Assessment of Environmental Impacts of the Cerro Prieto IV Geothermal Project, Baja California, México

Ricardo Zirahuén Ortega and Celia Gutiérrez Gómez

Comisión Federal de Electricidad, Gerencia de Proyectos Geotermoélectricos
Alejandro Volta No. 655 Col. Electricistas C.P. 58290. Morelia, Michoacán, México

ABSTRACT

The Cerro Prieto geothermal field is the most important geothermal field in México and Latin America, and the second in capacity in the world. It is located at the northern portion of Baja California, Mexico. At this moment the total installed capacity is 620 MW with three power plants (CPI, CPII and CPIII). The power plant of Cerro Prieto IV will increase the capacity by 100 MW. In this paper the methodology for the environmental impact assessment, the description of environmental impacts detected and proposed mitigation activities, are presented.

Introduction

As a primary source of energy the advantages of geothermics are evident compared to the option of fossil fuel burning. Among those advantages is the fact that it is a renewable resource (usually), that its environmental impacts are controllable at moderate costs, and that it has practically no gas emissions with greenhouse effect. However, its advantages are only valid if, during its development, ecological criteria is applied to avoid the impact associated with the construction process, to minimize chemical contamination of air, water and soil, and to lessen acoustic disturbances. These impacts can be avoided or minimized by an adequate design of the geothermal power plant, hence the importance of performing an Environmental Impact Assessment (EIA) before this stage is completed.

This paper presents the adaptation for power plant projects of two EIA methodologies (McHarg, 1971 and HidroQuébec, 1990), their application in the Cerro Prieto IV (CPIV) project, and measures for prevention, mitigation and compensation of detected environmental impacts, applied at the design stage.

Project Description

The project consists of the construction and commercial start-up of four 25 MW net condensing units each. The power plant installation area is 54000 sq. m, including the machine hall, electrical substation, surface equipment for vapor conditioning and areas for the cooling system and tower, as well as the extraction system for non-condensible gases. These units are automatic and only require personnel to supervise the machinery and operation data

In addition to the construction of the power plants, well drilling is required to obtain the necessary geothermal steam. The platforms for each of the wells will have an approximate surface of 3825 sq. m. (45x85 m), necessary for the installation of the drilling equipment and piping yard, as well as an additional surface of 2520 sq. m. (30x84 m) for the waste and mud containers. Steam will come from 20 productive wells with an average depth of 2800-3000 m. The expected well production is estimated at 40 t/h steam and 60 t/h brine for each one. The steam will contain non-condensable gases in a 2,0 to 4,0 ratio.

2000 meters of carbon steel pipes will be installed on cemented structural supports on concrete, to conduct the steam to the system. These steam pipelines will have every 100 m a structure called omega to absorb pipe expansion and contraction. The maximum consumption of separated steam for each unit will be 200 t/h with 99,9% quality. It will have a closed-type cooling system, with a direct contact condenser and a cooling tower. The power plant will be equipped with an electric substation connected to a 161 kV transmission line.

To access the power plant a double lane paved road will be constructed, 1660 m long and 10 m wide.

It is expected that the fraction of non-condensible gases (6 t/h maximum) extracted with geothermal steam (194 t/h) will be in the range of 96% carbon dioxide (CO_2), 3,5% hydrogen sulfide (H_2S) and 0,5% ammonia (NH_3). Through the condenser, a portion will dissolve in the cooling water. Then only a minor fraction of the gases (that which does not react with other dissolved chemical species in the cooling water) will be discharged to the atmosphere through the cooling tower. The amount not absorbed is extracted from the condenser and dispersed into the atmosphere through 50 m high stacks or by the stacks of the cooling towers ventilators.

Based on this, it is estimated that maximum gas flow for a 25 MW unit, and for each emission source, will be 5000 and 210 kg/h for CO_2 and H_2S, respectively. These amounts represent an approximate increase in the present field emissions of 7 and 8%, respectively. Of the gases discharged to the atmosphere, only H_2S modifies the quality of the air, because of its characteristic rotten-egg smell at low concentrations and toxic effects at high concentrations.

In the construction stage noise will be generated by the operation of machinery during the conditioning of access roads and terrain leveling, and by the operation of drilling machinery. Noise will also be generated by the circulation of motor vehicles. And noise will be emitted during the development and assessment of wells due to the discharge of geothermal fluids. In the operation stage of the project, there will be noise emissions by equipments, pipes and connections conducting the steam flow, separated water and/or steam-water mixtures. The noise will not be higher than in any other construction site and measures will be taken to comply with established limits under Mexico's environmental and labor norms.

Brief Description of the Natural Environment

Flora. The geothermal field is located at the northern portion of Baja California, México, in the floral Province of the Coastal Plains of the Northeast (Rzedowski 1978) (Figure 1), characterized by predominant xerophilous bushes and spiny woods. Among the most representative species of the area are *Larrea Tridentata, Pluchea sericea, Prosopis juliflora, Olneya tesota, Ambrosia chenopodiifolia, A. dumosa* and *A. deltoidea.* However, the construction site of the power plant, roads and platforms was once farming land abandoned because of its high salinity, which is also the reason for the sparse vegetation typical of desert land. Basically, there are salt cedars (*Tamarix* sp.), creosote bushes (*Larrea tridentata*), burbushes (*Ambrosia dumosa*) and arrow weeds (*Pluchea sericea*).

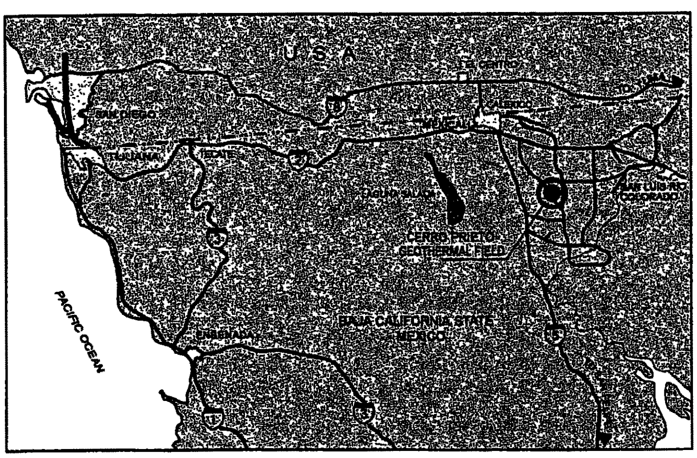

Figure 1. Cerro Prieto Location.

Fauna. The fauna of the place is a scarcely-populated community and it is conformed mainly of various species of very common animals, characteristic of places with disturbances. According to the official Mexican norm, none of these species is in danger of extinction nor are they under any other kind of ecological preservation status. However, it is convenient to mention the evaporation pond. Although it is an artificial body of water recently created, in biological terms it is being populated by such vertebrates as the *Micropterus salmoides* and *Cyprinus carpio* fishes, along with 30 other different species of migrating birds which, according to Gutiérrez et al. (1995), use it mainly as a winter haven.

Identification of Impacts and Mitigation Measures

Methodology

The environmental impact analysis was based on the McHarg (1971) resistance level matrix, based on impact hierarchy, which has demonstrated its versatility in all types of projects, and which can be used to classify all identified components (variables) as a function of their "vulnerability" or "resistance" to the project. Also used was the method of classification of the environmental variables (biotic and abiotic environment components) designed by HydroQuebec (1990). The level of identified (or predictable) impact is shown at three defined levels, as follows:

- **High**: When an environmental element is destroyed or very damaged. Implementation of the project requires extensive modifications that question the feasibility of the project.
- **Medium**: When an element is disturbed. It creates technical difficulties but does not question the feasibility of the project.
- **Low**: The element is modified by the project. Only minor technical adaptations are necessary.

The value given to the element is obtained from criteria such as: intrisinc value, rarity, importance, situation in the environment, and legislation affecting it. This assessment is done taking into consideration the estimated medium value given to the element by specialists, analysts and general public. The importance granted to the regional dimension of the element differentiates it from the predictable impact.

A determined value is given to an element considering the opinion given to the intrinsic value, rarity or frailty of the element by environmental specialists. A team of analysts determines the value after examining the files that the specialists have compiled on each of the environmental aspects considered, conclude with the information available to perform their tasks.

The value given to an element by the public is determined in two ways: opinions are gathered and main users found during the inventories and through information in public documents, such as city and state urban development blueprints. Five value levels have been established for the element:

- **Legal**: When the element is protected or in process of being protected through a law that prohibits or closely watches over the appropriate development of the project, or when it is very difficult to obtain the corresponding government permit.
- **High**: If the element demands, because of its uniqueness, a special protection or conservation, obtained by consensus.
- **Medium**: The element in question has characteristics that make its conservation of great interests, without needing general consensus.
- **Low**: When the conservation or protection of the element is not an object of excessive concern.
- **Very Low**: If the conservation and protection of the element is of no concern either from the public or the specialists.

From the interaction of the three impact levels and the five value levels for the element, six resistance levels are obtained:

- **Obstruction**: When an element is protected by law. It involves an element that demands a large investment to overcome the technical difficulties, almost unsurpassable.
- **Very Big**: Applied to an element that will only be disturbed in a limit situation. This kind of element must be avoided as much as possible.
- **Big**: In this case the element should be avoided because of its ecological frailty or its high protection cost.
- **Medium**: The element may be interfered with, evidently with prevention and mitigation measures.
- **Weak**: The element may be used applying minimal mitigation measures.
- **Very weak**: Intervention on this element does not imply inconvenience.

These arrangements are established on the following matrix (Table 1):

Table 1. Resistance Level Matrix.

Predictable Impact	Resistance				
High	Obstruction	Very big resistance	Big Resistance	Medium Resistance	Weak Resistance
Medium	Obstruction	Big Resistance	Medium Resistance	Weak Resistance	Very Weak Resistance
Low	Obstruction	Medium Resistance	Weak Resistance	Very Weak Resistance	Very weak Resistance
	Legal	High	Medium	Low	Very Low
	Value				

The analysis of the inventories to define them according to their resistance to the project, allows their grouping into several categories, according to their higher or lower sensitivity to the project. In this way the locations that need special protection in the affected area can be highlighted. This classification of inventories was useful in this paper to compare the variables, evaluate the impacts and place them in the different stages of the project through a check list.

The range of the impact allow to group the impacts as follows:

- **Regional**: If the impact of a certain activity exceeds the boundaries of the Cerro Prieto geothermal field.
- **Local**: If the impact caused by the assessed activity does not affect beyond the established boundaries of the geothermal field.
- **Punctual**: If the impact is evaluated as direct, and only if it circumscribes to the site.

In addition, a distinction was made between the significant and non-significant impacts, independently of the level they reach. Also defined is the description of the impacts, their beneficial or adverse nature.

Following, and as an example, is one of the four check lists made using this methodology, where previously it was defined that the significant and non-significant impacts have the same resistance level, with the difference that the latter are of local scope (Table 2).

Impact Description

As shown in the check list of impacts and resistance analysis, the elements susceptible to impact (identified elements) are: soil, flora, fauna, air, water, landscape, social and economy. Values were assigned to these elements, considering the following:

Soil. A low value was assigned to it, because on the sites with definite impacts, the soil has lost its farming condition due to high concentrations of soluble salts and its low percentage of organic matter.

Flora. According to observations and bibliography, the local flora and vegetation do not represent an obstacle for the realization of the project, evaluated from the viewpoint of its diversity, rarity, naturalness and/or singularity, thus, it was assigned a low value.

Fauna. Same case as before, with the understanding that this project will not influence significantly the present state of the solar evaporation pond, which is the place where some fish and bird species are found with some of the attributes mentioned in the fauna section.

Landscape. It was given a low value because of not having any aesthethically exceptional attribute.

The rest of the elements (air, water, social and economy) were assigned a medium value because of the special interest society in general has on these issues.

Site Preparation Stage

It is estimated, for soil and flora, significant impacts at low grade will have a punctual range with very weak resistance because these elements have low values due to high concentrations of soluble salts and the absence of individuals within the areas destined for the power plant, well platforms and access roads. Air and water elements are given low-level non-significant impacts with punctual ranges, the resistance they have on the project are in the weak level because of a general interest in preserving them in optimal conditions. For landscape, even though the impact is low non-significant with a local range, similar to the other two, its resistance in the project will be very weak because of the low value of this element, as CPIV is within the affected area of the geothermal field. The fauna element has a low value because the few individuals found in this part of the field are not objects of great concern and the impact on their habitat will yield a very weak resistance level.

The social element found in the affected area of the project to which a medium value is given, will be impacted on a low significant level, therefore, the resistance value for this element will be weak. The economy element, with characteristics similar to the social element, will show a beneficial non-significant low-level impact.

Drilling Stage

At this stage, although the non-beneficial impacts caused to all elements will remain in the low grades, in the cases of air and water they will transform from non-significant to significant because in this stage induction, development and assessment of the wells will take place, activities in which gases will be discharged at the atmosphere and an adequate disposal of water separated from steam will have to be made; consequently, the impact range of the water element will turn from punctual to local. The resistance that all the involved elements involved impart to the project remain at very weak to weak levels.

Construction Stage

Once the wells are evaluated in the power plant's construction stage, they will remain flowing through small diameter pipes, therefore the gases and separated water flows will be minimal and their impacts to the air and water elements will not be significant. The landscape will be altered one level higher than in the drilling stage as a consequence of the presence of machinery, support structures and construction materials, however, the resistance level will continue at a weak level. The range of the social impact in this stage will extend due to the noise generated by machinery, vehicles and employees.

Operation Stage

While meeting the energy demand required by the regional large and medium industry the economy element will be impacted significantly. Regionally, with the operation of the CPIV power plant, the soil, flora and fauna elements at this stage of the project are given punctual significantly low beneficial impacts, since they will be given special treatment, as described in the corrective or compensation measures.

Because during the project's useful life the non-condensable gases will be discharged to the atmosphere and the water to the solar evaporation pond, the elements air and water have been assigned for this period a non-beneficial significant impact of medium level and a local range; these values give a medium resistance to the operational stage on the project, which means a continuos assessment of their quality.

The landscape element recovers the resistance level characteristic in stages previous to the construction of the power plant and will even improve as a result of the reforesting activities. Although the range of the non-beneficial significant impact on the social element will suscribe to the area of the geothermal field, the impact level will change from low to medium. Thus, the CPIV power plant project interferes negatively at this stage on only four of the eight elements mentioned in the list of impacts and resistance analysis.

Corrective or Compensation Measures

Following is a brief description of the environmental protection programs already implemented at the Cerro Prieto geothermal field, as well as the ones proposed for the CPIV project:

Ecological Planification for the opening of roads and platforms. During the design and construction of roads and platforms environmental issues are taken into consideration, including: minimal area required, areas with plants that due to their ecological conservation status, size or aesthetic quality should be avoided, use of disturbed zones or with low flora and fauna density, etc. The old network of sideroads will permit easy access to each of the platforms.

Residual Control. A detailed physical and chemical characterization and a strict supervision in the field will be performed on solid and liquid residuals that are originated by the construction, in order that production, handling and disposal activities will be undertaken according to Mexican environmental norms.

Vegetation residues from clearing activities will be chopped and returned to the soil as organic matter in the sites to be reforested. Once dry the liquid residues at the drilling stage will undergo CRETIB testing to determine their handling and final disposal.

The water-proofing of the mud dams used during drilling, will be done by coating the bottom and sides of each dam, assuring a complete and durable water-proofing that will also permit cleaning and rehabilitation tasks without rupture problems.

All CFE facilities, permanent and temporary, will have systems for solid waste and domestic liquids collection and confinement. Treatment and disposal will be done according to the corresponding sanitary and environmental norms.

The separated water in the separation modules or in the off-line well platforms will be discharged by canals to the solar evaporation pond operating at the field. 60% of the incoming water evaporates and the rest is reinjected to the field through eight wells located in and around the pond. Presently, the solar evaporating pond and the injection wells have the sufficient capacity to dispose of all the residual water from the CPIV Power plant. It is estimated that this water will contribute approximately 12% to the volumetric flow of the residual water coming into the pond.

A drainage network and a treatment plant will be constructed for the discharge of sanitary residual waters. This plant, through a system of activated muds and extended aeration, will process flows from the temporary facilities at the construction and start-up stages, and the flows from the permanent installations of the power plant. The treated water will be used in the program of rehabilitation and reforestation of saline soils in the geothermal field, which will permit great water savings.

The operation of the power plant will not generate industrial residues because of the type of process, however, during the long maintenance periods residues that can be identified as dangerous include: wasted oils, expired paints, batteries, solvents, electrolytic solutions, woods treated, as well as muds from the basins of the cooling tower and some residues from compounds used to treat tower construction materials. Therefore a temporary warehouse for these residues is proposed, according to current normativity.

Reforestation Program. Due to high concentrations of soluble salts in the soil, during the construction and operation of the CPI, CPII and CPIII power plants a proposal was made for the ecological restoration of the site by means of a reforestation plan with tree species resistant to these conditions. However, there is a pilot plan under consideration specifically for CPIV, consisting of the creation of a unit for the reproduction of wild flora with the purpose of growing hard to find native plants to replenish the sites that will require it as well as to induce vegetation succession in previous plantations, in order to minimize or annul their expenses and water requirements, in such a way that their artificial condition will be reverted to a natural one ecologically and aesthetically harmonious with the surroundings. Available to date is a surface of 2800 sq. m. with water supply and infrastructure for drip irrigation, tree nurseries with polyester woven shades, and trained technical personnel.

Continuous measurement of hydrogen sulfide in the air. Semi-portable units will be installed for continuos monitoring of H_2S concentrations in the air at ground level in the urban zones of the affected area; based on acquired data optimal dispersion will be defined, under certain meteorological conditions of H_2S in the air and therefore, disposal through 50m-high stacks or by stacks in the cooling towers.

Botanical Gardens. Implementation of a scientific collection of local plants is under project, as a contribution to the conservation of the botanical patrimony of the local flora, that will include research and environmental education, in coordination with other institutions such as the University of Baja California and the Mexican Association of Botanical Gardens. Presently, SEMARNAP has granted authorization and a federal permit to collect plants. And, initially, CFE is offering 1000 sq. m. of space with water supply and the technical and material support needed to carry out the project.

Noise. To control the discharge of geothermal fluid in a plant, equipment known as silencers are used. Noise reduction is one of its two main functions. The other one is the separation of liquid from steam because salts and dissolved solids concentrations in geothermal brine make it necessary to safely separate and dispose of them. The experience with different silencers designs has made it possible today to have geothermal silencers with an excellent performance in the mitigation of noise as well as in liquid-vapor separation. Considering the different types of discharges, the following silencers will be used at CPIV:

Metal silencers for discharge of water-steam mixtures. With its unique design this silencer yielded high noise levels, 107 dB(A), and water carryover. However, by increasing the admission duct length noise was lowered to 83 dB(A), measured one meter from the equipment. To eliminate water carryover a concentric pipe was installed inside the silencer, whose upper part has a rim to capture water that goes up the pipe wall.

Silencer for excess steam. Excess silencers have been constructed of concrete or metal, similar to the above mentioned, plus a plate diffuser surrounded by fragments of porous basaltic rocks. The noise levels obtained with these silencers are in the order of 80 dB(A), measured one meter from the source.

Muffler silencer for purge discharges. The equipment used to date consists of a diffuser followed by a section of porous rocks. Measurements show a noise level of 113 dB(A) without the silencer, while showing only 60 dB(A) with a silencer, measured one meter from equipment.

All project activities are subject to compliance with legislation and current environmental normativity, in response to recommendations on environment protection issues mentioned in this document and those determined by environmental authorities as a condition for authorization.

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TABLE 2. IMPACTS CHECK LIST AND RESISTANCE ANALYSIS
CONSTRUCTION STAGE

*BENEFICIAL IMPACT

ACTIVITY	IMPACTED ELEMENT	IDENTIFIED IMPACT SIGNIFICANT YES	IDENTIFIED IMPACT SIGNIFICANT NO	RANGE OF THE IMPACT	ELEMENT VALUE	RESISTANCE GRADE
-CIVIL WORKS	SOIL	LOW		PUNCTUAL	LOW	VERY WEAK
-ELECTROMECHANICAL WORKS	FLORA	LOW		PUNCTUAL	LOW	VERY WEAK
-SERVICES	FAUNA	LOW		LOCAL	LOW	VERY WEAK
-MACHINERY AND EQUIPMENT	AIR		LOW	PUNCTUAL	MEDIUM	WEAK
-SOLID RESIDUES DISPOSAL	WATER		LOW	PUNCTUAL	MEDIUM	WEAK
	LANDSCAPE	MEDIUM		LOCAL	LOW	WEAK
	SOCIAL	LOW		REGIONAL	MEDIUM	WEAK
	ECONOMY	MEDIUM*		REGIONAL	MEDIUM	