Presented at Workshop for Decision Makers on Geothermal Projects in Central America, organized by UNU-GTP and LaGeo in San Salvador, El Salvador, 26 November to 2 December 2006.

ENVIRONMENTAL AND SOCIAL ISSUES IN GEOTHERMAL DEVELOPMENT IN COSTA RICA

Hartman Guido-Sequeira
Instituto Costarricense de Electricidad,
Centro de Servicio Recursos Geotérmicos, Campo Geotérmico Miravalles,
Guayabo de Bagaces, Guanacaste,
COSTA RICA
hguido@ice.go.cr

ABSTRACT

The great biological diversity of Costa Rica represents one of its biggest resources, and it is a focal point of the country's policies of environmental protection. For this reason the country is recognized worldwide as a leader in protecting the environment. This characteristic constitutes an important challenge for developing geothermal energy according to these policies, due to a great part of the recognized geothermal resources being associated with areas with different degrees of environmental protection.

This document discusses the different environmental aspects related to geothermal utilization at the Miravalles Geothermal Field, how the environmental management has been carried out and the results of this management so far. As a conclusion the feasibility of the sustainable development can be shown as a tool for protecting the environment, but also as a means to recover the environmental quality in areas that have previously been affected by human activity.

1. INTRODUCTION

The Miravalles Geothermal Field is located at the Miravalles Volcano in Bagaces Guanacaste between the Blanco and Cuipilapa river basins. The Miravalles I and Miravalles II power plants are located at coordinates 298 000 N-405 700 E at 610 m a.s.l and the Miravalles III power plant at coordinates 300 150 N-407 050 E at 720 m a.s.l. This field contains a high-temperature liquid-dominated reservoir with maximum temperature of about 240°C. The proven reservoir area is about 12 km^2, it is encountered at 700 m depth and the estimated thickness is between 1000–1200 m. The field is in an active hydrothermal area confined to a Caldera-type collapse structure with 15 km diameter. Total dissolved solids in the range of 7000-8000 ppm characterize most of the fluids from the Miravalles geothermal wells. These fluids are sodium chloride type water with a pH of about 8 at surface. The non-condensable geothermal gases emitted to the atmosphere are CO_2, $H2_S$, N_2, CH_4, O_2, H_2, Ar, He and others in tracer concentration.

The environmental impacts assessment (EIA) for Miravalles was carried out in 1988. Since it was the first EIA ever done in Costa Rica at that time it changed the way models for any new large project in Costa Rica were presented. Brief comments on the management and monitoring of some of these environmental aspects are presented in this paper.

2. ENVIRONMENTAL LEGISLATION IN COSTA RICA

Costa Rica has been developing important environmental legislation to protect and prevent negative environmental impacts. Article number 50, of the political constitution of Costa Rica, states that all citizens have the right to enjoy a healthy and ecologically balanced environment and for this reason any act than affects it is encouraged to be denounced and the impacts can demanded to be mitigated.

The main regulation is the Environmental Law number 7554 from the year 1995. This law carries the legal support to protect the environment and get a clean and ecologically balanced environment. The government has the obligation to protect the environment. The main principles of the law are: The environment is the property of all the inhabitants; those who pollute the environment will be responsible according to the laws; The environmental damage constitutes social, economic, cultural and ethical offence.

3. ENVIRONMENTAL MANAGEMENT AT MIRAVALLES

The environmental management at the Miravalles Geothermal Field had been carried out since 1987, before the start of commercial utilization of the field in 1994. The main purpose was to create a background that allowed a comparison of the environmental quality before the start of commercial utilization and any assessed future impact due to utilization.

3.1 Air quality management

In Miravalles there are different ways by which gas is released into the atmosphere. The gas can be released from the silencer when the wells are out of production. In the centrifugal separators waste water is sent to injection wells and steam towards the turbine. In the power plant the gas ejector system extracts the non-condensable gases from the turbine condenser. This gas is cooled and discharged into the atmosphere through the cooling tower.

Of these gases, CO_2 (96-97%), and H_2S (less than 1%) are the most important because of possible effects on the environment and human health.

Carbon Dioxide (CO_2)

The CO_2 is a heavy gas naturally present in the air at a concentration of 0.03 – 0.06 percent. It is odorless and acid tasting. In a concentration higher than 5% it will produce mental confusion, headaches and eventually a loss of consciousness, over a 10% concentration produces a loss of consciousness in few minutes and larger concentrations cause death due to an alteration of blood pH (Brown, 1995). CO_2 is also one of the principal greenhouse gases (GHGs). It is estimated that, due to the accumulation of greenhouse gases the global surface temperature will have risen between 1.5 to 3.5^{o}C by the year 2100 (WHO, 1997). There are international standards to control the maximum quantities emitted into the atmosphere. This climate change has indirect effects on ecosystems and the distribution patterns of vector populations. Table 1 shows some different international standards for permissible CO_2 emissions.

CO_2 concentration is relatively low in geothermal steam. The emitted level is more environmentally benign than that of sources such as thermal plants. One important aspect is that the geothermal steam does not emit NOx type gases to the atmosphere.

TABLE 1: Different standards for permissible CO_2 emissions

Norm	Standard
OSHA	5 000 ppm, 8 hour TWA
NIOSH	10 000 ppm TWA; 30 000 Ceiling (10 min)

Occupational Safety and Health administration (OSHA) regulations and National Institute for Occupational Safety and Health (NIOSH) recommendations, 1986)

Hydrogen Sulfide (H_2S)

H_2S is a poisonous gas. It can come from natural sources like volcanoes, geothermal springs and decaying organic matter, from man-made sources and also from industries. It is a colourless flammable gas with a vapour density of 1.189 and soluble in water, alcohol ether and glycerol.

The presence of H_2S in the atmosphere increases health risks. Low concentrations can produce human health problems, effects on flora and fauna and damages to human constructions by corrosion, and higher quantities may cause death. Due to the toxic characteristics of hydrogen sulfide different health and environmental organizations have-established exposure standards for work areas and for populated areas. Table 2 shows different international standards for permissible H_2S concentrations. The OSHA, NIOSH and ACGIH standard are for work areas, and the Italy and California standards are for populated areas.

TABLE 2: Different standards for permissible H_2S emissions

Norm	Standard
TWA PELs OSHA [a]	28 000 $\mu g/m^3$ acceptable ceiling; 70 000 $\mu g/m^3$, 10 minutes maximum ceiling.
RELs NIOSH [a]	14 000 $\mu g/m^3$ ceiling 10 minutes on exposures up to ten hours
ACGIH [b]	14 000 $\mu g/m^3$ like 8 hour average and 40 hour per week to workers
Italy [c]	42 $\mu g/m^3$ as 24-hour averaging time in urban areas.
California [d]	42 $\mu g/m^3$ like 1-hour averaging time.

[a]OSHA and NIOSH, 1986; [b]Brown, 1995; [c]ICE, 1996
[d]California air resources board, 1999

The human body does not accumulate H_2S, it is excreted in the urine, intestines and expired into the air (Brown, 1995). H_2S smells like rotting eggs and the smell is perceptible in concentrations less than 42 $\mu g/m^3$. When people are exposed to low concentrations of H_2S, it can cause lacrimation, photophobia, and irritation of the nasal mucosa it also has a profoundly irritating effect on the cornea producing pain, blurring of vision and keratitis.

At 500 $\mu g/m^3$ H_2S has a clearly perceptible odor and begins to cause damage to delicate plants. In the range 280,000 and 700,000 $\mu g/m^3$ it will produce intoxication and above 840,000 $\mu g/m^3$ it can produce rapid death by asphyxia.

The Miravalles environmental impact assessment (ICE, 1996) established the maximum concentration as 42 μg/m^3 in populated areas and 938 μg/m^3 at one kilometer from the power plants. In Miravalles the hydrogen sulfide emission was modeled in 1988 and 1999. The models estimated H_2S concentrations under 42 μg/m^3 in town and less than 938 μg/m^3 at one kilometer from the power plants (Guido, 1999). In order to study the H_2S evolution, the Instituto Costarricense de Electricidad (ICE), operates seven stations for H_2S monitoring.

Equipment with the capacity to measure concentrations from 0.003 ppm of H_2S is used. The CO_2 is measured using equipment with the range 0 ppm to 10,000 ppm. Figures 1 and 2 show the results of the measurements. The results of the monitoring shows that the geothermal utilization does not affect in any way the air quality of the project area. In Figure 1 the data at less than 1 km from the power plant is presented, and Figure 2 shows the result of the model calculations and the maximum concentration that has been measured during monitoring. The results of the model calculations are conservative because all the measured values are higher than the modelled ones.

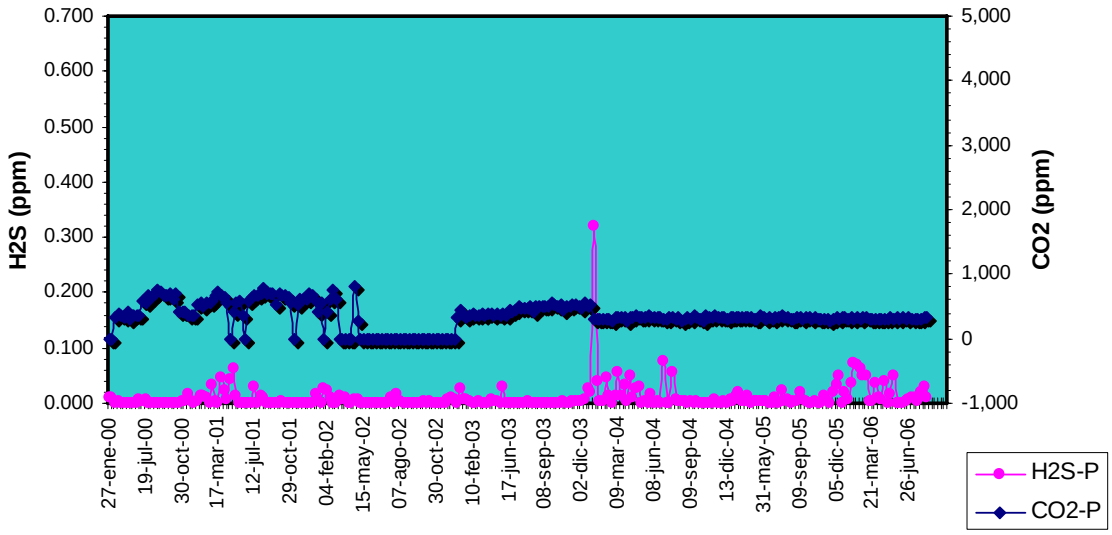

FIGURE 1: Concentration of H_2S at less than 1 km from the Power Plant

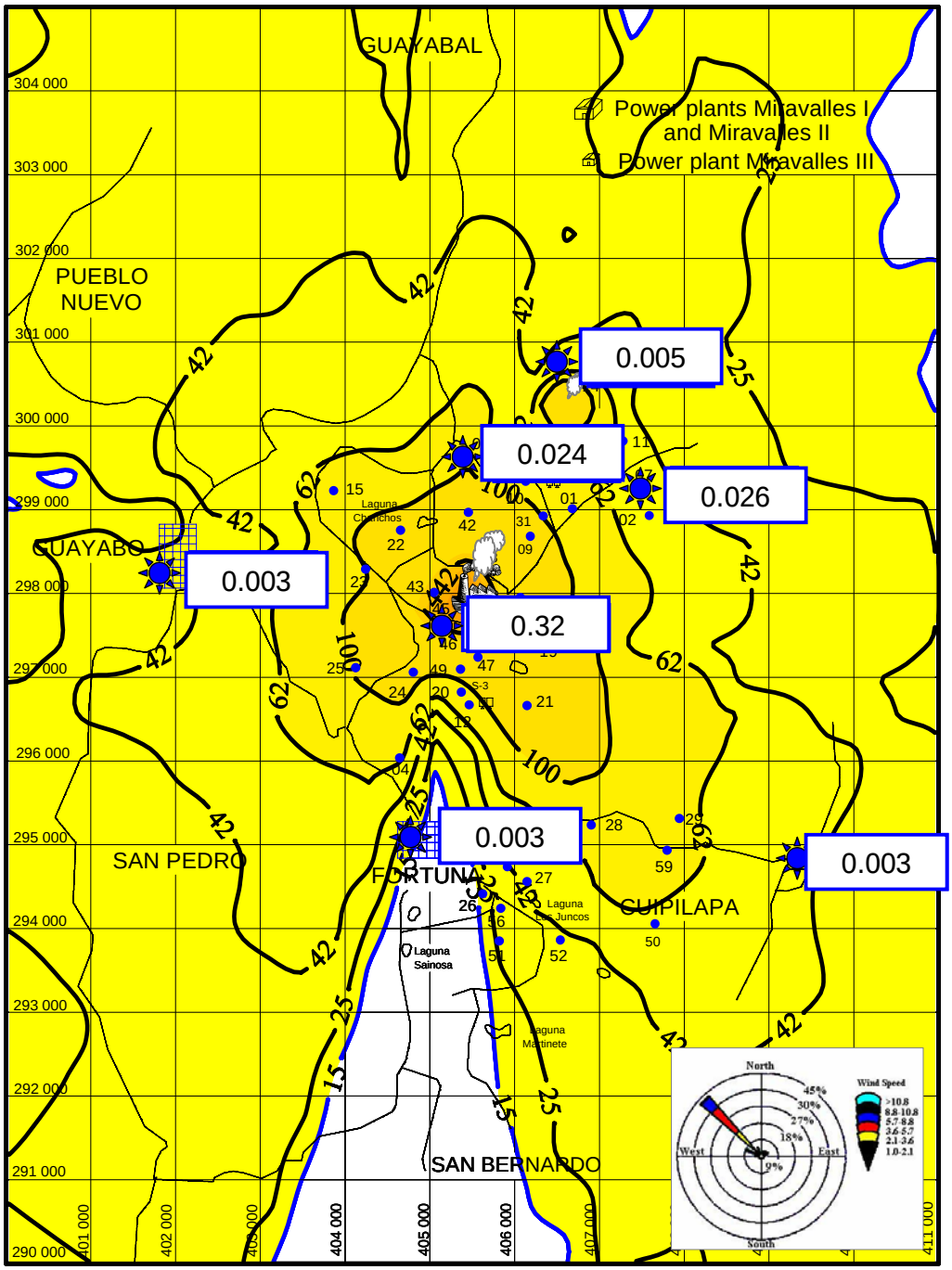

FIGURE 2: H_2S dispersion model for the Miravalles Geothermal Field

3.2 Water quality management

In Miravalles, the geothermal water is re-injected into the reservoir using deep wells. It therefore does not represent a pollution problem to the groundwater system. The physical and chemical characteristics of the Miravalles geothermal fluids do not allow wastewater disposal at the soil or into the springs or river in the area.

As a basis for water quality monitoring program in Miravalles established in 1987 26 points around the project area with the objective of detecting possible geothermal water pollution have been established. At the beginning the monitoring was more detailed (pH, Cl. B, As, Li, Rb, Cs), but after several years it was decided to reduce the number of chemical species monitored. Actually, the monitoring includes Cl, pH and conductivity, because they can be used to indicate the presence of both geothermal and fresh mixed water. Figure 3 shows the result of water monitoring at one of the stations in Miravalles.

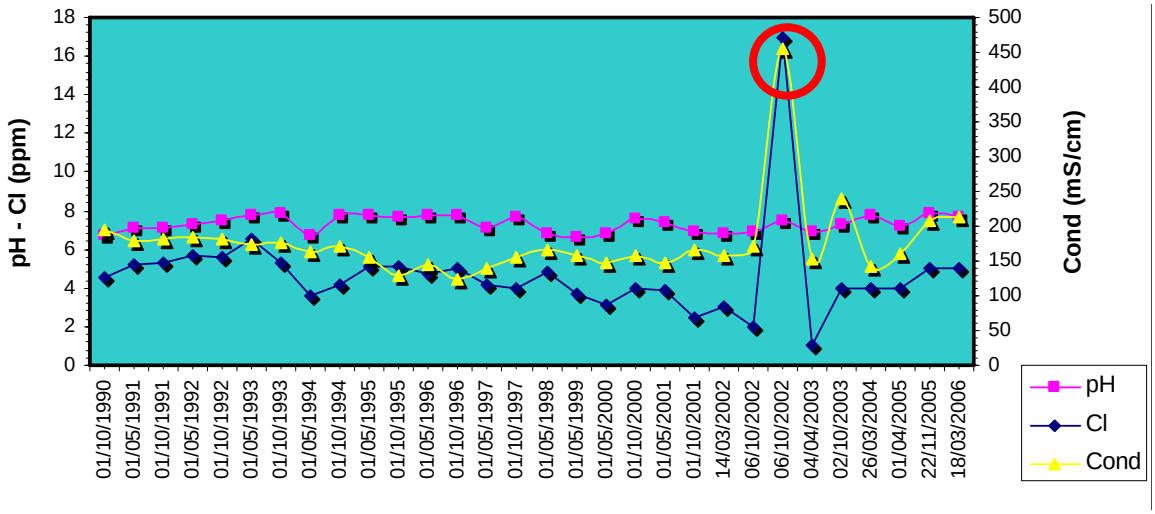

FIGURE 3: Water quality monitoring – Station 7

It is clear that one of the results is out of the normal range. This was due to a problem in one of the pools. It is an example of the effectiveness of the selected species as monitoring parameters to locate geothermal water pollution problems.

3.3 Effects of rain pH

Possible changes in pH in rain due to geothermal utilization have been monitored and studied in Miravalles since 1987. Continuous monitoring was established at ten points around the project area. The objective of the monitoring is to determine the pH background value, and use it as a comparison line that allows the identification of any pH changes after the start of the field operation. The commercial field operation started in 1994, and the monitoring has shown that the field exploitation has not had negative effects on the pH values. Figure 4 shows the results of pH in rain monitoring at the Miravalles Geothermal Field.

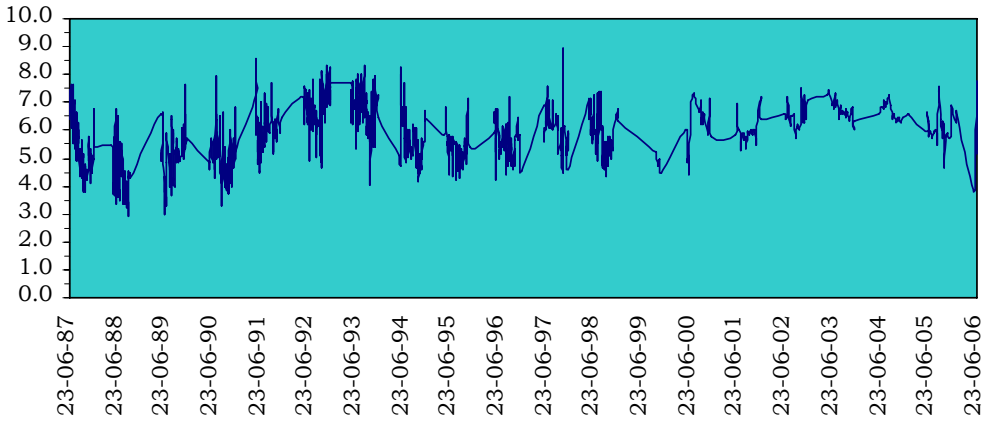

FIGURE 4: Rain water pH – Power Plants Miravalles I - II

3.4 Effects on forest

In Miravalles most of the land acquired for geothermal utilization has been reforested by using local flora and promoting natural recovery. When the geothermal activities began most of the land was used for grazing. ICE has recovered 800 hectares by planting 362,000 trees in the area. As a natural consequence it is now possible to see animals that were nearly impossible to find earlier. Figure 5 shows the difference between ICE´s properties and private-owned ones. The one on the right side of the picture is an ICE property. It is possible to see the degree of recovery.

FIGURE 5: Comparison between ICE and private areas

3.5 Visual impacts

The objective of controlling visual impact is to build harmony between nature and buildings and pipelines. For that reason the company has been working with some structures to find the way to improve their visual impact.
Figure 6 shows some of the results of the work for reducing the visual effects of geothermal development. Some of the activities are flora recovery and the use of various shades of green paint.

FIGURE 6: Work site before and after recovery activities

3.6 Social issues

The relations with communities and other people related with the environmental issues are maybe the most important issue in environmental management. One of the most important objectives of public relations is to inform the communities of the exact nature of the project, and to know the negative and positive impacts on the natural, economical and social aspects. In order to fulfill this objective it is necessary to educate the people. It is important to let them know what constitutes a geothermal project, what needs to be done in order to obtain the resources, how the environment will be impacted, what needs to be done to control the impact, what are the social and economical benefits of the project and the importance of protecting natural resources.

To manage this situation many strategies have been developed. First it was necessary to identify the strategic groups, for example: social organizations such as development associations, religious groups, students of different levels, hotels and tourist developments, business owners and their workers, NGOs, and many others.

ICE has organized training in conjunction with other governmental institutions. One of the most important aspects is related to tourism development. Now the use of natural hot springs water, fumaroles and geothermal utilization are new tourist attractions. About four small and medium tourist projects have been developed using geothermal resources and other small commercial development was born due to the improved life quality raised by the new job opportunities.


FIGURE 7: Environmental Education

4. CONCLUSIONS

- The results of the environmental parameters show that the geothermal development in the Miravalles Geothermal Field is sustainable.
- The natural recovery due to the presence of the Miravalles Geothermal Developments is extremely important mainly of the vegetation and the fauna.
- The presence of geothermal development produces a new tourist attraction.

REFERENCES

Brown, K., 1995: Occupational safety and health. In Brown, K.L (convenor). Environmental aspects of geothermal development. World Geothermal Congress 1995, IGA pre congress course, Pisa, Italy.

CCREM 1991

Guido, H., 1999: Hydrogen sulphide gas dispersion model for the Miravalles Geothermal Field, Costa Rica, and ground water dispersion and transport of pollutants models. UNU GTP, Iceland.

Guido, H., 2005: Environmental Management at the Miravalles Geothermal Field. World Geothermal Congress. IGA, Turkey. (not in text)

Guido, H., 2006: The EIA and the Environmental Management at the Miravalles Geothermal Field after 12 year of exploitation. International Association for Impact Assessment conference, Norway (not in text)

Instituto Costarricense de Electricidad, ELC Electroconsult ., 1996: Declaración de impacto ambiental 3a y 4a Unidad. ELC GMV-2-ELC-R-12535(R01), Costa Rica. 1996

Instituto Costarricense de Electricidad, ELC Electroconsult., 1996: Estudio de impacto ambiental Proyecto Geotérmico Miravalles. Instituto Costarricense de Electricidad, Costa Rica. 1988. (not in text)

MacClenahan, H.L, 1995: Introduction to geothermal development and regulatory requirements. In Brown, K.L. L (conventor) Environmental aspects of geothermal development. World Geothermal Congress 1995, IGA pre congress course, Pisa, Italy. (not in text)

NIOSH 1986

OSHA 1986

Reed, M.J. and Renner, J.L., 1995: Environmental compatibility of geothermal energy. In Frances, S.S. (editor). Lewis., Florida, USA, 23-37.

USEPA 1986

Vallejos, O., 1996: A conceptual reservoir model and numerical simulation studies for the Miravalles geothermal field, Costa Rica. Report 18 in: Geothermal training in Iceland 1996. UNU G.T.P., Iceland.

WHO 1993

WHO 1997