrial units, including meat processing, lumber drying, grain drying, feedmill, greenhouse production of cut flowers, vegetables and sprout-grass feed, mushroom production facility, livestock and poultry facilities, hog farrowing, fish raising facility
c. demonstration-educational center and office

ENGINEERING ASSESSMENT: COST OF GEOTHERMAL HEAT DELIVERED AT A UTILIZATION SITE

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. A method is presented 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. An outline of each of the steps in the procedure is presented. An example is worked using a standard worksheet. A justification is made of the procedure. The results obtained by applying the method in six typical cases and two minimum capital cost cases are discussed.

The cost estimating procedure is divided into three components: the estimate of cost of heat delivery; the estimate of total heat delivered; and the estimate of the cost of heat delivered. The cost of heat delivery is a function of total capital cost and total operating and maintenance cost. The costs of installing (capital cost) and operating the heat delivery facility, consisting of wells, pump, and pipeline, have been grouped into three compnents: wells, surface installation, and pumping power costs:

(a) 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.

(b) Surface Installation: the surface installation capital cost is the sum of the pump and motor, and pipeline costs.

(c) Pumping Power Cost: The total pumping power cost is the sum of the power costs resulting from supplying, utilizing, returning, and injecting the brine.

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 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.

The results tabulated from six typical cases 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 conditions of the brine, wells, and pipeline, this distance might increase or decrease. 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] or larger) would be competitive with the present day cost of fuel.

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 of 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.

SOCIOECONOMIC IMPACT ASSESSMENT

The objectives of this task 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. These direct heat applications should be compatible with values of residents, with present life styles, social behavior and goals prevalent in the county, compatible with the economic demands placed upon county resources, and with energy needs of the county as well as, within a broader socioeconomic context, with the energy requirements of the state and country.

The primary focus of the profiles and analysis is Lake County. The report includes:

(1) demographic characteristics, including age, sex, race, ethnicity, and minority character-

istics, geographic distribution of the population, past and current population trends, and an educational and occupational profile of the county;

(2) economic condition and perspective of Lake County;

(3) economic impact of geothermal development on selected sectors, including the technical labor force; beneficial impact on county tax revenues and tax base, and on major beneficiaries such as landowners in the county and Pacific Gas & Electric Co.;

(4) economic sectors and community groups identified for or against development;

(5) Socioeconomic impact of nonelectric uses, and the spectra of manpower requirements;

(6) Identification of the most desirable direct heat applications for Lake County based on selected interviews.

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

Coupled with the 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 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. The county's population increased 42% for the period 1960 to 1970, representing a very high growth rate.

Direct applications for industrial and agricultural purposes are 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. The focus is on temperatures, volumes, competitive costing of other forms of energy, etc. Notwithstanding the critical nature of these parameters is to be recognized, the projects for the most part, 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 facilities, is one of the most significant factors for the local population and economy.

The assessed valuation of a direct heat use facility is likely to be small compared to an electric power generating plant, with tax benefits to the county of a smaller scale. On the other hand, many direct heat applications are labor intensive and would provide local employment opportunities. The range of skills in manpower requirements are quite different for these facilities.

Based on the assumption that development of geothermal electrical power is likely to be of the order of 1000 MW by the year 2000 in Lake County, a total taxable revenue of about $200 million could be generated at that time. Direct heat energy applications may boost the above figures by 5-10%. The electric power generation would always be the dominant product of the geothermal resource in Lake County, mainly due to the predicted high quality of the resource. The scale differential between revenues to the steam supplier of power plants and revenues from the sale of energy for direct applications is a primary factor contributing to the low interest in these applications display by the exploration companies up to not.

Direct heat applications have, thus, not been included in any large scale development plans for the area. It is apparent that whereas these projects are considered to have direct benefit to the residents of the county, electric power generation utilizing the geothermal resource is viewed by some as another exploitation of a county resource which is exported for outside consumption. Not only does this appear to carry no tangible benefits to the residents, but it is also perceived as a threat of destroying certain aspects of the quality of life and environment.

A 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 are a source of frustration for county officials under pressure "to do something" about the control of geothermal development. County regulation of development could (a) minimize negative aspects of development, (b) improve land use planning, and (c) stimulate direct heat applications. Development of the resource can be turned into a positive force contributing to these goals as well as to the tax revenues and economic well-being of the county.

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 the resources, exploration, drilling, development, production and utilization.

Within the county, some interesting cross-currents in public opinion and economic realities are to be noted, and although these have not been thoroughly investigated, they indicate the

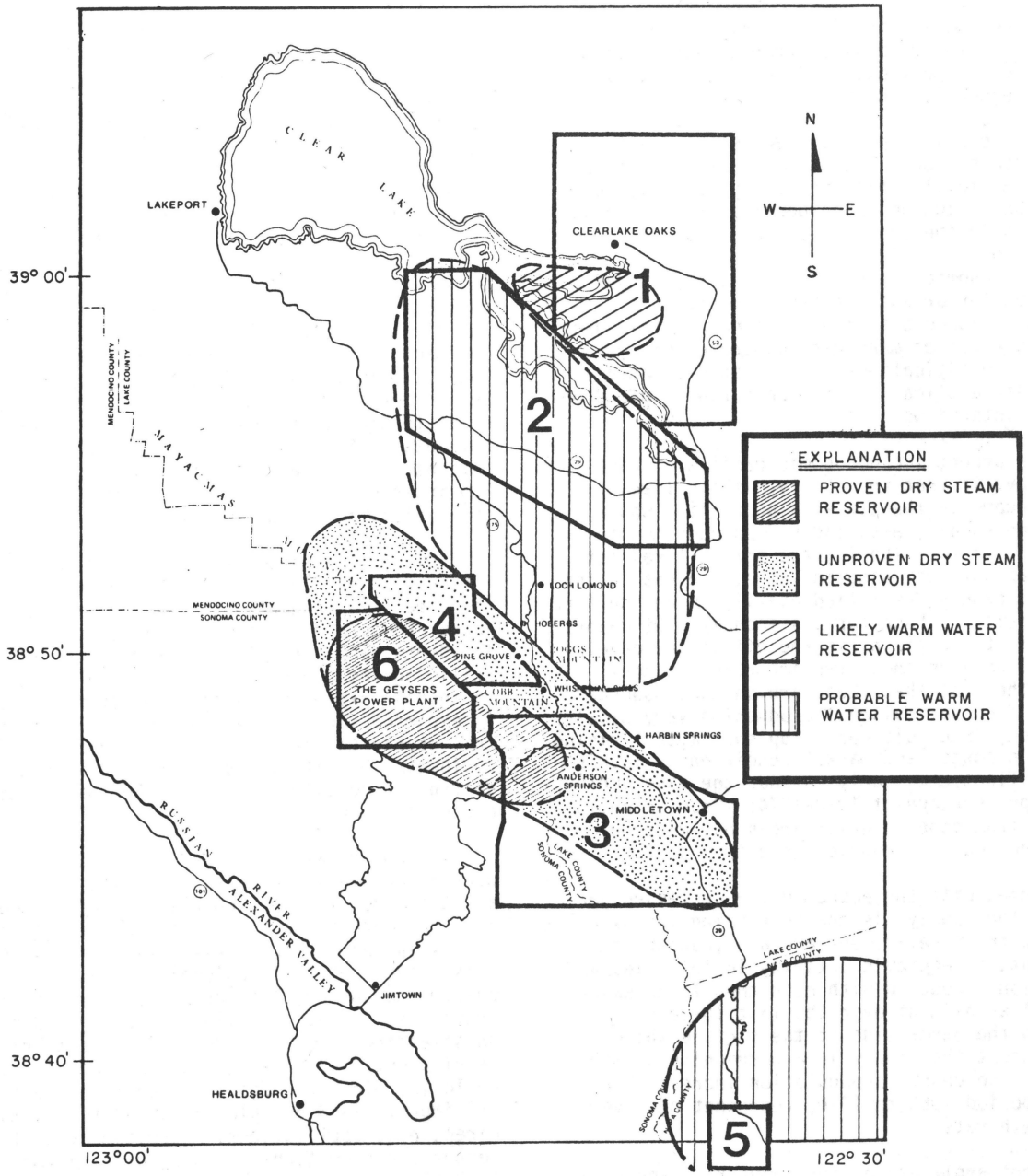

Figure 1. Location of the six sites of investigation and tentative classification of geothermal systems in the Geysers/Clear Lake region for nonelectric uses.

complexity of the issues. These are:

(1) Local attitudes, both young and old, seem to reflect a decidedly anti-growth sentiment. Yet, recent subdivision activity spurred activity in the construction industry and other service areas, and was not unwelcomed.

(2) The increase in private taxes due to increased assessment of property from geothermal activity is paid to a large degree (indirectly) by developers under the lease agreement.

(3) The impact from alternative uses of geothermal energy is not well defined at this stage, but direct heat used are regarded more positively than electric power generation with more potential benefits for the county residents.

(4) Fears that regional, state and national demands for energy are likely to overwhelm the county are countered by expectation of the predicted tax boon, stemming from electric power generation.

Any geothermal program which alleviates or addresses the dominant issues of the county--persistent unemployment, pollution of Clear Lake, and exploitation of it natural resources--would be given consideration. Geothermal development as a reality will touch the lives of county residents.