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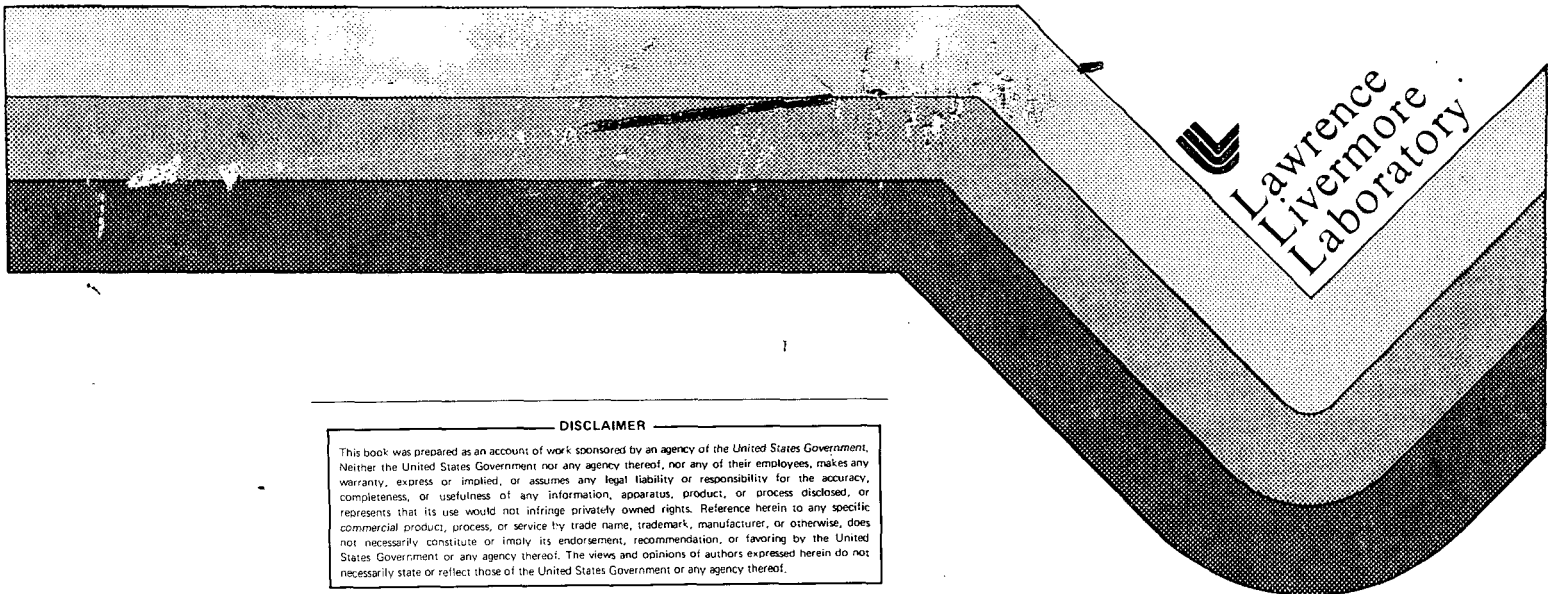
THE COSO GEOTHERMAL ENVIRONMENTAL OVERVIEW STUDY
ECOSYSTEM QUALITY

Philip Leitner

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ECOSYSTEM QUALITY

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ABSTRACT

The Coso Known Geothermal Resource Area is located just east of the Sierra Nevada, in the broad transition zone between the Mohave and Great Basin desert ecosystems. The prospect of large-scale geothermal energy development here in the near future has led to concern for the protection of biological resources. Objectives of this report are the identification of ecosystem issues, evaluation of the existing data base, and recommendation of additional studies needed to resolve key issues.

High-priority issues include the need for (1) site-specific data on the occurrence of plant and animal species of special concern, (2) accurate and detailed information on the nature and extent of the geothermal resource, and (3) implementation of a comprehensive plan for ecosystem protection. Recommendations are made that would help to resolve each of these issues. Site-specific inventories for species of special concern are recommended prior to initiation of each geothermal development project. Data regarding the geothermal resource should be gathered through a program of deep exploratory drilling and reservoir testing and made available for impact prediction and planning purposes. Regulatory agencies are urged to implement a plan for ecosystem protection that will minimize impacts and provide consistent guidelines for all developers.

Habitat loss and alteration is a medium-priority issue. Careful advance planning can minimize land requirements for geothermal facilities, while implementation of more effective revegetation techniques can help in reclamation of disturbed areas. Monitoring water levels in aquatic habitats is recommended in light of the potential effects of large-scale geothermal fluid withdrawals. A second medium-priority issue is the possibility that emissions of boron and heavy metals in cooling tower drift could have adverse ecological effects.

Baseline and monitoring studies of vegetation near cooling towers are recommended to deal with this question. The potential for increased wind and water erosion is a third medium-priority issue. No special studies are needed; effective mitigation measures should be put into operation.

Three ecosystem issues were considered to be of low priority. The possibility of ecological damage due to accidental spills could be better evaluated when adequate data on the chemistry of geothermal fluids becomes available. Potential noise effects on sensitive wildlife species can be avoided by maintaining a buffer zone around key habitat areas. Finally, current data indicate a low probability of weather modification due to cooling tower operations.

INTRODUCTION

There is the potential for large-scale geothermal energy development in the Coso Known Geothermal Resource Area (KGRA). The resource here is believed to be of a quality suitable for generation of electricity. Estimates of the total electric energy obtainable range up to 650 MW(e) for 30 years (Muffler, 1979). Most of the Coso KGRA consists of Federal lands. These include National Resource Lands administered by the USDI Bureau of Land Management (BLM), as well as public lands withdrawn for the use of the China Lake Naval Weapons Center (NWC) in its defense mission. The BLM has recently carried out a successful lease sale involving Federal lands of both kinds. Lessees will develop the geothermal resource for generation of electricity. The environmental effects of leasing these lands for geothermal development are addressed in an Environmental Impact Statement (EIS) prepared by the BLM Bakersfield District (USDI Bureau of Land Management, 1980e). The China Lake NWC has initiated a geothermal program on Navy fee-acquired lands within the KGRA. The environmental implications of this program are discussed in the NWC's Coso Programmatic EIS (U.S. Naval Weapons Center, 1979). A contractor is currently proceeding with plans to develop up to 110 MW(e) of generating capacity by 1985.

Because of the likelihood of extensive geothermal development in the Coso region, there is concern over possible impacts on ecosystem quality. Data regarding the biological resources of the Coso KGRA are needed to ensure that the desert ecosystem will be adequately protected during the development process. The purpose of this report is to present an assessment of issues concerning ecosystem quality at the Coso KGRA. This assessment includes:

- Identification of key ecosystem issues.
- Evaluation of their importance as barriers to geothermal development.
- Determination of the adequacy of available data to resolve these issues.
- Recommendation of additional data-gathering activities necessary for environmentally sound geothermal development.

Recommended studies include baseline, effects, mitigation, and monitoring investigations that will provide data useful in planning for protection of the KGRA's biological resources. These studies could be carried out by Federal land management and regulatory agencies, local and state government, or the geothermal industry.

ECOLOGICAL SETTING

The Coso KGRA is located in the southwestern portion of the vast Basin and Range physiographic province. It occupies part of the broad transition zone between the Mohave and Great Basin desert ecosystems. The escarpment of the Sierra Nevada forms the western boundary of the geothermal area. The eastern section of the KGRA is dominated by the Coso Range, an area of recurrent vulcanism since the Tertiary. Here several dozen steep-sided perlite domes and extensive lava flows provide evidence of recent volcanic activity. Between the Sierra Nevada and the Coso Range lies Rose Valley, a southward extension of Owens Valley. Elevations within the KGRA vary from about 3,000 ft. in the valleys and basins to over 8,000 ft. on the highest peak of the Coso Range.

Since the Coso KGRA lies in the rain shadow of the Sierra Nevada, the general climate is arid. Winters can be cold, with precipitation in the form of snow as well as rain. Summer thunderstorms may occur in July and August, but rarely provide much usable moisture. Annual precipitation averages about 5 inches, but as in most desert regions is highly variable and erratic in

amount from year to year. Summers are hot, with a growing season of about 225 days. Average dates for last spring and first fall frosts are April 1 and November 10. The productivity of the ecosystem is largely determined by the amount and timing of winter precipitation. If rain and snow are plentiful and well-distributed through the cool season, annual forbs and grasses can be remarkably rich and diverse. After a series of dry winters, on the other hand, even the woody drought-resistant shrubs may be virtually dormant.

The natural vegetation of the Coso KGRA is primarily made up of low, scattered desert shrubs. Other regular elements of the vegetation include various types of cactus, perennial grasses, and the winter annuals that occasionally produce spectacular wildflower displays. The most important plant communities are Shadscale Scrub, typical of the Great Basin to the north, and Creosote Bush Scrub, which extends southward over much of the Mohave Desert. Joshua Tree Woodland is found at moderate elevations in the Coso Range, while Sagebrush Scrub and Pinyon-Juniper Woodland occur in small stands on the highest mesas and peaks.

The desert ecosystem of the Coso KGRA provides suitable habitat for a relatively abundant fauna, although species diversity is somewhat limited. Small burrowing rodents, jack rabbits, and lizards of several kinds are the essential links in the food web that supports a variety of predators. Rap-torial birds include golden eagles, prairie falcons, red-tailed hawks, and ravens, while typical mammalian carnivores are coyotes, kit foxes, bobcats, and badgers. The introduced chukar partridge has adapted well to desert conditions; it is the only game species of significance, although mourning doves are also present. Breeding songbirds are mainly restricted to a few species that nest on the ground or in the low shrubs. Feral burros are found in small groups in many parts of the Coso Range. They are responsible for considerable

damage to the vegetation, especially when they congregate in the vicinity of water sources. The only other large mammals are the cattle that are grazed in the KGRA during winter and early spring.

There are no permanent streams in the Coso KGRA and very little surface water is available over most of the region. The largest body of water is Haiwee Reservoir just to the north of Rose Valley. It is a storage facility in the aqueduct system of the Los Angeles Department of Water and Power. At the south end of Rose Valley is Little Lake, a small impoundment that provides habitat for large numbers of migratory waterbirds in spring and fall. A few springs emerge along the fault traces on the Sierra Nevada escarpment. At Coso Hot Springs and the Devil's Kitchen in the eastern part of the KGRA small seeps and fumaroles provide some water for wildlife. In the northeastern section of the KGRA, Haiwee Spring is an important water source for wildlife and supports a half-mile long corridor of willows and other riparian vegetation. Because of the great scarcity of surface water in the summer, the few springs are of critical value and are heavily used by many species of birds and mammals.

Man's use of the Coso KGRA ecosystem has left relatively minor impacts. Rose Valley is traversed by a series of narrow north-south transportation corridors: U. S. Route 395, the Southern Pacific Railroad, two aqueducts, and two electric transmission lines. Formerly, sheep were brought into the region in great numbers, but at present only cattle grazing on a limited scale has been permitted during winter and early spring. In recent years several hundred acres of private land in the northern part of Rose Valley have been brought under cultivation. Alfalfa is now grown with sprinkler irrigation, using ground water pumped from shallow wells. Small scale extraction of cinders and pumice is carried out at several locations in the western part of the KGRA. The use of the eastern section of the KGRA for weapons testing has resulted in few changes in the natural ecosystem except for the maintenance of a road network.

ISSUES AND CONCERNS

A number of issues and concerns relating to ecosystem quality in the Coso KGRA have been identified and placed in order of priority (Table 1). Many participants were involved in the process of defining these issues. The Coso Advisory Committee, with members from all levels of government, the utilities, private landowners, and the Indian community, arrived at a preliminary listing of ecosystem issues during their second meeting on July 12, 1978. The next step was a full and open discussion of these concerns at the Coso Geothermal Workshop, held on August 17-18, 1978 at Lone Pine, California. Workshop participants representing government agencies, public utilities and private industry, universities, public interest groups, and local residents helped to identify ecosystem issues that could be raised by geothermal development in the Coso KGRA. Priorities were assigned to these issues using the following criteria:

- Does the issue present a potential barrier to geothermal development?
- Is there the likelihood of an important adverse impact on the local ecosystem?
- Does lack of information on this topic seriously impair the ability to accurately predict impacts?

Species and Habitats of Special Concern

Biological resources subject to special protection and management may act as impediments to geothermal development in the Coso KGRA. Adequate baseline data on the occurrence and status of rare or endangered species and sensitive habitats are needed prior to leasing decisions. Information is also needed regarding species that are fully or partially protected under Federal

TABLE 1
ISSUES AND CONCERNS: A SUMMARY

High Priority

1. Species and Habitats of Special Concern
Are adequate baseline data available regarding the status of
 (a) plant and animal species requiring special management and
 (b) habitats of critical concern?
2. Nature of the Geothermal Resource
Information on the location of the geothermal resource, its physical and chemical properties, and the possible modes of utilization are urgently needed to make accurate ecosystem impact assessments.
3. Ecosystem Protection
Detailed provisions must be made for regulation of geothermal development to protect the desert ecosystem and to mitigate impacts on biological resources.

Medium Priority

4. Habitat Loss and Alteration
What will be the extent of habitat loss and alteration due to geothermal development? What kinds of impacts can be expected?
5. Cooling Tower Emissions
What substances are likely to be emitted from geothermal power plant cooling towers? What adverse ecosystem effects may occur?
6. Wind and Water Erosion
What is the potential for increased wind and water erosion as a result of vegetation removal and soil disturbance?

Low Priority

7. Accidental Spills
What substances could be accidentally released in the event of a spill of geothermal fluids or steam condensate? What could be the impact on the local ecosystem?
8. Noise Emissions
What will be the effects of geothermal industry noise emissions on the distribution, abundance, and behavior of sensitive wildlife species?
9. Weather Modification
Could water vapor and heat emissions from evaporative cooling towers lead to local changes in humidity and precipitation, thereby impacting natural vegetation?

or state laws and species that are of special concern to governmental agencies or private organizations because of sensitivity to development, declining numbers, or restricted habitats. Geothermal leasing and development can be accomplished in a timely and environmentally acceptable manner only if sufficient baseline data are available to ensure the protection of species and habitats of special concern.

Nature of the Geothermal Resource

Accurate assessment of potential ecosystem impacts and planning for the protection of biological resources is seriously hampered by lack of data on the geothermal resource itself. For planning purposes, it is important to know the size of the commercial geothermal resource, its exact location, and its probable productive life. The physical properties of the geothermal fluids produced will play a large part in defining the utilization technology. Does the Coso KGRA contain a vapor-dominated or a liquid-dominated reservoir? What resource temperature and enthalpy can be expected? These data are needed in order to evaluate future requirements for land, cooling water, and waste disposal. Both qualitative and quantitative information on the chemical properties of the geothermal fluids are essential for ecosystem impact prediction. Of particular interest are source term data on concentrations of non-condensable gases and dissolved solids including borates and heavy metals.

Ecosystem Protection

Effective ecosystem protection was given a high priority at the Coso Geothermal Workshop. It was concluded that geothermal development should be carefully planned and regulated to protect the desert ecosystem and to

mitigate impacts on biological resources. Questions were raised concerning a number of related issues:

- (1) What agencies will be responsible for environmental assessment and permitting in relation to development operations?
- (2) What will be the schedule and procedure for decision-making on leasing and development?
- (3) What opportunities will be provided for public and agency participation and input to the process?
- (4) Where and when will leasing and development be permitted?
- (5) What conditions and stipulations will be implemented to assure ecosystem protection?
- (6) Are available mitigation measures, such as re-vegetation, really effective in the desert environment?
- (7) What are the opportunities for off-site as well as on-site mitigation?
- (8) Will monitoring be carried out to detect potential long-term ecosystem impacts and to evaluate the effectiveness of mitigation measures?

Habitat Loss and Alteration

Direct habitat loss will be the most obvious impact of geothermal development. Information is needed regarding the extent of land-use conversion and the ecological resources that would be lost. Surface disturbance and construction of facilities such as roads, wellpads, and pipelines may lead to more subtle alterations in habitat productivity and carrying capacity. For example, could roads and pipelines act as barriers to animal movements and migration? Will operation of vehicles off maintained roadways cause soil compaction over significant areas? What changes could occur in surface runoff patterns and in the distribution of moisture for plant growth? Finally, what is the potential for changes in either hot or cold springs as a result of large-scale withdrawal of geothermal fluid from the deep reservoir? Could there be

effects on flow rates, temperatures, or chemical composition that might adversely impact organisms dependent on these aquatic habitats?

Cooling Tower Emissions

Evaporative cooling towers are likely to be used at geothermal power plants in the Coso KGRA. At the Geysers Power Plant in northern California geothermal steam condensate is employed as the circulating fluid in the cooling cycle. There the cooling towers are the dominant source of environmental emissions for natural impurities in the steam such as non-condensable gases and dissolved solids. Cooling tower emissions at power plants in the Coso KGRA could potentially include hydrogen sulfide, ammonia, sulfate, boron, mercury, and arsenic if steam condensate is the source of cooling water. Possible ecosystem impacts might include damage to natural vegetation and concentration of toxic materials in the local food chain.

Wind and Water Erosion

The removal of vegetation and disturbance of the soil profile as a result of construction activities during geothermal development can lead to accelerated rates of erosion. Because high winds and occasional heavy rains are characteristic of the Coso KGRA, there is concern over possible ecosystem damage from increased erosion.

Accidental Spills

Depending upon the technologies employed in utilizing the geothermal resource of the Coso KGRA, there are many possible ways in which accidental spills of potentially harmful solid and liquid materials could occur. Large

quantities of geothermal fluid will be carried from wellhead to power plant through a system of gathering lines. Other pipelines will move cooling water between the generating unit and the cooling tower, while waste brines or steam condensate will be transported through pipes to injection wells. Failure of these lines can result in spills; malfunctions in control systems can lead to overflows of cooling tower basins. Drilling muds, petroleum products, and materials used or produced in pollution control systems are also at risk of spillage, both on-site and during transport. Information is needed regarding the kinds of substances that could be accidentally released as a result of geothermal industry operations.

Noise Emissions

Geothermal development activities will result in increased noise levels in many parts of the Coso KGRA. What changes in the ambient noise environment are expected and what could be the impacts on the distribution, abundance, and behavior of sensitive wildlife species?

Weather Modification

What is the potential for local changes in weather resulting from water vapor and heat emissions at evaporative cooling towers? Could such weather modification, if it occurs, impact the natural vegetation in some way?

AVAILABLE DATA

There is a great deal of baseline information available concerning the desert ecosystem of the Coso KGRA. Much of this information was obtained during recent studies sponsored by the China Lake NWC and the BLM in support of their respective geothermal programs in the Coso area (U. S. Naval Weapons Center, 1979; USDI Bureau of Land Management, 1980e).

On the other hand, little is known about the effects of geothermal energy development on ecological systems in a desert environment. In some cases, it may be possible to make reasonably accurate impact predictions based upon investigations at The Geysers geothermal field in northern California, where development has been underway for some time (Leitner, 1978). Research on the ecological effects of other types of construction projects in a desert setting may also provide data useful for impact assessment.

This section describes the ecosystem data base that is currently available for the Coso KGRA. It is organized in two parts: the first part presents general baseline data on soils, natural vegetation, wildlife, and aquatic habitats, while the second part directs particular attention to information that is relevant to ecosystem quality issues and concerns. A major purpose is assessment of the adequacy of existing information and identification of important data gaps.

General Baseline Data

Natural Vegetation and Soils

A soils inventory and analysis covering essentially the entire Coso KGRA was carried out by Rockwell International for the Bureau of Land Management. This work was performed to provide basic soils data for the EIS covering proposed leasing of Federal lands within the KGRA for geothermal exploration and

development (USDI Bureau of Land Management, 1980e). The results of this soil survey were published as a Technical Report (USDI Bureau of Land Management, 1980d).

The soils study included a Level 3 (medium intensity) Soil Survey. Mapping of soil units was based on interpretations of aerial photographs and geological maps and on an extensive and systematic field survey. A General Soils Map was prepared for the region at a scale of 1:62,500, with the boundaries of ten soil associations indicated. Thirty-six soil mapping units were identified and then delineated on a Detailed Soils Map prepared at the scale of 1:24,000. Both maps were included in the Soils Technical Report, with their respective legends and descriptions of mapping units.

In addition to the mapping and description of soil units, samples were taken for laboratory analysis. Selected physical and chemical properties were determined and presented in tabular form in the Soils Technical Report. Standard management and interpretation tables were also presented for the 36 detailed soil mapping units. These included measurements and interpretations of engineering properties, interpretive ratings for soil uses, and interpretive ratings for selected soil properties and qualities.

Two inventories of the natural vegetation resources of the Coso KGRA were performed recently. The first study was done under contract to the China Lake Naval Weapons Center and field investigations emphasized the four relatively small parcels of Navy fee land within the KGRA (Zemba1, Gall, Kruska, and Lobnitz, 1978). The second study was carried out by Rockwell International for the Bureau of Land Management; it covered almost the entire KGRA (Henrickson, 1979).

The vegetation inventory of Navy fee lands by Zemba1, Gall, Kruska, and Lobnitz (1978) included intensive sampling at eight field stations. Perennial

species were sampled by belt transects and standard parameters such as percent composition and percent ground cover were estimated for each species. Annual plants were sampled at quadrats located along the belt transects; density and frequency of occurrence were noted for each species. All plant species found on the fee land parcels were identified and voucher specimens taken to be deposited at the Rancho Santa Ana Botanic Garden. A checklist of vascular plants was developed, with brief notes on distribution, ecological requirements, and relative abundance. Three plant communities were recognized on the Navy fee lands, based upon the dominant shrub species, and their distribution was described and mapped. Special efforts were made to locate and identify plant species designated as rare, threatened, or endangered by Federal and state agencies and by private conservation groups such as the California Native Plant Society.

The vegetation study done by Henrickson (1979) under contract to Rockwell International was designed to provide baseline data for the EIS covering proposed geothermal leasing in the Coso KGRA (USDI Bureau of Land Management, 1980e). The results of this investigation were included in a Technical Report published at the same time as the EIS (USDI Bureau of Land Management, 1980c).

A vegetation map was prepared from large-scale infrared aerial photography of the region; it is on file at the Bakersfield District Office, USDI Bureau of Land Management. Nine vegetation units were recognized and mapped using the aerial photographs and extensive ground reconnaissance. These units consisted of important individual plant species and multispecies associations recognizable in the aerial photographs. Quantitative vegetation data were

obtained at 99 sampling sites distributed over most of the Coso KGRA. At each site a standard transect method was used to sample the perennial plant species. Data were taken to allow estimates of percent cover and frequency of occurrence for each species, as well as total percent cover and species diversity. A checklist of all vascular plants known from the Coso region was compiled, based upon extensive field collections, existing published records and herbarium specimens, and contacts with knowledgeable local botanists. The checklist provided information for each species concerning general frequency in the region and habitat preference. No plant species listed as rare, threatened, or endangered by the U. S. Fish & Wildlife Service or the California Department of Fish & Game were identified in this study. However, several species considered by the California Native Plant Society to be rare or rare and endangered were noted and their distribution discussed; several locally endemic plants were also indicated. Finally, habitats judged to be particularly sensitive from a botanical perspective were identified.

Data Adequacy

Soils data adequate for general planning purposes are available for all parts of the Coso KGRA that have reasonable geothermal potential. Detailed soils surveys would be required for siting of specific geothermal facilities. Such surveys should be designed to identify areas particularly susceptible to wind and water erosion or other soil-related hazards and constraints.

Vegetation data adequate for general planning purposes are also available for those portions of the Coso KGRA with reasonable geothermal potential. Facilities siting would require detailed surveys for rare or endangered plant species. These surveys should be carried out at the season when such plants are likely to be in flower or otherwise clearly identifiable.

Wildlife

Baseline data on the wildlife resources of the Coso region are available from several published sources. Almost all of the recent studies were carried out under contract to the China Lake Naval Weapons Center or the Bureau of Land Management. The results of the wildlife investigations sponsored by the BLM were published as part of a Technical Report on field ecology (USDI Bureau of Land Management, 1980c).

The amphibian and reptile fauna of much of the Coso KGRA was surveyed as part of the extensive field ecology studies performed by Rockwell International for the Bureau of Land Management (Brown, 1979). Techniques used were direct visual observation during both daytime and nighttime reconnaissance along roads throughout the KGRA, more intensive observation at eight study sites selected as representative of major habitats, and pitfall trap sampling at five of these sites. A list of amphibian and reptile species present in the region was developed as a result of this work. Relative abundance and habitat occurrence were indicated for each species. Sensitive habitats were identified and the possible presence of rare, threatened, or endangered species was discussed.

Two recent studies of the avifauna of the Coso region have been carried out under contract to the Bureau of Land Management. The first field survey was designed to provide quantitative data on winter bird populations (Zemal, Massey, and LaRocque, 1978). Eight sites representing major habitats were selected for general bird inventories. Sampling was conducted and population densities estimated using the techniques specified for Audubon winter bird population studies. Belt and pace transects were employed to sample the perennial vegetation and substrate at most of the study sites. Raptor

surveys were conducted twice in Rose Valley following the guidelines of the California Department of Fish & Game Statewide Raptor Survey Program. Observations of both diurnal and nocturnal raptors were recorded throughout much of the Coso KGRA, with special attention concentrated on areas of high raptor activity. The second field survey included a breeding bird census as well as bird population inventories during the winter months and the spring and fall migratory periods (Guthrie, 1979). It was carried out for the Bureau of Land Management by Rockwell International. The same eight sites selected for the winter bird studies of Zembal, Massey, and LaRocque (1978) were used in this investigation. Standard census techniques were utilized to estimate bird population densities and annotated lists of breeding, wintering, and migratory bird species were compiled for the Coso region. Detailed records were made of all raptor sightings and major areas of raptor use were identified. No rare, threatened, or endangered bird species were recorded.

The mammal fauna of the Coso region has been the subject of several recent investigations. Matson (1976) studied the distribution and relative abundance of rodents in the Owens Lake region immediately to the northwest of the Coso KGRA. Eleven field stations were established in ten plant associations, several of which are also found in the Coso area. Rodent populations were sampled by trapping at each station and data on soils and vegetation were also taken. The relationships among soil texture, vegetation properties, and rodent distribution and diversity were discussed.

Zembal, Gall, Kruska, and Lobnitz (1978) carried out a survey of mammal populations on the Navy fee lands within the Coso KGRA. This inventory was designed to determine the presence, distribution, relative abundance, and

preferred habitats of all small and medium-sized mammals. Nocturnal rodents were sampled by live-trapping at 19 sites, while diurnal ground squirrel populations were assessed by live-trapping at 15 sites and by direct visual observations. The Mohave ground squirrel, officially listed as rare by the California Department of Fish & Game, was found to be distributed throughout the Navy fee lands. Quantitative data were recorded on vegetation composition and soil texture in the vicinity of Mohave ground squirrel burrows at eight of the trapping locations. Bats were taken by mist-netting, usually at or near water sources. Direct observation and field signs such as burrows, tracks, and scat were used to estimate the abundance of carnivores and rabbits.

Baseline data on small and medium-sized mammals were gathered throughout much of the Coso KGRA by Rockwell International under contract to the Bureau of Land Management (Leitner, 1979). Live-trapping for nocturnal rodents and diurnal ground squirrels was carried out in early summer at five sites representing three major habitat types. Three supplementary sites were also sampled for ground squirrels in order to provide greater geographic coverage within the KGRA. The Mohave ground squirrel was taken at seven of the eight study sites; it appeared to be present in good numbers in virtually all habitats. Bat populations were sampled in fall and summer by mist-netting at seven locations, most of them in the vicinity of water sources. The carnivore fauna was inventoried by establishment of over 100 artificial tracking stations along roads within the KGRA. Carnivore species present were detected by identification of tracks left at these stations. Direct visual observations of carnivores as well as rabbits provided additional data on the occurrence and habitat preferences of these species.

Feral burros are the most important and abundant large mammals inhabiting the Coso KGRA. Considerable attention has been given to the management of feral burros on the China Lake Naval Weapons Center because they pose hazards to military test operations and cause damage to natural ecosystems. Recently, the Naval Weapons Center prepared a Draft Programmatic EIS that analyzed alternative management strategies for all burro herds within the NWC boundaries (U. S. Naval Weapons Center, 1981). Although this document does not specifically deal with the feral burro herd in the Coso region, it does summarize and discuss available data on burro population growth and its impacts on vegetation, soils, and water sources within the NWC in general. Feral burros in the Coso KGRA itself were studied by Rockwell International for the Bureau of Land Management (Woodward & McDonald, 1979). During January, March, and May burros were censused from the roads and the locations of all groups seen were plotted on a map. The size and composition of these groups were also recorded. Areas of relatively high burro use were identified by noting the extent of browse utilization on belt transects at ten sites representing major vegetation types and by constructing a use index through counts of burro droppings on transects at 29 sites.

Data Adequacy

Wildlife data adequate for general planning purposes are available for those portions of the Coso KGRA that have reasonable geothermal potential. There is a fairly complete inventory of wildlife species present, with data on their seasonal status and their distribution relative to major habitat types. Surveys were conducted in much of the area for rare, endangered, or otherwise protected wildlife species. A number of sensitive habitats such as water sources, raptor nesting and foraging sites, and carnivore den areas have been identified and located on regional maps. However, siting of geothermal

facilities would still require detailed investigations to determine the presence or absence of rare or sensitive wildlife species and important habitats.

Aquatic Habitats

Although the Coso KGRA is located in a desert region, a few aquatic habitats are present here. These include Haiwee Reservoir, Little Lake, Haiwee Spring, and a series of small streams that flow down the eastern slope of the Sierra Nevada.

Haiwee Reservoir, the largest body of water in the region, is located just north of Rose Valley. This long, narrow impoundment is a part of the Los Angeles Aqueduct system and is operated by the Los Angeles Department of Water and Power (LADWP). The LADWP has been collecting basic water quality data at Haiwee Reservoir for many years. Extensive chemical analyses of the water were run bimonthly prior to June 1979. Since then, they have been carried out on a monthly basis. These analyses have included routine determination of boron concentrations each month. Heavy metal analyses, including arsenic and mercury, are made once a year. Plankton samples have been taken weekly and standard counts recorded. These sampling data are published each year in the LADWP Annual Report (George Thomas, LADWP Reservoir Water Quality Control, personal communication).

The other aquatic habitats in the vicinity of the Coso KGRA were investigated by Rockwell International under contract to the Bureau of Land Management (Feldmeth & Soltz, 1979). The results of these studies were published as part of a Technical Report on field ecology (USDI Bureau of Land Management, 1980c). Data on physical, chemical, and biological character-

istics were gathered for Little Lake, Haiwee Spring, and the Sierra streams. Water temperatures and dissolved oxygen concentration were measured at Little Lake; depth profiles were also determined for this shallow body of water. Water chemistry analysis included the following parameters: total hardness (CaCO_3), calcium, magnesium, sodium, potassium, total alkalinity (CaCO_3), hydroxide, carbonate, bicarbonate, sulfate, chloride, nitrate, electrical conductivity, boron, fluoride, pH, and total dissolved residue. Both qualitative and quantitative assessments of zooplankton populations were carried out and invertebrates were collected with dipnets and an Ekman dredge. Dipnets and gill nets were used to sample fish populations. At Haiwee Spring temperatures were recorded and water samples taken for chemical analysis. Aquatic plants and invertebrates were also inventoried. Water chemistry was analyzed in two of the streams and in two springs on the eastern Sierra slope and aquatic invertebrates were collected from another of the streams.

Data Adequacy

All aquatic habitats in or near the Coso KGRA have been identified and located on regional maps. Most of them have been inventoried for rare, threatened, or endangered plant and animal species and for other sensitive biotic resources. Coverage has been adequate for all planning purposes.

The water chemistry of most of these aquatic habitats has been characterized. Samples for analysis were generally taken on only one or two occasions, so there is little information regarding seasonal or annual variability in water chemistry. Nevertheless, these data are adequate for purposes of planning for geothermal development.

Data Relating To Ecosystem Quality Issues

Species and Habitats of Special Concern

There have been a number of recent surveys of the Coso KGRA aimed at the identification of rare or endangered plant and animal species and the location of habitats of special significance.

The vascular plant inventory of the four relatively small Navy fee land parcels included systematic sampling of perennial and annual plants at several field sites (Zemba, Gall, Kruska, and Lobnitz, 1978). In addition, a few hundred hours were spent in reconnaissance of much of the area, methodically searching for and identifying all plant species. No species listed as rare, threatened, or endangered by either state or Federal authorities were encountered; a single population was found of a species considered to be rare by the California Native Plant Society (CNPS). Henrickson (1979) sampled vegetation at 99 sites scattered throughout most of the Coso KGRA and in some adjoining areas. His report also included a regional checklist of vascular plants, compiled from all available records. No plants officially listed as rare, threatened, or endangered were found. A population of one species considered by the CNPS to be rare and endangered was discovered and a few other plants of limited distribution were also located. Several botanically sensitive habitats were identified and located on regional maps.

Brown (1979) conducted an inventory of amphibians and reptiles in all major habitats within the Coso KGRA. Important amphibian and reptile habitats considered to be sensitive to disturbance were identified. Special efforts were also made to identify any rare, threatened, or endangered species that might be present. None were found, although a single specimen of the desert

tortoise (a California fully protected species) was observed in Rose Valley. It was concluded that no breeding populations of the desert tortoise are likely to be found within the KGRA, however.

Field surveys of bird populations were recently carried out in all major habitats and during all seasons (Zemba, Massey, and LaRocque, 1978; Guthrie, 1979). While no bird species officially listed as rare, threatened, or endangered were observed during these studies, a number of raptors were sighted throughout the Coso KGRA and in adjacent habitats. These included such high interest species as the prairie falcon and golden eagle. Areas important for raptor nesting and foraging were located and mapped.

The Mohave ground squirrel, classified as a rare mammal by the California Department of Fish & Game, was documented within the Coso KGRA during two wildlife inventories (Zemba, Gall, Kruska, and Lobnitz, 1978; Leitner, 1979). These diurnal rodents were found in almost all major habitats and at most sites where live-trapping was carried out. Data on relative abundance and habitat preferences were gathered in the course of these studies. The ringtail, a small nocturnal relative of the raccoon that is fully protected under California law, was determined to be present in the KGRA (Leitner, 1979). Ringtail footprints were found at two tracking stations during a carnivore survey. Feral burros, although not native to the region, constitute a species of special concern. There is a high level of public interest in these animals and both state and Federal laws govern their management. Data were collected on burro numbers and distribution within the KGRA and areas of high burro use were identified during a recent study (Woodward & McDonald, 1979).

Aquatic habitats are a rare resource in and adjacent to the Coso KGRA. The existing streams, springs, and other wetland areas have been identified

and mapped (Feldmeth & Soltz, 1979). These habitats were also inventoried for the presence of rare, threatened, or endangered species of plants and animals; none were discovered during this study.

Data Adequacy

The biological studies that have been carried out recently have identified several plant and animal species that are designated as rare or fully protected by the State of California or by private conservation groups. No species listed as threatened or endangered under Federal law have been recorded. Several habitats of high importance or sensitivity have also been identified and mapped. These surveys are adequate to indicate in a general way the biological resources that will require special protection or management. In addition, there are some data available to indicate the exact location of certain species or habitats of special concern. However, much of the KGRA has not been inventoried in detail. Site-specific data on the presence of rare or fully protected plants and animals are not available for many locations that could be used in the future for roads, wellpads, or power plants.

Nature of the Geothermal Resource

While there have been a number of geological and geophysical studies of the geothermal system at the Coso KGRA (USDI Bureau of Land Management, 1980b), little direct information is available concerning the nature and extent of the geothermal resource itself. Only two exploratory drill holes have been completed within the KGRA and very limited fluid production was obtained in both cases. The results of chemical analyses of the geothermal fluids are presented in USDI Bureau of Land Management (1980b). They indicate that the reservoir fluid may be relatively high in total dissolved solids

(5000-6000 mg/l) and dominated by sodium chloride. High levels of arsenic and boron were reported, but no determinations were made for other potentially hazardous constituents. Concentrations of non-condensable gases, such as hydrogen sulfide, in the reservoir fluid are unknown. The total geographic extent of the reservoir is also unknown; determination of its limits will require additional deep exploratory drilling.

Data Adequacy

Information regarding the physical and chemical properties of the geothermal resource at the Coso KGRA is inadequate for assessment of potential impacts to the local ecosystem. Since existing data are insufficient to define the size and extent of the geothermal reservoir, planning for protection of biological resources during the development process is also seriously hampered.

Ecosystem Protection

Geothermal development within the Coso KGRA will take place primarily on public lands administered by the BLM and on lands withdrawn for or owned by the China Lake NWC. These two agencies have recently prepared Environmental Impact Statements that deal with the environmental effects of their respective geothermal programs (U. S. Naval Weapons Center, 1979; USDI Bureau of Land Management, 1980e). As a result, there is a great deal of information available that is relevant to the concerns for ecosystem protection that were identified at the Coso Geothermal Workshop.

Development activities on the Navy fee land parcels will be permitted by the China Lake NWC and will be undertaken only after additional site-specific environmental assessments. Conditions for the mitigation of impacts

to the local ecosystem will be specified by the authorities at the China Lake NWC. Mitigation measures to protect soil, vegetation, and wildlife resources on each of the four parcels of fee land were described in the Coso Programmatic EIS (U. S. Naval Weapons Center, 1979). The China Lake NWC will require the geothermal contractor to take appropriate mitigation measures during each phase of development.

Development activities on the lands leased by the BLM will be subject to mitigation and monitoring requirements specified in the pre-leasing EIS (USDI Bureau of Land Management, 1980e). The mitigation measures include:

- Plans for the protection of aquatic habitats such as Little Lake and springs used as wildlife water sources.
- Plans for the protection of soils against wind and water erosion and for revegetation of disturbed areas.
- Plans for the protection of sensitive wildlife and their habitats from noise and disturbance, for minimizing surface disruption of habitat, and for prevention of wildlife access to waste sumps.
- Plans for the protection of the habitats of rare and endangered plant species.

A number of monitoring programs designed to detect ecosystem impacts and to evaluate the effectiveness of mitigation measures are outlined in the appendices to the pre-leasing EIS (USDI Bureau of Land Management, 1980e). In most cases, the lease field developer will be responsible for gathering the required environmental data. Baseline data for water chemistry and water levels in aquatic habitats will be acquired prior to development and monitoring continued on an appropriate schedule during the production phase. A detailed soils monitoring plan was provided that would evaluate erosion and the possible effects of cooling tower drift deposition. Effects on wildlife and vegetation will be monitored by documenting habitat loss, changes

in numbers of the rare Mohave ground squirrel, buildup of cooling tower drift components in the bodies of plants and animals, and any alteration in physiological condition of vegetation near cooling towers. Sensitive habitat features such as raptor nesting sites and carnivore den areas will be identified and mapped on a site-specific basis.

The Conservation Division of the U. S. Geological Survey (USGS) will be responsible for regulation of lessee activities, including those that may affect ecosystem resources. A lessee must submit to the USGS a Plan of Operations prior to initiating each new development phase on a given leasehold. The USGS must then prepare an Environmental Assessment for each Plan of Operations and will require implementation of the appropriate mitigation and monitoring plans.

Data Adequacy

The geothermal development programs of both the China Lake NWC and the BLM incorporate many safeguards for the protection of ecosystem quality. Available documents address most of the issues that have been raised. The schedules and procedures for leasing and development have been clarified and the agencies responsible for environmental protection have been identified. Detailed mitigation measures and monitoring plans have been proposed and the mechanisms for implementation have been specified.

A comprehensive ecosystem protection plan that would apply to all developers of the geothermal resource would be desirable, however. Duplication of effort might be avoided and greater cost-effectiveness achieved by the imposition of standard mitigation and monitoring requirements throughout the KGRA. In addition, it would be desirable to involve all participants in

a coordinated advance planning effort. Such an approach could help developers to identify and avoid environmentally-sensitive areas at the outset and minimize surface disturbance by encouraging shared construction and use of facilities like roads and pipelines.

Habitat Loss and Alteration

Since there is no definitive information on the size and geographic location of the geothermal resource in the Coso KGRA, it is impossible to accurately predict the total cumulative habitat loss that could accompany full geothermal development. For the same reason, it is also difficult to specify the kinds of habitats that could be affected. The development scenario described in USDI Bureau of Land Management (1980e) proposed that a total of 12 electric generating units and 300 wellpads might be constructed within the KGRA. The estimated cumulative habitat loss was given as 2260 acres, although another estimate from the same document was approximately 74 acres for each 50 MW(e) generating unit. The latter figure included all supporting facilities, such as wellpads, roads, pipelines, and transmission lines. A recent study of habitat loss at The Geysers geothermal field yielded an average value of 90 acres per standard 110 MW(e) generating unit, again including all support facilities (Eaton, 1981).

It may be possible to mitigate habitat losses to some extent by a systematic revegetation program. Restoring vegetative cover to cut and fill slopes along roads and on wellpads, as well as replanting all disturbed areas upon project closeout, would be of great value. However, it is well-known that desert vegetation re-establishes itself very slowly following disturbance and that efforts at revegetation are often ineffective (Wallace, et al., 1980).

There is now considerable information available that is relevant to problems of arid land revegetation. Wallace, et al. (1980) have summarized a number of important recent findings regarding the ecology and physiology of Mohave Desert plants that would be of value for planning revegetation programs in the Coso region. Recommendations for native shrub species that might be useful can be found in Graves (1976) and Wallace and Romney (1980). Methods for facilitating germination and establishment of several important Mohave Desert shrubs are presented in Graves, et al. (1975), Springfield (1970), and Williams, et al. (1975). Other reports discuss the use of nitrogen fertilizer and sprinkler irrigation in re-establishing desert vegetation (Hunter, Romney, Wallace, and Kinnear, 1980; Wallace and Romney, 1972) and the need to protect plantings from depredations by wildlife (Hunter, Romney, and Wallace, 1980; Hunter, Wallace, and Romney, 1980).

The construction and maintenance of roads, pipelines, and transmission lines in the Coso KGRA will lead to habitat alterations in addition to the obvious elimination of some areas of natural vegetation. The effects of desert roadways in collecting, concentrating, and redistributing surface water runoff was investigated by Johnson, et al. (1975). They found that both paved and unpaved roads in the Mohave Desert were bordered by strips of natural vegetation that showed greatly increased productivity and diversity, probably due to greater water availability. Vasek, Johnson, and Eslinger (1975) studied the impacts of a buried natural gas pipeline on Mohave Desert vegetation. They noted the rates of natural re-establishment of vegetation in areas of differing productivity and attempted to estimate the time that would be required for complete restoration to original conditions. They also observed the capabilities of various desert plant species to become

established on disturbed surfaces. The impacts of construction and operation of transmission lines on natural vegetation were examined at a number of sites in the Mohave Desert (Vasek, Johnson, and Brum, 1975). Two transmission lines were chosen for the study, one quite recent and the other constructed 33 years before. Vegetation along the edges of maintenance roads and under the conductors between supporting pylons showed an enhancement, while at the bases of the pylons there was drastic disturbance that was not completely repaired after 33 years.

Habitat alterations might also occur during geothermal development as a result of the operation of vehicles off maintained roadways. Several investigators have documented the effects of heavy off-road vehicle use at various sites in the Mohave Desert (Davidson and Fox, 1974; Stebbins, 1974; Wilshire and Nakata, 1976). These studies are in agreement that long-term adverse impacts can result. Among the observed effects are soil compaction, removal of vegetation, and increased wind and water erosion.

There is the potential for alteration of aquatic habitats as a result of large-scale production of geothermal fluids during electric generation. Unfortunately, the possible hydrologic connections between the deep geothermal reservoir and surface springs are not well understood (USDI Bureau of Land Management, 1980b). Although the cold springs in the area probably represent discharges of shallow ground water and are very likely unrelated to the geothermal reservoir, there are no data available that would help to resolve this issue directly.

Data Adequacy

Estimates of potential habitat loss per generating unit, based upon

experience at The Geysers and elsewhere, seem reasonably accurate. However, steps should be taken to site geothermal facilities carefully, minimizing habitat loss and avoiding sensitive biological resources. Data should be collected during the development process to document the effectiveness of such mitigation measures.

The difficult problems of revegetation of disturbed lands under arid conditions have been addressed in a number of studies. Methods have been developed to facilitate revegetation, using native desert shrubs. However, site-specific investigations should be carried out at the Coso KGRA to identify the plant species best adapted to local conditions and to determine the best procedures to ensure successful establishment.

Data concerning the effects of construction and operation of roads, pipelines, and transmission lines on natural desert vegetation are readily available and the effects of off-road vehicle traffic on the desert environment are also well documented.

There is a serious lack of data regarding the possible effects on aquatic habitats of large-scale withdrawal from the deep geothermal reservoir. Knowledge of the hydrologic connections that may exist is not adequate to allow impact prediction.

Cooling Tower Emissions

Stress and damage to native vegetation has been observed near the geothermal power plant units at The Geysers since 1973. Pacific Gas & Electric Company has carried out a number of studies to determine the cause and to document the extent of this phenomenon (Osterling, 1976; Malloch, et al., 1979). The evidence now strongly suggests that boric acid (H_3BO_3)

emitted in cooling tower drift is responsible for these effects. Boron is present as a dissolved solid in the geothermal steam produced at The Geysers field. Since the condensed steam is used as the circulating fluid in the cooling cycle, boron appears as boric acid dissolved in drift droplets emitted from the power plant cooling towers. Both arsenic and mercury are also present in the wellhead steam at The Geysers and are known to be released from the cooling towers (Robertson, et al., 1977). However, rates of deposition in the environment are believed to be so low as to rule out these elements as potential causes of damage to plants or other ecosystem components (Malloch, et al., 1979). Hydrogen sulfide is emitted from the cooling towers at the Geysers Power Plant, but ambient air concentrations (even without abatement) are well below the threshold at which vegetation damage would be expected (Malloch, et al., 1979).

Data Adequacy

It is not possible at present to accurately assess the potential for vegetation damage from cooling tower emissions at the Coso KGRA. While it is probable that evaporative cooling towers using steam condensate will be installed at geothermal power plants here, their drift eliminator designs and drift rates are unknown. Furthermore, the chemical composition of the geothermal fluid has not been adequately characterized and the concentrations of boron and other elements such as arsenic and mercury are not known. The sensitivity of important native plant species to boron and heavy metals has not been determined. Finally, there are no data available that would indicate the predevelopment concentrations of boron, arsenic, or mercury in soils, vegetation, or animal life in the Coso area.

Since experience at The Geysers suggests the potential for impacts on vegetation in the vicinity of power plant cooling towers, certain baseline and monitoring studies should be carried out at the Coso KGRA to help resolve this issue.

Wind and Water Erosion

Most of the Coso KGRA was included in a soils inventory carried out by Rockwell International for the Bureau of Land Management and published as a Technical Report (USDI Bureau of Land Management, 1980d). Soils were grouped into ten general soil units and were mapped at the scale of 1:62,500. Their susceptibilities to wind and water erosion were rated, specific sensitivities and constraints to development were outlined, and potential impacts of the various phases of geothermal development were described (USDI Bureau of Land Management, 1980e).

Data Adequacy

The BLM soils inventory provides data adequate to identify general areas of high susceptibility to wind and water erosion. It will be useful in regional planning, making it possible to avoid soils with high erosion hazard and to take steps to mitigate potential erosion impacts. Site-specific soils investigations will be needed for final location of roads, wellpads, power plants, and other facilities.

Accidental Spills

There have been a number of accidental spills related to geothermal development activities at The Geysers. The pollution incidents recorded from 1965 through early 1978 were summarized and tabulated in Appendix A

of Pimentel (1978). Many spills involved discharge of steam condensate as a result of pipeline ruptures or malfunctions of condensate reinjection systems. Other pollution incidents resulted from failure of waste sumps at drill sites, landslides, or spills of petroleum products or abatement chemicals. Although these accidental releases reached streams in many cases, few spills have caused significant impacts to aquatic biota and even then the effects appear to have been transient. There is a great deal of information available for The Geysers on the chemical composition of materials that may be subject to accidental release and on their potential toxicity to aquatic biota. This information is reviewed and extensive references are provided in Leitner (1978) and Pimentel (1978).

The possibility that agricultural soils in the Imperial Valley could be contaminated by accidental releases of geothermal brines has been the subject of several studies. Layton, et al. (1980) have reviewed the results of these investigations. They include estimates of the probabilities of spills at geothermal power plants (Sung, et al., 1979) and computer simulations of chemical changes that could occur as geothermal fluid mixed with soil (Sposito, et al., 1979). Much of this information may be relevant to impact prediction for the Coso KGRA.

Data Adequacy

The potential for accidental spills will certainly exist in the Coso KGRA as geothermal development proceeds. Since there are very few aquatic habitats in this area, spills are most likely to affect the soils and vegetation of the desert ecosystem. The most important data gap is the lack of information on the chemistry of the geothermal fluid itself or of the steam

condensate and waste brine that will be generated during utilization of the geothermal fluid. Furthermore, there are no site-specific data regarding the interaction of spilled materials with the desert soils or with the natural vegetation. This is not so serious, however, since information on the chemical composition of materials that could be accidentally released would allow adequate general estimates of potential impacts.

Noise Emissions

The existing noise environment of the Coso KGRA has been characterized in two recent documents. The EIS for the Navy Geothermal Development Program (U. S. Naval Weapons Center, 1979) provided a qualitative description of ambient noise conditions on the Navy fee-acquired lands and discussed emission levels typical of aircraft overflights and other intermittent noise sources that presently impact the area. Rockwell International prepared a Technical Report on noise (USDI Bureau of Land Management, 1980a) as part of the environmental assessment of the BLM geothermal leasing program. This report described the existing noise environment of the KGRA in general terms, including present noise sources and human noise receptor sites. It also presented the results of a noise monitoring program that was carried out for two weeks at each of two locations (Rose Valley and Coso Basin).

Bondello and Brattstrom (1978) gathered representative data on ambient sound pressure levels at a number of sites in the California desert. The results of this study include measurements of ambient sound levels in the desert environment both under natural conditions and in the presence of aircraft, motor vehicles, and other man-made noise sources. Although these data were not taken in the Coso region, they indicate the range of sound pressure levels that would be expected there.

Geothermal development will involve the introduction of a variety of intermittent and continuous noise sources to the Coso KGRA. Increased motor vehicle traffic, construction of drill sites, well drilling and testing, and the construction and operation of power plants will all affect the existing noise environment. The potential impacts have been analyzed and modeled, with special emphasis on the attenuation of sound between noise source and human receptor due to distance and topographic barriers (U. S. Naval Weapons Center, 1979; USDI Bureau of Land Management, 1980a). The possibility that geothermal industry noise emissions could have adverse effects on sensitive wildlife species was raised briefly in both of these documents.

The effects of noise on wildlife species in their native habitats are not well understood. The need for carefully controlled field studies of the physiological and behavioral responses of free-living wild animals to long-term, relatively low-level noise exposure was documented several years ago (U. S. Environmental Protection Agency, 1971). A review of recent investigations in this field (Fletcher & Busnel, 1978) indicates little progress; this is confirmed by reference to an extensive bibliography of studies on the effects of noise on vertebrate animals (Brattstrom & Bondello, 1978).

Since these publications appeared, laboratory experiments with three wildlife species typical of the California desert have demonstrated adverse effects from moderate exposures to the recorded sounds of off-road vehicles such as motorcycles and dune buggies (Bondello & Brattstrom, 1979). The effects included hearing loss, greater vulnerability to predation, and misinterpretation of environmental acoustic signals. It is unlikely that such impacts would occur under field conditions in the vicinity of geothermal noise sources because of the rapid attenuation of sound pressure levels with distance.

Field studies of raptors (ferruginous hawks) in Idaho have shown that noise and human disturbance may reduce nesting success (Spencer, Sullivan, and Stanley, 1979). While the discharge of firearms and continuous operation of motors near nest sites produced no significant impact, the disturbance resulting from approach to nests by observers in vehicles or on foot clearly reduced the production of young. The authors recommend that human activity be excluded within 0.8 km (0.5 mi) of active nests and that construction operations be prohibited within 1.6 km (1.0 mi), a proposal that might be applied to raptor nest sites and other sensitive wildlife habitats in the Coso region. The general locations of such habitat features within the KGRA are shown on maps in USDI Bureau of Land Management (1980c).

Data Adequacy

Data on the existing noise levels and on the noise emissions characteristic of the various phases of geothermal development are adequate to predict the most likely changes in the acoustic environment. However, not enough is known of the effects of noise on wildlife to accurately predict the impacts of these changes, especially on the more sensitive raptor and carnivore species. Methodological difficulties make it impractical to carry out the definitive studies that would be required to resolve this issue. The most effective approach to protection of wildlife resources would be to site noisy facilities or operations so as to avoid sensitive habitat features. This will require additional efforts to locate and map all such features prior to development on specific parcels of land.

Weather Modification

The potential for changes in local microclimate as a result of the emission of heated water vapor at geothermal power plant cooling towers has been analyzed at The Geysers (Pacific Gas & Electric Company, 1977a & 1977b). The volume of water vapor emitted is very small in relation to the absorption capacity of the local air mass. Furthermore, the buoyancy of the warm cooling tower plume will tend to minimize any effects close to the ground surface. Simple calculations suggest that ambient relative humidity in the vicinity of a power plant in the Coso KGRA might increase, but by no more than ten percent (USDI Bureau of Land Management, 1980e). There is no evidence that such a minor change would affect native vegetation. Because of the low relative humidities typical of the region, there should be no detectable increase in fogging or icing. No changes in precipitation patterns would be expected.

Data Adequacy

Existing methodology and analyses are adequate to predict the extent of local weather modification that might result from cooling tower operations.

RECOMMENDATIONS

Although existing information is adequate to resolve many of the issues and concerns regarding ecosystem quality, some important data gaps have been identified. As a result of discussions at the Coso Geothermal Workshop and consultation with a number of interested groups and organizations, recommendations have been drawn up that address these data requirements (Table 2). The actions recommended here include ecosystem baseline and monitoring programs, development of effective mitigation techniques, careful advance planning of development projects, and characterization of the geothermal resource itself. These recommendations can only be implemented through a cooperative effort involving geothermal developers, electric utilities, and government agencies at the local, state, and Federal levels.

Species and Habitats of Special Concern

Recent studies in the Coso KGRA have identified biological resources requiring special protection and management. At present, general information is available regarding the location and status of rare and fully protected species and of particularly valuable and sensitive habitats. In the future, site-specific inventories should be conducted for each proposed geothermal development project to ensure that no species or habitats of special concern will be adversely impacted. Such studies should be carried out well in advance of construction activity, as an integral part of the planning process. Particular biological resources that are of concern include:

- (1) rare, threatened, or endangered plants

TABLE 2

RECOMMENDED STUDIES AND ACTIONS

Species and Habitats of Special Concern

Site-specific inventories for rare, endangered, or otherwise protected species and important habitats prior to development.

Nature of the Geothermal Resource

Deep exploratory drilling and reservoir testing to locate and characterize the geothermal resource for purposes of environmental planning and impact prediction.

Ecosystem Protection

Comprehensive ecosystem protection plan to minimize impacts and provide consistent regulatory guidelines for all development programs.

Habitat Loss and Alteration

Minimize land requirements for development through careful advance planning; document actual habitat loss through aerial photography.

Monitor for potential effects of large-scale geothermal fluid withdrawal on springs and their dependent biota.

Develop more effective methodologies for revegetation of disturbed habitat.

Cooling Tower Emissions

Determine baseline ecosystem levels of boron, sulfur, mercury, arsenic, and other materials that may be emitted from evaporative cooling towers and monitor for changing concentrations.

Use aerial photography to detect changes in vegetative health near power plants.

Wind and Water Erosion

No special studies are recommended; site-specific soils surveys and mitigation plans should be effective in minimizing impacts.

Accidental Spills

Gather data on chemical composition and potential ecological effects of geothermal fluids and other materials that may be subject to accidental spills.

Noise Emissions

Map noise-sensitive wildlife areas.

Weather Modification

No special studies are recommended; existing knowledge is adequate for impact prediction.

- (2) Mohave ground squirrel (listed as rare by California Department of Fish & Game)
- (3) fully protected raptor species and their nest sites
- (4) fully protected carnivores (e.g., the ringtail) and carnivore den sites
- (5) feral burros
- (6) springs and other wildlife water sources
- (7) riparian and wetland habitats

Nature of the Geothermal Resource

A program of deep exploratory drilling and reservoir testing should be initiated as soon as possible. This research effort must be adequate to locate and characterize the geothermal resource that is believed to exist in the Coso KGRA. The total number and optimal spacing of exploratory wells cannot be determined in advance, but will depend upon the results of the initial drilling program. The data required for environmental planning and impact prediction include:

- (1) the location and geographic extent of the geothermal resource
- (2) the physical state of the resource--vapor-dominated or liquid-dominated
- (3) reservoir temperatures, pressures, and heat content
- (4) sustained production capability--mass flow vs. time
- (5) appropriate utilization of the resource--electrical generation, space heating and cooling, industrial and agricultural processing
- (6) chemical species and concentrations of non-condensable gases and dissolved solids in geothermal fluids
- (7) ability of the reservoir to receive the necessary volumes of injected waste fluids
- (8) the source of cooling water for alternative electrical power generation systems--steam condensate, surface water, ground water

Ecosystem Protection

A comprehensive plan for ecosystem protection should be part of any commercial development program. An ecosystem protection plan can actually facilitate geothermal development because it will give assurance to all interested parties that impacts will be minimized and that potential problems will be resolved in an environmentally acceptable manner. Such a plan could be incorporated into lease agreements between the owners or managers of lands within the Coso KGRA and the operators that will actually carry out geothermal exploration, development, and utilization. An important element of the plan will be a set of conditions and stipulations that include practical and effective mitigation and monitoring requirements. These conditions and stipulations should be applied uniformly and consistently throughout the KGRA. A second element will be advance planning coordinated among land owners and managers, permitting agencies, and development firms. Advance planning will be concerned with determining when, where, and how development work will proceed. It will include provisions for adequate public and agency input to the process. It will specify the physical siting and arrangement of geothermal facilities so as to avoid sensitive resources and minimize habitat loss. Biologists and ecologists should be involved in the planning process from the start to ensure that all available data and expertise are provided on a timely basis.

Habitat Loss and Alteration

Habitat loss should be minimized and monitored through a three-step process:

- (1) existing aerial photography coverage of the Coso KGRA can be used to document the location and extent of current development features such as roads, mines, and Naval Weapons Center test installations.

- (2) the development plans for each proposed geothermal project can be examined to determine the amount of habitat loss that would take place and to suggest ways of reducing land use conversion.
- (3) new aerial photography can be flown and analyzed following development to show the actual amount of habitat loss, thus acting as a check on the effectiveness of mitigations and providing a more accurate basis for future impact prediction.

Possible effects of large-scale fluid withdrawal on the flow rates, temperature, and chemistry of both hot and cold springs should be monitored. Baseline conditions must be established prior to the initiation of commercial production from the geothermal reservoir.

Research should be carried out to determine the most effective methodologies for revegetation under the climatic and soil conditions of the Coso KGRA. This could include identification of the plant species best adapted to the area, the fertilizer and irrigation regime needed to start plants, and the best procedures for soil preparation.

Cooling Tower Emissions

The ecological effects of substances emitted from evaporative cooling towers can be evaluated through a program of baseline and monitoring studies. Soils, vegetation, and animal life in the vicinity of power plants should be analyzed before operations begin to determine baseline concentrations of boron, sulfur, mercury, arsenic, and possibly other elements that may occur in the geothermal fluid. These concentrations should be monitored every 1 to 2 years during the first 5 to 10 years of operation in order to detect accumulations that might be related to cooling tower emissions. The physiological condition of vegetation near power plants should be assessed visually on the same sampling schedule, using aerial photography with false-color infrared film.

This technique is most effective in detecting areas of stressed or damaged vegetation if the photograph is repeated each time at the season when photosynthetic activity is highest. Results of these monitoring efforts will be most useful if correlated with source term studies designed to determine the chemical and physical form of cooling tower emissions and to measure emission rates.

Wind and Water Erosion

While no extensive studies are required, site-specific soils surveys should be carried out to identify areas of high erosion hazard. Careful implementation of a mitigation plan will help to control fugitive dust and minimize erosion from surface runoff.

Accidental Spills

It is recommended that analyses be carried out to determine the chemical composition of any geothermal fluids or other materials that could be subject to accidental spills. Any potential toxic effects of spills on the ecosystem could then be evaluated by reference to published studies. No further investigations will be needed, but standard mitigation measures should be incorporated into the ecosystem protection plan. These should include adequate design specifications for all pipes, valves, and fluid-handling equipment to prevent operational failures. Contingency plans for containment and cleanup of any spills should also be required.

Noise Emissions

Noise-sensitive wildlife areas, such as water sources and nesting or denning sites, should be carefully identified and mapped prior to development. Geothermal facilities that may be significant noise sources could then be

located so as to avoid adversely impacting these areas.

Weather Modification

It should be possible to predict potential changes in relative humidity, precipitation rates, and incidence of fogging and icing by standard calculations based on evaporation rates from cooling towers, plume mixing characteristics, and water-holding capacity of the ambient air. The remote sensing baseline and monitoring program designed to detect damage to vegetation due to boron or other substances emitted from cooling towers should also indicate changes that might be caused by such factors as increased humidity.

SUMMARY

The prospect for large-scale development of geothermal energy in the Coso Known Geothermal Resource Area (KGRA) has raised concerns for the protection of ecosystem quality. Exploration work is now underway in this California desert region and estimates of the energy resource available here range as high as 650 MW of electric generating capacity for 30 years. The present study was undertaken to identify issues relating to ecosystem quality and to assemble the data base that is available to help resolve these issues. This report then evaluates the adequacy of the existing information and recommends additional work required to close any data gaps.

The Coso KGRA is located just east of the Sierra Nevada in the broad transition zone between the Mohave and Great Basin desert ecosystems. It is a region of low precipitation, with hot summers and relatively cold winters. The natural vegetation is dominated by low, scattered desert shrubs. The fauna is abundant, although limited in diversity. Burrowing rodents, jack rabbits, lizards, and a few breeding birds are among the common species. Other wildlife include raptors and mammalian carnivores such as coyotes, bobcats, and kit foxes. There is little surface water in or near the KGRA. Aquatic habitats are limited to a few springs and a small lake. No Federally-listed threatened or endangered species are found in the region, although the Mohave ground squirrel (listed as a rare species by the California Department of Fish & Game) is present in most habitats.

A number of issues and concerns about ecosystem quality were identified and placed in order of priority during this study. Representatives of many government agencies, the geothermal industry and public utilities,

universities and national laboratories, and the general public all took part in the process of defining these issues. The Coso Geothermal Workshop provided a forum for open public discussion and participation.

The high priority issues included (1) the need for adequate inventories of plant and animal species, as well as habitats, that might require special protection, (2) the need for detailed information about the geothermal resource to assist in planning and impact prediction, and (3) the need for an effective and reasonable ecosystem protection plan. Concern was also expressed for habitat loss and alteration during the course of geothermal development, potential ecological effects of power plant cooling tower emissions, and increased rates of wind and water erosion. Other issues were identified, but were assigned a relatively low priority: accidental spills of potentially harmful materials, noise effects on wildlife, and possible weather modification resulting from the operation of evaporative cooling towers.

The data base available to help resolve these issues was identified, evaluated for adequacy, and summarized in this report. A total of 50 publications and documents were considered to form the relevant data base. They fell into two major categories: (1) those that presented baseline data on the biological resources of the Coso KGRA, including soils, natural vegetation, wildlife, and aquatic habitats and (2) those that were of value in resolving the issues and concerns relating to ecosystem quality.

A variety of recommendations followed from this analysis. The actions proposed here include ecosystem baseline and monitoring programs, development of effective mitigation techniques, careful advance planning of development projects, and characterization of the geothermal resource itself. Resolution of the high priority issues would require such measures as site-

specific inventories for plant and animal species of special concern prior to development, deep exploratory drilling and reservoir testing to characterize the geothermal resource, and development of a comprehensive ecosystem protection plan for the entire KGRA. Most of the other concerns could be adequately met by relatively modest data collection efforts. In some cases, existing data are adequate and no additional studies are felt to be necessary.

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