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AN ENVIRONMENTAL OVERVIEW OF GEOTHERMAL DEVELOPMENT: THE GEYSERS–CALISTOGA KGRA

Volume 3
Noise

P. Leitner

August 16, 1978

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MS. date: August 16, 1978

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PREFACE

This preliminary environmental and socioeconomic assessment of The Geysers–Calistoga Known Geothermal Resource Area (KGRA) is part of the Department of Energy's (DOE) Geothermal Overview Project. The purpose of that project is to identify, summarize, and assess the environmental issues of KGRAs currently identified by DOE as having strong possibilities for commercial development. Project results are reported to the Assistant Secretary for Environment of DOE and provide a basis for selecting those geothermal areas having the most critical need for regional environmental studies.

The Geothermal Overview Project addresses issues pertaining to air quality, ecosystems quality, noise effects, geological effects, water quality, socioeconomic effects, and health effects. At each KGRA under study, the key issues are identified and all available data are collected and analyzed. Finally, recommendations for future research and data collection are made.

The Geysers–Calistoga KGRA study was the first to be undertaken in the overview project. In this effort, the Lawrence Livermore Laboratory worked cooperatively with the Geothermal Resources Impact Projection Study (GRIPS), a regional body consisting of the counties of Lake, Mendocino, Napa, and Sonoma. Vital to the approach used in this study, and all the overview studies, is the free flow of information and the early involvement of all interested parties including local, state, and federal agencies, electrical utilities, resource developers, universities, and other private and public groups. With all interested parties involved from the onset of the project, the overview reports should reflect a consensus of these groups.

This report is intended to serve as the basis for planning future research, field studies, and assessments addressing critical environmental and socioeconomic concerns associated with the development of geothermal resources in The Geysers–Calistoga region.

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ABSTRACT

Noise from geothermal resource development at The Geysers–Calistoga Known Geothermal Resource Area (KGRA) will cause community annoyance unless noise-level standards are set and adhered to. Venting of steam is the loudest source of noise and can reach 100 to 125 dBA at 20 to 100 ft; most of the other noise sources fall below 100 dBA and are those usually associated with construction and industrial projects. Enough data exist for assessment and decision making, but it is scattered and must be compiled. In addition, communities must decide on their criteria for noise levels. Residential areas in The Geysers–Calistoga KGRA will require more stringent controls on noise than will the open space of which the KGRA is primarily composed. Existing technology can reduce noise levels somewhat, but more effective silencing devices are needed, particularly on steam venting systems.

INTRODUCTION

Geothermal energy development in The Geysers–Calistoga Known Geothermal Resource Area (KGRA) was, for many years, confined to a remote, almost uninhabited mountainous area. Since the early 1970s, however, geothermal development projects have been moving much closer to residential districts, and citizen complaints about noise emissions have become an issue. This is particularly true in Lake County, where small recreational/retirement communities are located within one-half mile of existing or planned geothermal wells, power plants, and other facilities. The same potential for conflict exists in other parts of The Geysers–Calistoga KGRA, particularly Sonoma and Napa counties.

The geothermal industry is actively involved in a program to reduce noise emissions and a number of important technological improvements in noise control have become standard practice in recent years. In spite of these advances, at times large quantities of geothermal steam must still be vented to the atmosphere without effective silencing. This is, by far, the most serious noise problem remaining, and its solution should be given a high priority.

This report deals exclusively with the impact of geothermal industry noise on adjacent communities and the extent to which it may reduce the public acceptability of this promising energy source. It is based, in part, on findings of the Geothermal Noise Workshop held on November 14 and 15, 1977, at the University of California (Davis) under the sponsorship of Lawrence Livermore Laboratory and the Geothermal Resources Impact Projection Study (GRIPS). Additional discussions with knowledgeable individuals in regulatory agencies, industry, and acoustical consulting firms provided valuable supplementary information.

GEOTHERMAL NOISE SOURCES

The noise sources that accompany the development and utilization of geothermal energy in The Geysers–Calistoga KGRA are summarized in Table 1. Except for the operations involving the venting of geothermal steam, these sources are typical of many construction or industrial projects.

Table 1. Noise sources associated with geothermal development in The Geysers–Calistoga KGRA.

Site preparation/road construction
Geothermal well drilling
Mud drilling
Compressed air drilling
Geothermal well clean-out and testing
Geothermal steam venting
Muffled
Unmuffled
Construction of facilities
Steam pipeline
Transmission line
Generating unit
Generating unit operation
Turbine/generator building
Steam-vent gas ejector
Cooling tower
Vehicular traffic

Site Preparation/Road Construction

Heavy earthmoving equipment is generally used to construct access roads, well pads, and generating unit sites. Noise conditions during site preparation for Geysers Power Plant Unit 13 were investigated in 1977 by the PG&E Department of Engineering Research; a report will be available by the end of 1978. A general reference source for noise emissions from construction equipment is the EPA document PB 206 717. [1]

Geothermal Well Drilling

Extensive data are available for both mud and compressed-air drilling phases. Union Oil Company and Republic Geothermal, Inc. have both conducted noise monitoring at a well site during the entire drilling process. All developers, as well as the Lake County Air Pollution Control District and Sonoma County Planning Department, have routinely taken sound-level readings to confirm adherence to use-permit requirements. Sound-level measurements for both mud and compressed-air drilling operations have been published in a number of references. [2–7]

Geothermal Well Clean-Out and Testing

After a successful geothermal well has been drilled, loose rocks and other particulates are cleared from the bore by venting the steam to the atmosphere at full production rates. A conventional muffler often cannot be used during this initial clean-out process because of potential damage from ejected debris. Extended production testing following clean-out is usually conducted with commercial mufflers of limited effectiveness. A-weighted sound pressure levels have been collected during these operations by developers as well as county and state agencies. Octave band frequency analyses are available from several sources. [2,3,5,7,8]

Geothermal Steam Venting

After the initial completion and testing of geothermal wells, steam venting occurs during many different operations. These include the long-term bleeding of steam from partially shut-in wells, additional production testing, commissioning of steam pipelines, venting at the wellhead or generating unit during outage conditions, venting at the wellhead and along the steam pipeline during unit startup, and replacement of wellhead valves. Some of these sources can be adequately silenced with present technology, but others cannot. The highest sound pressure levels are associated with the relatively infrequent unmuffled venting at wellhead or pipeline installations. Data are available to describe the A-weighted levels and frequency spectra of all major sources of steam-venting noise. [2–9]

Construction of Facilities

Steam-pipeline, transmission-line, and power-plant construction requires many standard types of heavy machinery. Several generating units are now under construction at The Geysers and noise at these sites has recently been studied by the PG&E Department of Engineering Research. These data will be made available in the near future. While no site studies of other construction activities have been conducted at The Geysers, extensive published data on noise levels from construction equipment can be found in the EPA document PB 206 717. [1]

Generating Unit Operation

Three major operational noise sources can be identified within the generating unit complex: the turbine/generator building, the steam-vent gas ejector, and the cooling tower. Sound pressure levels and octave-band frequency spectra are available for all sources. [7,8]

Vehicular Traffic

Geothermal development activities result in increases in vehicular traffic. This traffic may constitute a significant noise source, especially when vehicles such as large, diesel-powered trucks must be operated on steep grades. No field measurements of traffic noise related to geothermal development seem to have been made at The Geysers; nevertheless, standard references provide an adequate description of vehicular noise sources. [10]

Data Adequacy and Recommendations

Existing data adequately characterize the sound pressure levels, frequency spectra, and duration of the various geothermal industry noise sources. Thus, it is possible to readily identify the sources that can cause the greatest concern in the adjacent communities. No further collection of geothermal noise-source data appears to be necessary for environmental assessment or decision making.

However, much of the existing noise-source information has been gathered very recently and is available only in scattered reports or is not yet published. To facilitate the preparation of more accurate environmental impact documents, it would be useful to have all of these data brought together in a handbook for convenient reference; such a handbook would also be valuable to noise assessment studies in other geothermal resource areas.

GEOTHERMAL NOISE PROPAGATION

Methodology

To predict the impacts of geothermal noise emissions, we must be able to accurately forecast should pressure levels and frequency spectra at various distances from the nosie source. This issue must be considered in all environmental impact documents, and it can become a very important factor in decision making.

Although methods exist for making these predictions, no noise propagation model has been generally agreed upon or systematically evaluated for accuracy by comparison with field measurements. There are presently two basic methods to predict the propagation of geothermal noise from source to receptor—an analytical method based on wave divergence plus excess attenuation factors and an empirical approach using noise propagation data recorded at various distances from geothermal sources.

The analytical approach to noise propagation starts with the basic phenomenon of wave divergence. Wave divergence reduces the sound pressure level by 6 dB every time the distance from the source doubles. In addition, excess attenuation occurs from such factors as molecular absorption, physical barriers, wind, temperature inversions, vegetation, and ground surface properties; this attenuation can be calculated from generally accepted and verified sources.* A worst-case prediction would only take account of the combined attenuation from wave divergence and molecular absorption. A more realistic prediction would also have to count the contributions of several of the other excess attenuation factors mentioned.

The empirical approach would use data on noise propagation from actual geothermal sources in The Geysers terrain. A large series of sound pressure level measurements and one-third octave frequency spectra have been taken at distances up to 1 mi from various geothermal operations.† A predictive empirical model could be derived from these data and tested in field situations.

In addition, a semiempirical A-weighted attenuation curve has been developed by R. C. Bush. [4] This curve is based on a combination of theoretical acoustics and field measurements made on noise sources at The Geysers and elsewhere. [11] It has been used to predict sound pressure levels at receptor sites near a proposed geothermal generating unit. [12] Union Oil Company recently carried out a field test of this attenuation curve that predicted sound pressure levels up to several miles from a venting well with reasonable success. [13]

*One such source is "Sound Propagation Outdoors," by U. Kurze in *Noise and Vibration Control*, L. L. Beranek, ed. (McGraw-Hill, New York, 1971).

†Unpublished data, P. Leitner, Biology Department, St. Mary's College, Moraga, California.

Adequacy of Available Methodologies

Methods currently available seem reasonably accurate in their predictions of geothermal noise propagation. The effects of site-specific terrain factors such as barriers or elevation differences between source and receptor can be calculated on the basis of known theoretical and empirical relations. Local meteorological conditions such as winds and temperature inversions can also be taken into consideration when making predictions. Unfortunately, there have been few field studies to test the the accuracy of predictions made with different methodologies. No existing noise propagation model has been generally agreed upon and accepted as appropriate for use under local terrain and meteorological conditions at The Geysers.

Recommendations

The alternative predictive approaches need to be systematically evaluated by a committee of knowledgeable individuals directly involved with geothermal resource development and impact assessment. This working group should include representatives of steam-supply companies, utilities, regulatory agencies, and consulting firms. All existing data on noise propagation should be assembled and a family of propagation curves generated. Field measurements should be conducted, as agreed upon by the committee, to confirm and/or modify these curves. Such a model-validation procedure, would provide a standard predictive methodology useful in both planning and impact assessment. A thoroughly validated noise propagation model could greatly assist evaluation of noise impact in other geothermal resource areas and in other energy technologies.

COMMUNITY NOISE CRITERIA

In making decisions concerning proposed geothermal development projects, it is not enough to know the characteristics of geothermal noise sources and accurately predict the values of important noise parameters at receptor sites. Community noise criteria adequate to protect against annoyance and activity interference must be established and accepted before it is possible to judge project acceptability or to set source standards.

A number of factors must be considered in determining community noise criteria, including the existing noise environment, current land use patterns, the prior history of community response to noise, and general standards and guidelines.

Existing Noise Environment

Baseline noise levels unaffected by geothermal industry noise sources have been measured at many locations in The Geysers–Calistoga KGRA. [3,9] In recent years, most environmental impact documents prepared for geothermal development projects in Sonoma and Lake counties have included field measurements of baseline noise conditions. [2–7] Data usually consist of A-weighted sound pressure levels, although occasionally octave-band, statistical, or energy-equivalent levels have been taken. Sampling procedures usually involve short-term measurements at a few sites on and adjacent to the project area over a single day–night cycle. Long-term monitoring is rarely conducted. As expected in an essentially rural area, measured noise levels at most sites are very low and are dominated by natural sounds.

The Community and Its Response to Geothermal Noise

The most noise-sensitive land use within The Geysers–Calistoga KGRA is clearly residential, and it is the residents of rural areas and small communities in Lake and Sonoma counties who have reacted adversely to geothermal noise intrusion. Critical receptor sites where residents could be affected by geothermal noise are well known or easily determined. However, much of the KGRA is private land remote from residential development, and quite different criteria may apply in these areas.

Because of the low ambient-noise levels throughout much of the KGRA, residents are readily aware of geothermal noise intrusion. This can be particularly disturbing to people who have chosen to live in the KGRA region because they place a high value on quiet and serenity. Some individuals' response to noise may be partly conditioned by a negative attitude toward other impacts of geothermal development including odor

(H_2S) and visual aesthetics. Citizen complaints in Lake County communities adjacent to geothermal development have been analyzed by the Lake County Air Pollution Control District and by Long/Davy/Associates for the Noise Element of the Lake County General Plan. [14] They found that most community annoyance is related to noise from steam venting, well drilling, and truck traffic. Community response appears to follow fairly well a typical curve relating severity of public reaction to the magnitude of the outdoor day/night average sound level. [15] The most vigorous and widespread complaints come from receptor sound-pressure levels of 60-70 dBA or higher. However, in some cases, levels as low as 40-55 dBA have drawn a more vigorous response than would be expected in a typical urban or suburban community. It is not clear whether such complaints are related to the low ambient-noise levels of the region or to nonacoustic factors, such as opposition to geothermal development in general.

General Standards and Guidelines

Regulatory authority over noise from geothermal industry sources is shared among federal, state, and local levels of government. Federal and state legislation governs occupational exposure and applies to geothermal noise as it affects industry employees. Trucks and other motor vehicles operated on public highways are subject to the noise standards of the California Motor Vehicle Code. Local government holds the responsibility for regulating all other aspects of geothermal noise.

State law requires that a Noise Element be included in the General Plan for each county. The Noise Element provides the basis for local programs to control environmental noise and protect the community from excessive noise exposure. It does not set standards, but rather describes existing noise conditions, develops criteria for noise-compatible land-use planning, and outlines techniques for achieving an acceptable noise environment. A draft Noise Element has been prepared for Lake County, [14] and a noise ordinance may follow. Sonoma County has adopted a Noise Element for its General Plan.

Geothermal noise emissions are usually regulated on a project-by-project basis in Lake and Sonoma counties. A variety of noise standards have been applied to geothermal projects as conditions on county use permits. Those standards have not always been adequate to prevent community annoyance and complaints.

A number of studies that have attempted to specify the relationship between noise level and community annoyance or activity interference are summarized in Appendix D of Ref. 15. This EPA document identifies an outdoor day/night average sound level (L_{dn}) of 55 dB as a reasonable protection in residential areas. It points out that this level should satisfy most people but will not completely eliminate annoyance and complaints. It also cautions that an L_{dn} of 55 dB is not to be construed as a federal standard and that the economic and technological feasibilities of reaching this level were not considered.

While the noise exposure of residential communities within The Geysers–Calistoga KGRA is a prime issue, much of the KGRA is uninhabited open space. The EPA "Levels Document" suggests that an appropriate noise limit for open space is an equivalent A-weighted sound level of 70 dB averaged over 24 hours. [15] Any proposal for noise standards for the geothermal industry should clearly consider separate standards for areas where no residential or other sensitive receptors would be affected.

The draft Noise Element of the Lake County General Plan has proposed land-use/noise-level compatibility criteria for Lake County, taking into account the conclusions of the EPA "Levels Document" [15] as well as the State of California Noise Element Guidelines. [16] These criteria would, of course, apply to all land uses, not just geothermal industry activities.

Data Adequacy

Available background information seems adequate to establish acceptable noise levels for both residential and open space areas within The Geysers–Calistoga KGRA. Ambient noise has been measured at a number of locations; existing land-use patterns and the location of critical receptors, such as small residential communities, are well known. The pattern of citizen complaints about geothermal noise has been analyzed and can be related in a general way to the type and energy level of noise intrusions. There is considerable local experience in Lake and Sonoma counties with the relative effectiveness of various geothermal project noise standards in reducing complaints. By comparing this experience to EPA noise criteria for residential and open space areas, it should be possible to arrive at reasonable standards that will protect the public welfare without imposing unrealistic conditions on the geothermal industry.

Recommendations

Ambient noise conditions should be determined before permitting geothermal development projects so that appropriate noise criteria can be selected. This is best accomplished on a project-by-project basis. When a specific project is under consideration, noise sources and their locations will be known and critical receptor sites can then be identified with accuracy. Regional baseline noise surveys are not recommended.

In general, community response to noise intrusion seems well defined and predictable enough that criteria can be chosen to minimize annoyance and complaints. However, the factors that lead to annoyance when geothermal noise is barely audible (40-55 dBA) are poorly understood. Additional study should be directed at identifying these factors and incorporating then into noise-impact assessment procedures.

Local regulatory agencies with authority over geothermal development projects should establish uniform and acceptable noise criteria for residential and open space areas. These criteria should not apply just to the geothermal industry, but to all activities that may impact local communities, such as logging, mining, resort operations, and off-road vehicles. Although the criteria should minimize complaints, the elimination of all adverse public reaction is not a realistic goal.

Once acceptable levels are identified and reasonable standards established, responsibility for noise control falls on the developer. Permits for particular projects would be issued on the basis of the developer's demonstrated ability to control noise and meet community criteria.

Elaborate noise-monitoring systems are not recommended as a general rule. Occasional checking by regulatory agencies should be sufficient to establish compliance with standards. Agencies must be provided with adequate resources to carry out this function.

GEOTHERMAL NOISE CONTROL

Venting large quantities of geothermal steam at the wellhead, along pipelines, and at the generating unit is clearly the loudest source of industrial noise at The Geysers. Measured sound pressure levels at distances of 25 to 100 ft range from 100 to 125 dBA. All other noise sources are well below 100 dBA in intensity. Although large-scale steam venting does not occur frequently or for long periods, it can be audible at three miles and can produce annoyance at two miles. Furthermore, it is not restricted to early project stages but occurs periodically throughout the entire life of a geothermal field. If more effective silencing devices cannot be developed, use of geothermal energy may be restricted in areas of The Geysers–Calistoga KGRA that are close to residential development.

Existing Control Technology

In recent years, the geothermal industry has improved control of the noise generated by venting steam with advances in such areas as compressed-air drilling procedures, steam discharge during a power-plant outage, and wellhead and pipeline venting during power-plant start-up.

Compressed-Air Drilling

Drilling in a steam-bearing zone is accomplished with compressed air rather than mud. Compressed air is forced down the drill pipe and returns carrying rock cuttings and any geothermal steam produced. The steam, air, and cuttings are vented through a pipe known as a blooie line. All developers currently operating at The Geysers use a large cyclonic separator/muffler at the end of the blooie line to control particulate and noise emissions. Control is particularly effective when water is injected into the blooie line upstream from the cyclonic muffler. Noise levels from air drilling can be reduced from about 120 dBA at 50 feet with only a blooie line expander tube to below 90 dBA with the cyclonic muffler.

In many cases, the cyclonic muffler can also control noise during the initial clean-out and production test at a newly completed well when the drill rig and related equipment are still on location.

Steam Discharge During Power Plant Outage

It is not practical to shut in the wells in a steam supply field during a short-term outage at the generating unit, and large quantities of steam may have to be released to the atmosphere. Rock mufflers have recently been constructed adjacent to several of the existing generating units. These large rock-filled pits replace conventional metal mufflers, which were relatively ineffective and corroded quickly. They have reduced sound pressure levels from more than 100 dBA at 75 ft to 72 dBA at 25 ft. Most generating units will be equipped with rock mufflers in the near future.

Wellhead and Pipeline Venting During Power-Plant Start-up

Previously, during a long-term outage at a generating unit all wells in the steam supply field had to be completely shut in. The start-up procedure is extremely noisy because all wells must be vented to the atmosphere to clean out rocks and other debris that could damage the turbine. Venting is also necessary at various points along the steam pipelines to clear condensate that had accumulated during the outage. Sound pressure levels as high as 125 dBA can be measured 50 ft from these steam vents.

Although no effective mufflers have been developed, certain improvements have been made to reduce the frequency of well shut-in. New V-ball throttling valves have been installed on many high-production wells and, during an outage, can reduce the steam production from a field to 50-60% of normal. A portion of the rest can be sent to other units via intertie pipeline systems or can be vented through the rock muffler near the power plant. These new developments can, in some situations, avoid the necessity of complete well shut-in and the subsequent large-scale venting during power-plant start-up.

Requirements for Additional Control Technology

Steam-Vent Noise

In spite of these recent advances in noise control, procedures during both the development and operation of a geothermal field still require venting large quantities of steam under conditions that preclude effective silencing. Extended production testing of new wells and clean-out of previously shut-in wells are the most common noise sources that can exceed 100 dBA at 50 to 100 ft. A muffling system is required that can attenuate this steam-venting noise by at least 20 to 30 dBA.

Drilling Noise

Although the sound pressure levels associated with mud and compressed air drilling are much lower (80 to 90 dBA at 50 ft), complaints are sometimes received from persons living within 1000 to 3000 ft of a drill site. This is due, in part, to the continuous round-the-clock operation and, in part, to occasional noise peaks occurring when the drill string is raised or lowered. Inexpensive methods of attenuating the low-frequency components of noise from large diesel engines and compressors would be very useful.

Recommendations

Steam-Vent Noise

The highest priority should be given to developing a system to muffle the free venting of steam wells to the atmosphere.

One developer has used a rock-filled muffler mounted on a flat-bed semi-trailer. While it can be moved by truck tractor from one well pad to another, it is extremely heavy and difficult to maneuver, especially on mountain roads. Such mufflers do not seem practical for short-term venting procedures because of the cost and the time required for hookup. However, improvements on this design might be effective in certain applications.

As an alternative, a rock-filled muffler similar to that developed for the generating units could be constructed on some well pads for use during venting. While these installations are quite expensive, they might provide a practical means of noise abatement for venting occurring close to residential areas, especially if several wells on the same pad could be served by a single muffler.

In addition, some large metal test mufflers of conventional design are capable of attenuating venting noise to about 100 dBA at 50 ft. Investigating the possibility of new designs might be worthwhile to achieve an additional reduction of 10 to 20 dBA during extended production tests.

There is, however, real need for a light-weight, easily portable silencing device for use during well clean-out when conventional mufflers would be damaged by ejected rocks and debris. Various jet nozzle configurations have been investigated by NASA to reduce the sound pressure levels from aircraft and rocket engines and to shape the frequency spectrum. Applying this research to geothermal steam venting, as well as developing techniques for directing the steam flow away from receptors, could help achieve a satisfactory level of noise reduction.

A feasibility study should be initiated as soon as possible to determine the most promising approaches to reducing steam-venting noise. This should be followed by the design, construction, and testing of prototype and standard muffling devices.

This effort should be carried out in close cooperation with geothermal developers at The Geysers. Such a program can probably be completed within one year.

Drilling Noise

Second priority should be given to the control of drilling noise. Techniques are available for developing acoustic enclosures and better exhaust noise control for large engines and compressors, as well as improvements in cyclonic muffler design. Some of these advances are currently being implemented by geothermal developers. Further reduction of drilling noise can probably be accomplished by the industry and will not require an extensive research and development effort.

REFERENCES

1. U.S. Environmental Protection Agency, *Noise from Construction Equipment and Operations, Building Equipment, and Home Appliances,* Rept. PB 206 717, prepared by Bolt, Beranek, and Newman (Dec. 31, 1971).
2. Atlantis Scientific, *Environmental Impact Report, Castle Rock Springs Geothermal Steam Area, Lake County, California,* prepared for Burmah Oil and Gas Co. (Aug. 22, 1975).
3. Atlantis Scientific, *Environmental Impact Report, Ford Flat Geothermal Steam Area, Lake County, California,* prepared for the County of Lake Planning Department (Jul. 5, 1976).
4. ECOVIEW Environmental Consultants, *A Draft Environmental Impact Report for Union Oil Company Unit #17 Development Area, Lake County, California,* prepared for the County of Lake Planning Department (Dec. 15, 1977).
5. Environmental Impact Planning Corporation. *Long Ridge Geothermal Leasehold—Draft Environmental Impact Report,* prepared for the County of Lake Planning Department (Apr. 1977).
6. Gennis and Associates, *Draft Environmental Impact Report: McCulloch Oil Corporation Cobb Valley Geothermal Leasehold,* prepared for County of Lake Planning Department (Feb. 1977).
7. Sociotechnical Systems, Inc., *Draft Environmental Impact Report, Northern California Power Agency/Resource Funding Limited, Cobb Valley Geothermal Project*, prepared for County of Lake planning Department (Sept. 20, 1977).
8. R. C. Bush, "An Overview of PG&E's Audible Noise Measurement Program at The Geysers," *Geothermal Environmental Seminar—'76,* (Lake County, California, Oct. 27-29, 1976).
9. R. R. Illingworth, "Factors Contributing to Annoyance by Geothermal Steam Well Venting at The Geysers," *Geothermal Environmental Seminar—'76* (Lake County, California, Oct. 27-29, 1976).
10. U.S. Environmental Protection Agency, *Transportation Noise and Noise from Equipment Powered by Internal Combustion Engines,* Rept. NTID 300.13 (Dec. 1971).
11. R. C. Bush, "Plant and Equipment Noise Treatment," *in Proc. of Pacific Coast Electrical Association Engineering and Operation Conference,* (Los Angeles, California, Mar. 17-18, 1977).
12. Pacific Gas & Electric Company, *Environmental Data Statement, Geysers Unit 16* (Aug. 19, 1977).
13. A. S. Timmons and O. D. Whitescarver, *Geysers Simplified Noise Model, Unit 17 Geothermal Development Area,* Union Oil Company of California, Santa Rosa, California (Mar. 15, 1978).
14. Vibron West, *Noise Element of the General Plan, Lake County, California,* prepared in cooperation with Sociotechnical Systems, Inc. (Feb. 11, 1977).
15. U.S. Environmental Protection Agency, *Information on the Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety,* Document No. 550/9-74-004.
16. California Department of Health, *Guidelines for the Preparation and Content of Noise Elements of the General Plan.* Office of Noise Control, California Department of Health in cooperation with the Office of Planning and Research (1976).
17. S. L. Hester, *et al., Ambient Sound Level Anderson Springs-Cobb Valley, Lake County, North Bay Division,* prepared by Pacific Gas & Electric Co. (Mar. 13, 1974).

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