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Identification and Assessment of Environmental Impacts of the Los Azufres II Geothermal Project

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ABSTRACT

In Los Azufres Geothermal Field, there are eleven power plants in operation, with an accumulated generation capacity of 88 Mw. The installations (power plants, well access roads, gathering system and transmission lines) are distributed in a forest surface of 11000 hectares. The forest is a mixed pine - spruce - oak. In a portion of this surface the Comisión Federal de Electricidad (CFE) has drilled 66 geothermal wells with environmental effects on 114 hectares of the geothermal area. CFE is increasing the generation capacity to 188 MW in this Geothermal Field, with four 25 Mw new units. Before the approval of this capacity increase, CFE determined the impacted environment and the preventive and corrective actions to protect the environment.

Introduction

The Los Azufres Field is the second most important geothermal power project in México. After the technical, economical and feasibility studies, CFE received the approval to increase in this field the capacity from 88 to 188 Mw. This approval requires being respectful to the natural resources and the environment.

Therefore, the observance of the Environmental Legislation was essential. To ensure the ecological equilibrium and minimize landscape changes it is necessary to carry out some compensatory actions. These actions are oriented to prevent, restore and mitigate the negative effects during the various project stages as the construction of access roads, well platforms, and power plants.

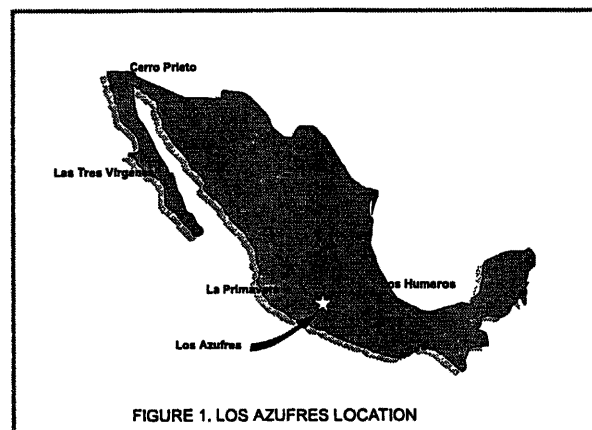
Project Background and Present State

In the fifties, CFE initiated geophysical, geological and geochemical, exploratory studies in Los Azufres area, to locate sites with possibilities of geothermal energy development for electric generation proposes. In 1972 additional exploratory

surveys were carried out and in 1977 the first production wells were drilled. To date, 64 geothermal wells with depths between 600 and 3500 m produce steam for seven 5 MW backpressure units, one 50 Mw condensing unit and two 1.5 Mw binary units. The expansion plan for the near future is the construction of the Los Azufres II project with four 25 Mw condensing units.

Geothermal Project Location

Los Azufres Geothermal Field is located in the "Sierra de San Andres" (San Andres Range), east of Michoacán State. Physiographically is part of the "Eje Neovolcanico Mexicanó" (Mexican Volcanic Belt). Geographically it is located between the 19° 45' 30" - 19° 50' 30" north latitude parallels and the 100° 38' 30" - 100° 43' 00" west longitude meridians. The covered area is approximately 11,100 hectares see Figure 1.



According to the Koppen climatic classification, modified by Garcia (1992), the climate of this region is type C(w1)(w)b(i'), moderate sub-humid. The mean annual

temperature is 18°C. and the annual mean precipitation is 1200 mm.

The geothermal field soil derives from recent volcanic ashes. According to INEGI (Instituto Nacional de Estadística Geografía e Informática) (1981), the present soils in the area, classified with the FAO/UNESCO system are: Andosol humico + Andosol vitrico, Andosol humico + Andosol molico, Andosol humico and Andosol molico.

The vegetation in the influence area is a mixed forest of coniferous and latifoliadas (*Pinus*, *Abies* and *Quercus*) of most important are the following groups.

Mexican Spruce and Pine Forest

This type of vegetal association is developed in elevated sites. The dominant specie is *Abies religiosa* which form a canopy of 20 - 40 m high. Also *Pinus* + *Quercus*, *Alnus acuminata*, *Arbutus glandulosa* associations can be found in this forest. The more common small shrub species founded are *Bacharis conferta*, *Senecio angustifolius*, *Lupinus montanus*, and *Acaena elongate*.

Pine - Oak Forest

This association is found forming dense tree forests of 15 to- 20 m high, characteristic of high sea level sites (2600 m) on the "Eje Neovolcanico Mexicano" (Mexican Neovolcanic Belt). The common species are: *Pinus michoacana*, *Pinus pseudostrobus*, *Pinus montezumae*, *Quercus rugosa*, *Quercus laurina*, *Quercus castanea*, *Alnus acuminata* and *Arbutus xalapensis*.

Both preceding associations show a distribution influenced, in most part, by the effects of the altitude, climate, physiography and soil type. The surface covered by these is almost 80% of the total area.

Legal Aspects

The applicable Mexican environmental legislation to the Los Azufres Geothermal project including the laws, regulations, standards, criteria and programs. The relevant documents are:

Laws

- General Law of Ecological Equilibrium and Environmental Protection. LGEEPA (DOF 16/12/96).
- Forestal Law. (DOF, 22/12/96).

Regulations

- Regulations of the LGEEPA with respect to environmental impact. (DOF, 07/6/1988).
- Hazardous wastes regulations. (DOF, 25/11/1988).
- Forestal Law regulations (DOF, 22/12/1992).

Standards

- NOM-059-ECOL/1994. List of species and subspecies of wild aquatic flora and fauna in extinction, threatened, strange and in special protection program; specifications for protection.
- NOM-003-RECNAT-1996. Procedures, criteria and specifications for exploitation, transport and storage of native soil. (DOF30/5/1997).
- NOM-007-RECNAT-1997. Procedures, criteria and specifications for exploitation, transport and storage of tree branches, leaves, flower fruits and seeds. (DOF30/5/1997)
- NOM-081-ECOL-1994. Maximum allowable noise emission of fixed sources and measurement method. The maximum allowable noise level is between 68(A) and 65(a), for urban zones. For rural zones there are not noise level limits established.

Ecological Criteria

- CE-OESE-004/1989. Ecological criteria for selection, exploration, site preparation and construction of geothermal power systems. (DOF 07/06/1989).

Programs

- Environmental Protection Institutional Program (PIPA) 1993 - 1994.

Environmental Impacts. Identification and Description

The "Matrix Interaction" method is used for identification and description of impacted environment in geothermal power projects. This is a laborious method but is practical and allows one to establish the relations between cause and effects as a result of the participation of interdisciplinary groups.

The "Matrix Interactions" are a modification of the "Leopold" method and presents two analysis levels. Level one is used to connect specific activities of each project stage. In the second level a best analysis is obtained starting from general to particular aspects of the environmental effects. Then the activities are identified in relation with its effects: Activities without negative effects, activities with mitigation actions, activities with unknown effects and activities with potentially important effects.

Taking advantage of the experience gained on other geothermal projects, CFE has identified the impacted environment on Los Azufres II project. The main environmental impacts producing activities are: access road construction, well drilling, plant construction, steam and brine transportation, and well and power facilities operations. Once the impacted environment identification has been made, the preventative actions will be practiced to prevent negative

environmental effects. Those actions are oriented to avoid negative changes in air, water, native soil and vegetation.

Preventative and Corrective Mitigation Actions

To the preventative and mitigation the environmental impacts, have been adopted strategies of the ecological restoration it is most competition actions applied during development of the projects, have been carried out to conform with the following identified impacts:

Construction of Access Roads and Well Drilling Platform

The roads with have been reduced to the minimum necessary (4 m). Also the well platform surfaces have been reduced to 0.7 hectares each. One more important action to reduce the environmental impact produced by platform construction is the use of directional wells. This allows drilling various geothermal wells from one platforms reducing the surface affected by access roads.

In the areas where vegetation classified with some special conservation status is present, the Standard NOM-059-ECOL/1994 is strictly observed. Also the areas with high population density of wild flora and fauna are particularly respected, including the species with special ecological value or size.

H2S. Emission and Monitoring

In Los Azufres Geothermal Power Plants the gas emission composition by weight is: 97% steam water and 3% non-condensable gases. The non-condensable gases composition 97% CO₂ and 3% H₂S.

For recording local climatic information and H₂S content in the air, there are six air quality-monitoring stations in the geothermal field. The recorded information is used to run gas dispersion models, to advance regulations and research purposes. The Mexican environmental legislation has not yet established the limits of H₂S content in the air. The historical data of H₂S air content shown that it is below the EPA allowable limits adopted by the State of California, US.

Residue Control

The liquid and solid residues generated as result of the activities in this Geothermal Project are disposed as the present Mexican environmental legislation permits.

✓Solid Residues

Before the disposal of rocks cuttings and drilling mud derived from the well drilling activities, periodica standard analyses are carried out. This allows verifying the presence and concentration of some compound, element or characteristic that classifies them as hazardous wastes. This standard analysis named "CRETIB" (acronym in Spanish) is oriented to select the approved disposal method.

✓Liquid Residues

During geothermal well drilling, small mud dams or sum holes are used to store the rock cuttings and the residual drilling mud. To avoid soil and surface water pollution, the floor is covered with resistant plastic film or special geo-mesh and a layer of non-permeable clay or both.

The geothermal hot brine is fully injected at depths similar to reservoir. This is an effective environmental, technical and economical solution for geothermal brine disposal.

To ensure that the geothermal fluids do not affect the fresh groundwater during the extraction and injection operations, since 1984 to date, the spring waters have been chemically since 1984 monitored. The monitored springs are distributed over a radius of 20 to 25 km from the Los Azufres Geothermal Field. The monitored chemical and physical data are: pH, C.E., Cl, B, HCO₃, SiO₂, SO₄, Na, K, Li, Rb, Cs, Ca, Mg and As.

Noise Reduction

At beginning of the geothermal field development, the measured noise level in the mufflers was between 100 and 130 dB(A). After an intense research and test program with different muffler models, in 1991 was possible to reduce the level below the maximum permitted by the Standard NOM-081-ECOL 1994. The maximum permitted noise level, established by this standard in urban zones, is from 68(A) to 65(A). There are not yet noise limits for rural zones.

Ecological Restoration

The ecological restoration to reduce the negative effects of the geothermal development in Los Azufres Field, has been done as a process of vegetal succession. The vegetal cover was recovered in the impacted sites, in similar times than the native original vegetation need for. To achieve this process, forestation and grass sowing are the main techniques used:

✓Forestation

The forest conservation is a relevant activity adopted by CFE since the beginning of the exploration works in the area. The well road access and the well platform construction are the two activities with most impact on forest. other serious negative activities, not controlled by CFE, is are the illegal deforestation and the legal but irrational deforestation. **Because is reason** forestation performed by CFE since 1981 has been a permanent seasonal activity. The number of trees planted in that period was roughly 704,560 in a surface of 3000 hectares. The mean surviving factor of tree planting in Los Azufres was improved from 60% in 1981 to 78% in 1994.

These surviving factors were achieved thanks to effective conservation and maintaining practices as pruning, auxiliary irrigation, and a strict phytosanitary control.

✓Grass Sowing

The grass sowing techniques are used to establish a vegetal cover to help or induce the natural propagation of native species in slopes, cooling ponds and well platforms. Two methods are

employed to grass sowing: seed sowing and planting grass in rolls.

Soil Conservation

The techniques applied to soil conservation and prevention of erosion have been the construction of wood squares, and the use of special geo-mesh. Those methods are used in the road slopes and well platform sides. In both cases, the wood squares and the geo-meshes, are anchored to the soil surface. Other common techniques utilized in Los Azufres to prevent pluvial soil erosion are to pave roads and construction of drain and small trenches, sewers, drainage channels, etc.

Flora and Fauna Conservation

On this matter the full observance of the standard NOM-059-ECOL-1994 is the main goal of CFE. If some specie of flora listed in the Standard is located and it's recovery is feasible, then the transplanting to a similar habitat site is done.

The training and cultural diffusion to local inhabitants and to CFE workers with respect to the importance of the conservation of native species is part of the conservation program. Also the CFE workers have instructions to be respectful with the wild flora and fauna species.

Environmental Monitoring

A sampling program of soil and trees into the forest of Los Azufres is established. The porpoise of this program is to obtain an environmental diagnostic. The chemistry analysis of the samples and the damage evaluation of soils and vegetation is necessary for programming corrective actions to recover and preserve the species.

Results

Resuming

Using in site developed and well-known techniques for ecological restoration, recovery to near original conditions is feasible. Also mitigating the negative effects produced during the development of Los Azufres geothermal project has been possible.

The following is the degree of the achievements in each matter:

◊Noise Reduction

The effective design of the silencers used in Los Azufres, which also reduce the water drops drag in the steam discharge to the atmosphere. Those helicoidal silencers, named "ecologicos" produce noise levels below the maximum permitted by the Mexican Labor Standard NOM-081-ECOL-1994 (90 dB during eight exposition hours).

◊Forestation

- ✓ Forested trees adapted and compatible to native forest conditions.

- ✓ Good conserving status and maintenance of native vegetation.
- ✓ The proliferation of natural germination of forest species.
- ✓ Dead leaves and organic matter retention, useful for natural soil formation.
- ✓ Accelerated vegetal succession in affected areas.
- ✓ Reduction of the soil erosion potential.
- ✓ Establishment of various species, mainly of secondary vegetation.

◊Grass sowing

- ✓ Forest regeneration and natural induction.
- ✓ Vegetal succession of native species in grass sowing areas.

With the preceding actions was possible:

- ✓ To reach high surviving factors in the forestation programs.
- ✓ Diminish the erosion on roads and slopes of well platforms. The stabilization of premature riverbed and reduction of suspended solids in pluvial waters. Increase of rainwater infiltration rate. Increase the moisture content of soils for vegetal sustaining.
- ✓ Reduce the negative visual effects in access roads and wells platforms.
- ✓ Create an adequate ambient for the proliferation of some native vegetal species.

Conclusions

In Los Azufres, the required protection and conservation activities have led to contributed to the application of effective methods to restore and preserve the original forest environment.

In Los Azufres Geothermal Field it was possible to reach ecological reordering. This achievement is the best proof of the CFE protection and conservation conscience with in the respect to the environment.

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