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ENVIRONMENTAL ISSUES IN GEOTHERMAL EXPLORATION IN CENTRAL AMERICA

Ana Silvia Arévalo and Luz Barrios
LaGeo S.A. de C.V.
15 Av. Sur, La Libertad
EL SALVADOR
sarevalo@lageo.com.sv, lbarrios@lageo.com.sv

ABSTRACT

One of the objectives of this paper is to present an overview of the guidelines designed for Latin American countries, and also used in Central America, for developing a geothermal project, focusing mainly on the exploration stage. It is important to discuss the diversity of the environmental regulations and social experiences acquired during the geothermal exploration assessment in Central American countries.

Exploration activities in the reconnaissance, prefeasibility and feasibility phases are aimed at carrying out a series of studies under a multidisciplinary team made up of geologists, geophysicists, geochemists and environmental specialists. Studies undertaken such as structural geology, geological mapping, resistivity survey, fumarolic and spring sampling, etc., generally do not have an impact on the environment. Social encounter is more evident during field surveys for the first two phases as it involves contact with crops, vegetation, soil and wildlife.

To minimize social impact, the technical team is obliged to request a permit from the land owners aside from the corresponding permit from the Ministry of Environment before entering any property. The team, on the other hand, is exposed to danger from nature when obtaining data such as accidents while walking through a river bed, animal bites, sun burn, rock and land falls and robbery as well.

1. INTRODUCTION

In the 1980's, the Latin American Energy Organization (OLADE) under the auspices of the Inter-American Development Bank (IDB) established a guideline for the development of geothermal projects for the countries in the region, which was divided into two stages: exploration and exploitation.

The geothermal exploration involves proving the viability of geothermal energy to generate power and/or heat. After the exploration of the possible resource, engineering design and construction costs are planned and assessed, and the geothermal potential is estimated. Accurate information from the exploration stage is crucial in assessing not only the overall viability but also the detailed physical challenges in drilling, the production expectations and costs.

The geothermal exploration is divided into three phases: a) reconnaissance, b) prefeasibility and c) feasibility (Figure 1); and is carried out with emphasis on using more effective and less-cost exploration techniques. Results of the first two phases help in the decision-making, the risk in investment and/or the abandonment of the project.

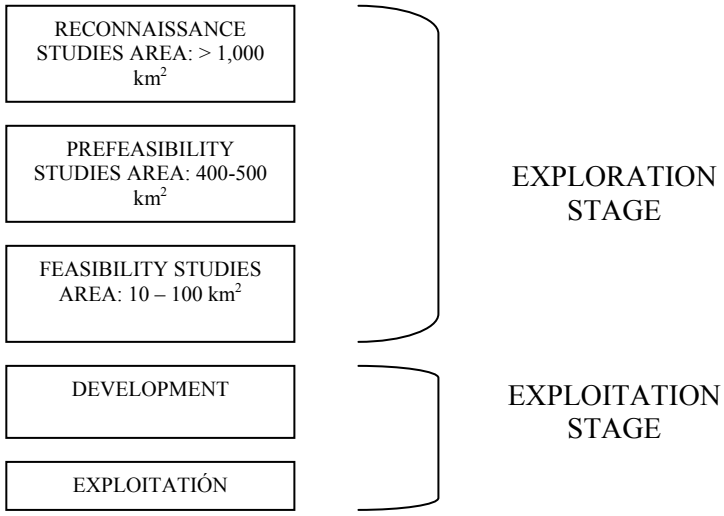

FIGURE 1: Exploration and exploitation stages in a geothermal project

2. ACTUAL GUIDELINES IN DEVELOPING A GEOTHERMAL PROJECT IN THE EXPLORATION STAGE

2.1 Reconnaissance study

The fundamental purpose of the reconnaissance phase is to determine if there exists a commercially exploitable geothermal resource for power generation and for other uses in a determined area. The first task is to perform a desk study, which entails the collection and analysis of all available existing data regarding the geothermal field and its environment in order to define the resource and scope of the following exploration activities. This is usually followed up by field work, which includes:

- Geological mapping of important geological features in order to get acquainted to the geological structure of the geothermal system; remote sensing studies, topographic and morphological studies; hydrogeological and hydrological studies.
- Geochemical analysis of fluids from surface manifestations or shallow wells, if available, to get indications on the reservoir temperatures; geothermometry.
- Geophysical explorations, like resistivity measurement, gravity and seismic profiling where needed, to get a better understanding of the subsurface features of the geothermal resource.

It culminates in delimiting areas of interest and the initial models of the areas. In this stage, additional studies are carried out to estimate the size of the resource and the preliminary potential through a volumetric model.

2.2 Prefeasibility study

The evaluation is done by collecting, analyzing and processing all geoscientific information through the existing techniques, and consisting in the execution of field surveys, geological, geochemical and hydrogeological studies.

The prefeasibility phase focuses on the exploration per se and suggests the most favourable site for drilling. Geophysics studies further complements the conceptual model of the geothermal reservoir. All the characteristics of the geothermal systems are included as a result of the exploratory studies (OLADE, 1993).

Among the techniques a geoscientist applies to obtain information during field studies in a lesser degree are:

- Geology: Surface geological mapping, structural geology, topographic and 3D terrain modelling, rock dating and chemical analysis, volcanological studies and hazard evaluation.
- Geochemistry: Chemical analysis of springs, geothermometry, gas diffusion, isotopic data, hydrogeology and hydrology studies.
- Geophysics: Active geophysics (continuous current) and passive (gravity, magnetic, TDEM-AMT-MT; MEQ).MT Resistivity surveys.
- Micro-seismic study and thermal gradient wells.
- Drilling shallow slim wells and shallow exploration wells (usually 50-300 m) to measure temperature gradients in order to locate the up-flow zone of hot fluids in the geothermal reservoir; drilling of a deep exploration well.
- Reservoir evaluation and production potential assessment.
- Environmental studies (environmental impact assessment).
- Prefeasibility report which includes an update of the geothermal model. A strategy for exploratory drilling is selected. During the exploratory drilling, the information is carefully analyzed in order to propose whether or not to continue to the next feasibility phase. Even though the drilling is confined to a very small area, the impacts can be higher. Therefore, the involvement of the environmental specialists is greatly needed.

2.3 Feasibility phase

In the feasibility phase, the same studies are performed but with limited areas and with more detailed geophysics, such as MT studies and active seismic in a greater detail (electric tomography and seismic). This phase is to confirm the geothermal resource and estimate
its potential. The commercial level of the geothermal resource is generally demonstrated by the following activities:

- Environmental impact assessment;
- Drilling of production/injection wells;
- Fluid sampling and chemical analysis;
- Well testing and well logging;
- Conceptual modelling and further geoscientific study;
- Production potential assessment (reservoir modelling);
- Geological-, geochemical- and reservoir modelling;
- Preliminary design of the power plant and surface equipment;
- Feasibility report.

This guideline has been of great use for many project developers for the last 30 years in all the Central American countries. Thus the enrichment, modification or a proposal for a review of the actual guideline applied in the future geothermal projects should be considered.

3. ENVIRONMENTAL ASPECTS

Environmental aspects, under the OLADE guidelines, are already considered from the stage of reconnaissance and feasibility studies to assess and prevent the effects that geothermal activities have on the surrounding area. Hence, it is very important to conduct a preliminary study of the

environmental impact, to identify and characterize all the environmental factors, such as biotic as well as the political and economic conditions that the geothermal development can encounter in the future. For this, a professional in the environmental area is necessary.

The Environmental Impact Assessment (EIA) is an important aspect of any geothermal project, from the earliest planning stages through post-project analysis. An EIA of a geothermal project involves comparison with alternative energy sources like fossil fuels, hydropower, nuclear power, renewable energy sources (solar, wind, tide etc.).

The main environmental concerns in geothermal utilization are:

- Surface disturbance
- Physical effects - fluid withdrawal
- Noise, thermal pollution, chemical pollution.

4. GEOTHERMAL POTENTIAL AREAS IDENTIFIED IN CENTRAL AMERICA

The application of the OLADE guidelines in the region helped raise awareness in countries where geothermal resources are explored. In the 1980's, 20 of the 26 member countries already had reconnaissance studies, eight countries with feasibility and four under exploitation; and are now generating electricity in their evaluated geothermal fields.

4.1 Guatemala

The National Electrification Institute (INDE) reports exploration studies since 1972 to areas near the volcanoes, identifying Zunil, Amatitlán, San Marcos, Tecuamburro and Moyuta. In 1993, the Totonicapán area was explored.

There are two operating geothermal fields: Zunil I and II and Amatitlan, and exploratory drilling in the Tecuamburro area. A mining project in the Cerro Blanco village in Asuncion Mita, Jutiapa located close to a geothermal site is conducting studies to install an electrical power plant. The company estimates 30MW of power generation and will use only a third part for their consumption. The rest will contribute substantially to the National Electric System (SEN).

Direct uses as well are applied by some industries, such as in Amatitlan where they manufacture blocks using steam to dry. They also produce dehydrated fruits and vegetables.

4.2 Honduras

Drilling of shallow exploratory gradient wells started in the Platanares area, which estimates a potential of 120 MWe. In the future, a 40 MWe power plant is planned to be installed.

4.3 El Salvador

During the years 1975, 1992, 1999 and 2007, the country has had the Ahuachapan and Berlin geothermal field under exploitation. Drilling of shallow and deep exploratory wells has been done in the Chipilapa, San Vicente, Cuyanausul and Chinameca areas and they are in the prefeasibility stage.

4.4 Nicaragua

Currently, the Momotombo geothermal field is under exploitation. In the San Jacinto geothermal field a back-pressure turbine was recently commissioned.

In 2009, the first deep exploratory well (HMG-1) was drilled in the Hoyo Monte Galán area and three more wells will be drilled in the year 2010. Exploratory studies were performed in the Managua-Chiltepe area, and recently a continued core well was drilled in the southern sector of the geothermal area. In the future, a concession might be awarded to extract energy from the San Cristobal volcano, which has the highest energy potential of the 12 geothermal fields in the country.

4.5 Costa Rica

ICE has in operation several power plants in the Miravalles geothermal field. Deep drilling has been carried out at the Rincon de la Vieja, Borinquen and Las Pailas geothermal areas.

Figure 2 presents all the geothermal areas in Central America.

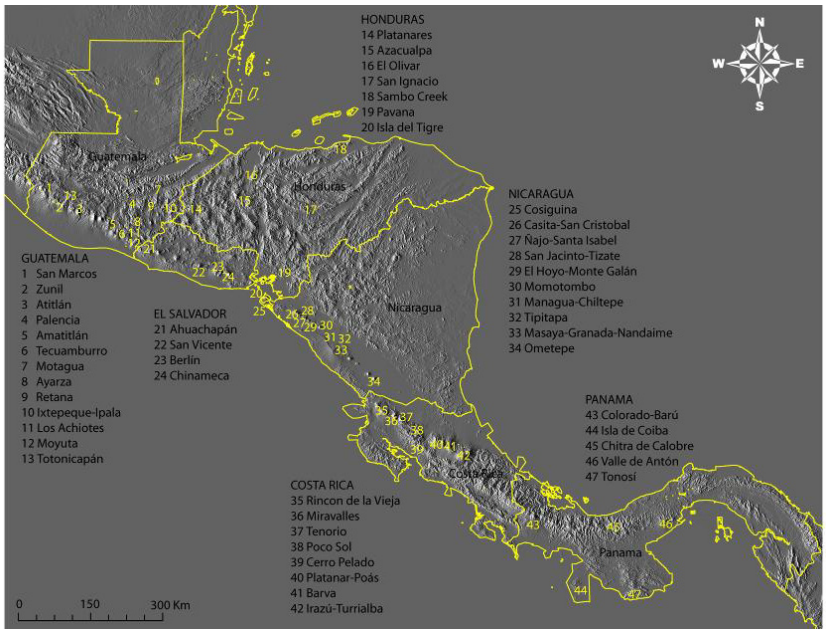

FIGURE 2: Geothermal areas in the Central American region.

5. ENVIRONMENTAL REGULATION IN SUPERFICIAL EXPLORATION IN CENTRAL AMERICA

Central American countries have established and developed over the years their own environmental regulations. Some of these countries started in the late 1980's by creating environmental laws, in the 1990's by creating national committees and in the late 1990's, their respective Ministries of Environment.

TABLE 1: General environmental laws

Country	National committees of the environment (1974-1990) and 1990-2000	Year
Guatemala	Law for the Protection and Improvement of the Environment	1986
Honduras	General Environmental Law	1993
El Salvador	Environmental Law	1998
Nicaragua	General Law of Environment and Natural Resources	1996
Costa Rica	Organic Environmental Law	1995
Panamá	General Environmental Law	1998

TABLE 2: National committees to the environment

Country	National Committees of the Environment (1990)	Year
Guatemala	National Environment Commission	1986
Honduras	National Environment Commission	1990
El Salvador	National Environment Council	1990
Nicaragua	National Commission of Environment and Land Management	1990
Panamá	National Environment Commission	1985

TABLE 3: Ministry of Environment

Country	Ministries of Environment (2000)	Year
Guatemala	Ministry of Environment and Natural Resources	1999
Honduras	Ministry of Natural Resources and Environment	1997
El Salvador	Ministry of Environment and Natural Resources	1998
Nicaragua	Ministry of Environment and Natural Resources	1994
Panamá	National Environmental Authority	1998

An environmental legislation is a general instruction for the implementation of: 1) Environmental planning and land management, 2) Environmental Impact Assessment, 3) Economic instruments, 4) Civil, criminal and administrative matters, and 5) Others. It has also the specific application for sustainable management of ecosystems such as: 1) Biodiversity and biosafety, 2) Wildlife, 3) Forest Resources 4) Soil, water and atmosphere 5) Marine ecosystems, and 6) Others.

The work of the different entities and their environmental legislations has shown significant progress, but it is not equal between countries and entities and is still incomplete in its application; and it presents implementation problems due to deficiencies in their own regulations or due to obstacles in administrative and judicial areas. (Brañes, 2001).

5.1 Guatemala

According to the Electricity Law established in 1997, the country deregulated its electricity sector, allowing private industry to participate in the business of power generation. In the case of geothermal development, the private participation has been through concession, initiating after the project has reached the plant construction stage.

The principal actors in the electricity market are the Ministry of Energy and Mines-MEM as planners, the National Electric Energy Commission-CNEE as regulator and grants permits for the construction of any power plant, the Wholesale Market Administrator-AMM, and the production and distribution agents including the National Institute of Electrification-INDE (Roldán, 2005).

In Guatemala, INDE is the state developer in charge of the geothermal prefeasibility and feasibility studies. Funding can come from the state, international grants and technical cooperation, and loans from different organizations e.g. JICA, USAID, IAEA, OLADE.

An Environmental Impact Assessment EIA is required for each energy project and acts as a community license for any construction in the area. The entity in charge of the EIA approval is the Ministry of Environment and Natural Resources (Ministerio de Ambiente y Recursos Naturales-MARN) (Moya, et al., 2007).

5.2 Honduras

According to the Laws of the Republic of Honduras, the concessions for exploration and exploitation of renewable energy projects should be carried out, through the SERNA Secretary of Natural Resources. Geoplatanares obtained the environmental license for the Platanares geothermal project in January 2006, under the Resolution No. 064-2006, with an agreement of mitigation measures for areas that will be affected in one way or another because of the exploitation and operation of the geothermal resource in the area.

Among the mitigation measures adopted by SERNA the following items are included (personal Communication, César Lagos, 2009):

1) Environmental studies during the exploration and construction stages;

2) The findings of cultural value must be reported to the Honduran Institute of Anthropology and History;
3) Perform socialization campaigns of the project with the affected localities;
4) Provide health and safety training to staff and employees and provide them with the necessary safety equipment.
5) Prohibition of the contamination of water sources with solid waste or construction wastes.
6) Assign a gathering place for the temporary collection of household waste.
7) Avoid, if possible, the construction of wellpads near housing or professional centres

5.3 El Salvador

The office in charge of awarding concessions of geothermal areas for the production of electricity is SIGET. In order to obtain a concession, the interested developer must apply to SIGET with a feasibility study and the approved environmental impact assessment documents. SIGET then holds a public hearing for opposition to the project (separate from MARN), competing projects, and/or other parties interested in developing the resource. If there is no significant opposition or competing projects, SIGET holds a public bidding process to award the concession, and grants it to the highest bidder.

SIGET is the official entity for power generation, transmission, distribution, and energy trading, which deals with the public, private and mixed sectors. Being the only geothermal developer in El Salvador, LaGeo has carried out all its requirements under the General Electricity Law and deals directly with SIGET. The awarding of the concession requires that the developer presents SIGET with an environmental impact study, previously approved by the Ministry of the Environment and Natural Resources (MARN) (Moya et al., 2007).

5.4 Nicaragua

The Ministry of Energy and Mines is in charge of granting concessions for the exploration and exploitation of any geothermal project. Once it is granted, their main task is to regulate, supervise and monitor all the exploration and exploitation activities to be developed during the geothermal project. The MEM tasks are based under the following laws recently emitted:

- Law 443: Law on exploration and exploitation of geothermal resources.

Law 443 has been in effect since November 1st, 2002. On September 5th, 2006, a reform to law No. 443 was passed and was published by Judiciary norms (Normas Jurídicas de Nicaragua) in La Gaceta No. 173. It refers to exploring and exploiting a geothermal resource in partially or totally protected areas. The concession holder must obtain approval of the Environmental Impact Study and the Environmental Permit from the Ministry of Environment and Natural Resources (MARENA) before initiating the studies (Article 7).

- It is a must for the concession holder to present to the Nicaraguan Institute of Energy a legal proof of the environmental permits.
- An extension of the exploitation concession must be approved by the energy regulating entity and contracts granted prior to the present law may be adapted if it is requested by the concession holder (Moya et al., 2007).
- Regulation of the law exploration and resource exploitation geothermal, effective since January 13th, 2003 (Perez, 2007).

The concession holder submits the environmental permit before starting the prefeasibility and feasibility phase and before starting to drill wells. This permit is applied when drilling wells with depths greater than 50 m.

In the technical and economic proposal, the concession holder must include within the technical staff of the project, an environmental specialist responsible for the environmental part of the exploration project. In the case of success in the exploration stage, this must be done also in the exploitation stage.

5.5 Costa Rica

Costa Rica has considerable undeveloped geothermal resources (estimated at a minimum of 865 MW), most of this potential is located inside the national parks. The current law does not permit exploration or exploitation of geothermal energy inside the national parks, and thus the potential for future geothermal development of the country is very limited. A new bill, entitled "Law to regulate geothermal energy production in national parks" (File No. 16,137), has been written and presented to the Costa Rican congress. Its main purpose is to authorize ICE to develop geothermal resources inside the national parks while maintaining their protection for future generations (Moya et al., 2007).

6. ENVIRONMENTAL AND SOCIAL EXPERIENCIES DURING EXPLORATION STUDIES IN C.A.

The environmental and social experiences during the exploration studies in Central American countries to be described will be the ones that geologists, geophysicists, and geochemist encounter during the reconnaissance, prefeasibility and feasibility studies in an area approximately 20 × 20 km (400-500 km^2). The studies cover a variety of surface and land characteristics with different occupations. The environmental and social experiences during the set up work and drilling jobs are not mentioned in this paper.

6.1 Guatemala

The permit for the prefeasibility and feasibility studies is given by the Ministry of Environment and even though the geothermal developer meets all the requirements and the project undergoes municipality authorization, then during exploration and fieldwork, it is common to avoid giving information that could be misinterpreted by the community. Therefore, the strategy implemented with the public is to avoid informal comments about the geothermal resource. Once the project has been confirmed, public meetings are held to clear doubts and as the technical information is shared, problems with the community are reduced. This helps the project developer finish the project on time. Permission is directly requested from the land owners before starting the field work.

The communities nearby can stop any project if the consultation and information are not properly managed. This was the case of a project in exploitation in the Amatitlán Area where the drilling of a well was not authorized by the appropriate municipality. Ortitlán was authorized by the National Electrification Institute (INDE) to exploit the geothermal resource, but permission was granted by the Amatitlán jurisdiction and not in Escuintla. This was practically settled but the people blocked the path to the village to prevent the transit of the drilling rig. However, another group arrived at the scene to demand that the blockade be lifted. A group of people, who know about the benefits of developing a geothermal resource, supports the project.

6.2 Honduras

Since the beginning, there has been a good social relationship among Geoplatanares, the residents of nearby communities and the mining company. Open meetings have been conducted with the patronage of the community and villagers to divulge the geothermal project. It has also been important to inform the public about the benefits brought by the development of a geothermal field in the community (Figures 3 and 4). In 2005, Geoplatanares performed the following:

1. Work undertaken in the exploration and exploitation stage;

2. Effects of civil work towards the environment;
3. Social benefits for the community (new source of work):
4. Future social contributions of Geoplatanares to the community once the project is in the operating stage.

The period granted by SERNA for the environmental permit is due every two years and can be renewed if it is required. However, governmental bureaucracy has made it impossible so far to renew the environmental license for the Platanares geothermal project. Due to the expiration of the environmental permit, the exploitation work in the geothermal field has been stopped because the government agencies have prohibited any development and exploitation of resources without proper authorization and related environmental permits (Personal Communication Lagos, 2009).

FIGURE 3: Meeting in the San Andres town with Geoplatanares and an education programme on the importance of geothermal exploration and its benefits

FIGURE 4: People from the community of San Andrés visiting a hydrothermal alteration zone where gradient well PLTG-02 is located

6.3 El Salvador

The first party to do the reconnaissance work in a new geothermal prospect is the one in charge of the environmental and social issues (even before the geologist sets foot on the site). The first task is to establish an environmental and social baseline in the project area, and identify the potential points of conflict for the early exploration phases. This involves meeting with local leaders and organizations, and compiling existing information on the socioeconomic status of the neighbouring communities. Local leaders are thus informed of the exploration program, and educated about the basics of geothermal development. (Arévalo, 1998)

One of the problems that often occur at the beginning of the exploration studies is when the geophysical crew who performs surveys enters a private property without the respective permits from land owners. Discomfort and complaints are felt by the community against the company as the technical crew enters the cultivation areas, or picks some of the fruits or vegetable crops, or opens pits or remove vegetation without permission. The pictures below (Figure 5) show the staff working in the field while taking geophysical measurements.

Geophysicists, geologists and geochemists usually work and pass on cultivated areas with corn or sugar cane. At times, even though the geoscientific work is accomplished with care, there could be some damage to the crops. Therefore, the geothermal company must establish ways to compensate the land owner.

The pictures at the right side in Figure 5 show the possible risks to personnel during measurements in order to comply with their objectives.

FIGURE 5: Working environments of the geophysicists and geologists in the Chinameca and Chilanguera areas

During the reconnaissance and prefeasibility studies, the geologists encounter geological risks while doing structural measurements. The geological outcrop to be measured are usually are in high slopes, negative slopes, or high fractured rock areas which can provoke small rock and land slides, while collecting samples or making a fault measurement. These events might put the specialists in danger; therefore, caution should be taken (Arevalo, 2006).

6.6 Nicaragua

Nicaragua experiences similar problems as in El Salvador, however, many of the geothermal resources where the exploration studies are carried out, are in areas with dense vegetation, which is usually in protected areas. Members of the technical crew enter these remote areas, but generally find themselves exposed to harm such as encountering poisonous snakes and spiders, etc., which oblige them to kill these animals for their safety. The communities nearby find these dead animals in trails and walkways and usually complain to the municipal leaders.

A mutual communication must exist between the two parties (the project developer/technical staff and the community), to decide what actions can be taken with regard to the safety of the personnel and wildlife.

6.7 Costa Rica

The most important issue when exploring a geothermal area is the relationship between communities and the geothermal company. The objective of environmental management is to inform the communities about the project. They need to know all about the project, the social and economic benefits and the importance of protecting the natural resources. Communication by the developer about the resource, the environmental aspects of the project, and the control that it will undertake is so vital.

ICE has been able to implement many strategies so the geothermal project can be developed. The identification of the strategic groups and economic and social participants in the area is very important. Organizations such as social groups, religious groups, the education level of inhabitants, hotel and tourist development, business owners and workers, NGO's working in the area, etc. are all identified and listed. From these, training activities are carried out with support from ICE and

governmental institutions. Business and tourism development using the geothermal resources improves the standard of living, and create new job opportunities (Guido, 2007)

7. CONCLUSIONS

The OLADE guidelines implemented in the Central American countries have been of great help for the geothermal project developers. Over the past 40 years, Central American countries have identified close to 467 geothermal areas, accomplished mostly during the reconnaissance studies. The United Nations experts were the main actors during the late 1960's for most Central American countries in finding potential geothermal sites.

The prefeasibility and feasibility studies have been completed by specialists in the areas of geology, geophysics and geochemistry, since the 1980's with the help of the OLADE guidelines. The geoscientific field studies were supported with the knowledge from experts from countries who started developing geothermal resources decades earlier (e.g. Mexico, United States). Environmental studies became more important in the exploration stage of a geothermal project since the creation of environmental entities in the late 1980's.

Therefore, nowadays a geothermal exploration study must include an environmental expert who should be part of the technical staff alongside the geologists, geophysicists and geochemists.

The environmental specialist works more with the social aspects than the environmental aspects during the exploration stages. The reason is because when specialists study a geothermal area, the environmental impact is usually minor, compared to the impacts the specialist gets from nature. For example, they are exposed to robbery, fractures, sun burning, animal bites, slides, rock falls, etc.

The social experiences encountered during the exploration stages are similar to all the Central American countries. Excellent relationships should be established between the geothermal project developer and the community and municipalities, while extending the exploration work in a determined area.

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