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# Sound Pressure Level Measurements at and around the Las Pailas Geothermal Project and in Rincón de la Vieja National Park, Guanacaste, Costa Rica

**Edward Charles Hakanson, Geologist, BSc.**

**Instituto Costarricense de Electricidad**
**La Fortuna de Bagaces, Guanacaste, Costa Rica**
**edward_hakanson@yahoo.com**

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## ABSTRACT

From September 2008 to June 2009, as part of a field investigation for a Masters degree in Natural Resource Management, sound pressure level measurements were made in the area under development for the Las Pailas Geothermal Project as well as within the north-bordering Rincón de la Vieja National Park and a region of open grasslands to the northwest in order to identify the environmental noise level ($L_{A90}$) and the existing natural sources of noise. Las Pailas Geothermal Project is located on the Pacific slope of the Quaternary Rincón de la Vieja volcanic complex in northwestern Costa Rica and is expected to come on line with a 35 MWe powerhouse in 2011. Each noise level measurement was taken at 120 cm above the soil level at equally spaced observation points on a one-kilometer grid. Throughout the field area there are important differences in elevation, topographic gradient, and land use, all of which may influence the measured sound pressure levels. All of these data have been compiled in an Access database and integrated so that they may be visualilzed with Geographic Information System software. This paper presents new field data on naturally occurring sound pressure levels at and around the Las Pailas geothermal Project. Specifically, this paper addresses how environmental noise levels change with changing land use practices. These results may be utilized in the decision making process for future development of the Las Pailas Geothermal Project.

## Introduction

Costa Rica is a Central American country located between Nicaragua and Panama with the Pacific Ocean to the west and the Caribbean Sea to the East. As part of a field investigation for a Master's Thesis in Natural Resource Management, sound pressure levels have been collected in a field area with an extension of approximately 3200 Hectares (32 km2) located within the Costa Rica Lambert North coordinates 300-311 N, 382-391 E (Curubandé topographic base map, 1:50000) on the Pacific slope of Rincón de la Vieja Volcano in Guanacaste, Costa Rica (Figure 1), sound pressure levels were recorded at 56 observation points to obtain environmental noise data collected on a one kilometer grid in order to determine a baseline for environmental noise and evaluate how land use and topographic gradient may affect the environmental noise level.

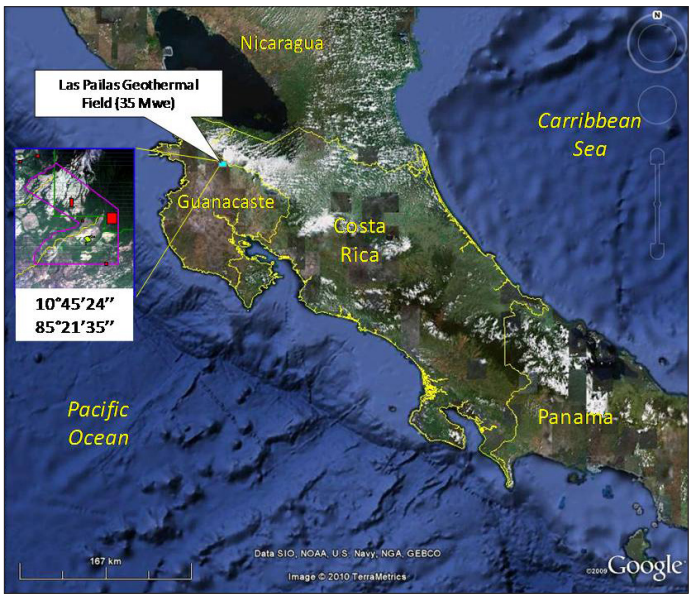


**Figure 1.** Location of the field area with respect to the Las Pailas Geothermal Field in northwestern Costa Rica.

The field area is concentrated at and around the currently under development Las Pailas Geothermal Project (Instituto Costarricense de Electricidad, 2005) with a total area of 1312 Ha, the southwestern corner of Rincón de la Vieja National Park (1189 Ha) and extends towards the northwest covering an additional 788 Ha. Sources of environmental noise are reported as continuous, intermittent, and impact during 3 minute and 45 second data collection sessions at each observation point. The nearest population centers

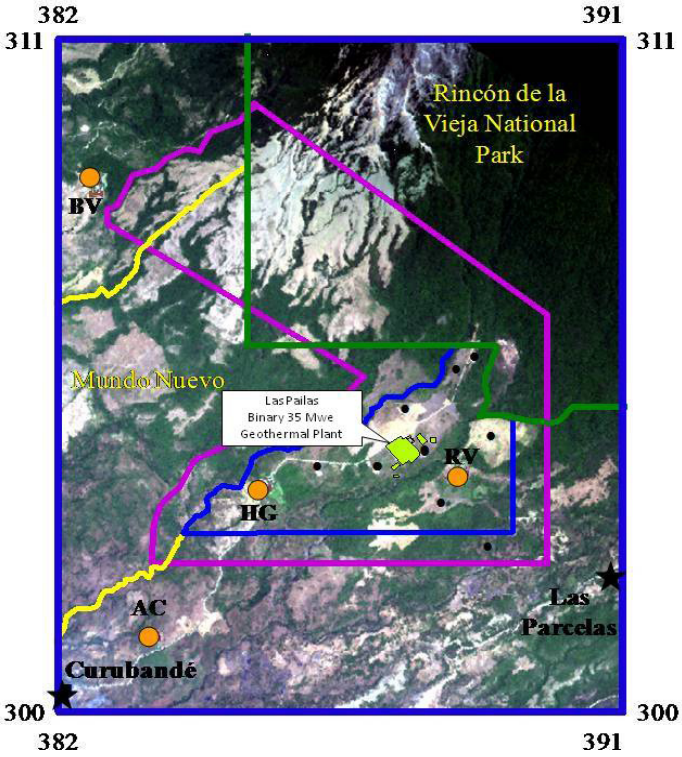


**Figure 2.** Location map of the field area (outlined in purple). The blue outline (inner) marks the Project Area of the Las Pailas Geothermal Project and the purple outline (outer) encloses the field area. The green border marks the Rincón de la Vieja National Park and the yellow border outlines the privately owned protected property Mundo Nuevo. The light green box indicates the precise location of where the 35 MWe geothermal plant is currently being constructed and the black dots represent the deep borehole drilling pads at the Pailas Geothermal field. Mountain lodges are represented by the orange circles: AC (Aroma de Campo); HG (Hacienda Guachipelín); y RV (Rincón de la Vieja Lodge).

to the Las Pailas Geothermal Plant are the Las Parcelas settlement at 4 km to the southeast and Curubandé at 6.5 km to the southwest. Also, two mountain lodges (Hacienda Guachipelín and Rincón de la Vieja Lodge) are located within the Project Area of the Las Pailas Geothermal Project (Figure 2).

The basic parameter of environmental noise is the $L_{A90}$, defined as the noise level perceived during 90 percent of the time of the noise level measurement session. It can also be considered as the 90$^{th}$ percentile of all of the noise level measurements obtained during a specified period of time.

Environmental noise (referred to in this paper as $L_{A90}$) is reported in decibels using the A weighted scale (dB-A) because this scale best resembles the sensitivity of the human ear.

Noise is regulated in Costa Rica during daytime and nighttime hours and is based on the noise levels coming from three main noise provinces, namely: residential areas, commercial areas and industrial areas as it is perceived from different noise receptor provinces (Table 1).

## Fieldwork and Site Description

At fifty-six observation points distributed between 422 and 1291 m s.n.m., sound level pressure data were taken from 20/09/2008 to 19/01/2009 utilizing a Quest Type 2 model 2800

**Table 1.** Maximum permissible sound pressure levels from Residential, Commercial and Industrial Areas in Costa Rica. Source: Decreto Ejecutivo 28718-S del 14 de agosto del 2000.

| Noise Source | Noise Receptor | Daytime (dB-A) | Nighttime (dB-A) |
|---|---|---|---|
| Residential Area | Residential Area | 65 | 45 |
| | Commercial Area | 65 | 55 |
| | Industrial Area | 75 | 65 |
| | Quiet Area | 50 | 45 |
| Commercial Area | Residential Area | 65 | 45 |
| | Commercial Area | 65 | 55 |
| | Industrial Area | 75 | 65 |
| | Quiet Area | 50 | 45 |
| Industrial Area | Residential Area | 65 | 45 |
| | Commercial Area | 70 | 65 |
| | Industrial Area | 75 | 75 |
| | Quiet Area | 50 | 45 |

integrated sound level meter and on 21/05/2009 utilizing a Quest SoudPro DL Datalogging sound level meter. Each was configured for a slow response, A-weighted measurement with an upper limit of 80 dB-A. The Costa Rican Decree No. 32692-S was consulted for the minimum duration of the sampling session. Following the recommendation in this document, at each observation point, sixteen sound pressure level measurements were taken, one every fifteen seconds, during a three minute and forty-five second sampling session. Also, field data on land use, topographic gradient and environmental noise sources were recorded. The topographic gradient is reported as inclined slightly (0-10%), moderately (10-30%) or highly (> 30%). Site description data is presented according to fourteen subdivided field sectors (Figure 2). Preferential wind direction was not considered in this field study.

### *Sector Guachipelín (I)*

Three environmental noise measurements were made in open grassland (TS-001, TS-002) and riparian forest (TS-003) with a slightly to highly inclined topographic gradient towards the southwest (TS-001) and south-southeast (TS-002 and TS-003).

### *Sitio Varillales (II)*

Three environmental noise measurements were made in open grassland (TS-004) and secondary forest (TS-005, TS-006) with a slightly to moderately inclined topographic gradient towards the southeast.

### *Las Parcelas de Santa María (III)*

Three environmental noise measurements were made in intervened forest (TS-007), secondary forest (TS-008) and open grassland (TS-016) with a moderately to highly inclined topographic gradient towards the southeast (TS-007), south (TS-016) and southwest (TS-008).

### *Sitio Cabuyal (IV)*

Six environmental noise measurements were made in open grassland (TS-013), secondary forest (TS-014, TS-021, TS-022, TS-023) and riparian forest (TS-015) with a slightly to highly

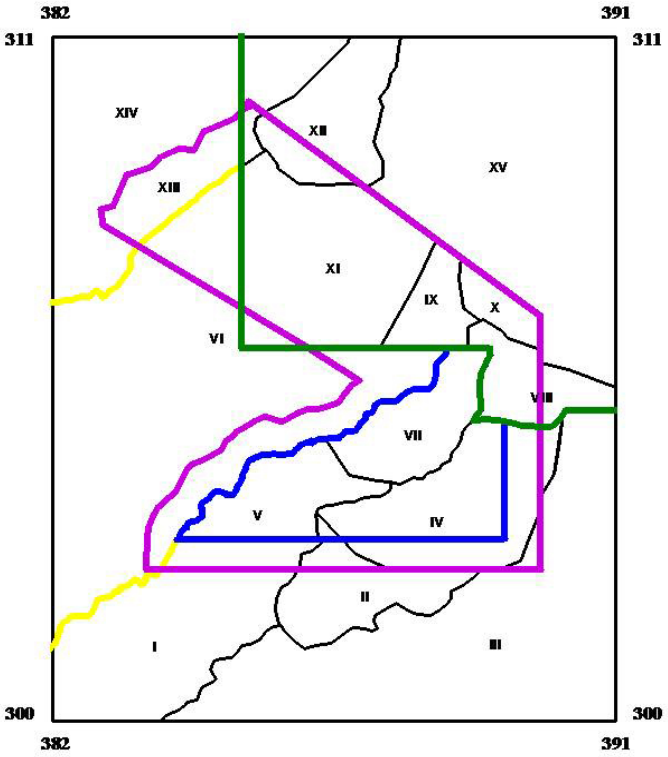


**Figure 3.** Field Sectors: I (Sector Guachipelín); II (Sitio Varialles); III (Las Parcelas de Santa María); IV (Sitio Cabuyal); V (Hacienda Guachipelín); VI (Mundo Nuevo); VII (Sitio Modesto); VIII (Sitio Coyol Guape); IX (Sitio Pará); X (Sitio Balsa); XI (Sitio Las Hornillas); XII (Sitio Ojos de Agua); XIII (Sitio Salsipuedes); XIV (Borinquen); XV (Parque Nacional Rincón de la Vieja.

inclined topographic towards the north (TS-013), south (TS-022, TS-023) and southwest (TS-014) and west (TS-015, TS-021).

### *Hacienda Guachipelín (V)*

Three environmental noise measurements were made in open grassland (TS-011), secondary forest (TS-012) and a tree plantation of *Bombacopsis quintata* (TS-019) with a slightly to moderately inclined topographic gradient towards the northeast (TS-011), southeast (TS-019) and northwest (TS-012).

### *Mundo Nuevo (VI)*

Ten environmental noise measurements were made in secondary forest (TS-10, TS-017, TS-018, TS-025, TS-037), undisturbed low land forest (TS-009), regenerating forest (TS-024, TS-026), riparian forest (TS-036) and open grassland (TS-046) with a slightly to highly inclined topographic gradient towards the southeast (TS-009, TS-010, TS-017, TS-018, TS-025, TS-026), southwest (TS-024, TS-036, TS-046) and northwest (TS-037).

### *Sitio Modesto (VII)*

Two environmental noise measurements were made in intervened secondary forest (TS-020) and open grassland (TS-027) with a slightly inclined topographic gradient towards the south (TS-020) and southwest (TS-027).

### *Sitio Coyol Guape (VIII)*

Five environmental noise measurements were made in primary forest (TS-28, TS-029, TS-34, TS-35, TS-041) with a slightly to highly inclined topographic gradient towards the south (TS-028, TS-041), southwest (TS-029, TS-035) and northwest (TS-034).

### *Sitio Pará (IX)*

One environmental noise measurement was made in a secondary forest (TS-033) with a moderately inclined topographic gradient towards the south.

### *Sitio Balsa (X)*

Two environmental noise measurements were made in primary forest (TS-042, TS-051) with a slightly to highly inclined topographic gradient to the northwest (TS-042) and west (TS-051).

### *Sitio Las Hornillas (XI)*

Nine environmental noise measurements were made in secondary forest (TS-030, TS-032, TS-038, TS-039, TS-040), riparian forest (TS-031, TS-049) and open grassland (TS-047, TS-048) with a slightly to highly inclined topographic gradient to the southeast (TS-031, TS-038, TS-039, TS-049), south (TS-032), west (TS-040, TS-047, TS-048) and northwest (TS-030).

### *Sitio Ojos de Agua (XII)*

Three environmental noise measurements were made in regenerating forest (TS-056, TS-060) and open grassland (TS-055) with a topographic gradient moderately to highly inclined towards the south (TS-055, TS-056) and southwest (TS-060).

### *Sitio Salsipuedes (XIII)*

Three environmental noise measurements were made in open grassland (TS-045, TS-053, TS-054) with a topographic gradient slightly to highly inclined towards the south.

### *Borinquen (XIV)*

Four environmental noise measurements were made in open grassland (TS-044) and secondary forest (TS-052, TS-058, TS-059) with a topographic gradient moderately to highly inclined towards the south (TS-044, TS-058, TS-059) and west (TS-052).

## Environmental Noise Level (LA90) Results

In the field area, a total of 960 environmental noise measurements were taken during the sampling season and the $L_{A90}$ determined at each observation point ranged from 33.3 to 72.4 dB-A (Figures 3 and 4). The most frequent value $L_{A90}$ value was in the 50 dB-A range, followed by the 40 and 55 dB-A ranges and then by the 45 and 70 dB-A ranges (Figure 4).

### *Environmental Noise Sources*

Environmental noise sources can be considered as continuous, intermittent or impact. In this field study an attempt was made to identify and classify the sources of naturally occurring environmental noises as well as non-naturally occurring sounds in the area under study. In general the most common sounds were produced by natural sources such as wind, rivers, various different families of birds, cattle, mosquitos, crickets and ciqueda bugs, each of which have varying intensities throughout the field. Other types of naturally occurring sounds perceived during the field survey

were waterfalls, thunder, rain, monkeys, frogs, and humming birds. Sources of non-naturally occurring sounds perceived during the field survey were heavy machinery (dump trucks and steam rollers), vehicles, over flying airplanes, drilling operations and well production tests at the nearby deep boreholes of the Pailas Geothermal borehole field (Table 2).

**Table 2.** Continuous, Intermittent and Impact sources of noise perceived during the environmental noise level ($L_{A90}$) field surveys.

| Continuous | Intermittent | Impact |
|---|---|---|
| Cattle | Cars | Detonations |
| Ciqueda Bugs | Canopy (Hacienda | Dogs |
| Crickets | Guachipelín) | Heavy Machinery |
| Drilling Operations | Cattle | Hummingbirds |
| Flying insects | Chainsaw | Overflying airplanes |
| Frogs | Dogs | |
| Rain | Drilling Operations | |
| Ravines | Flying Insects | |
| Rivers | Heavy Machinery | |
| Various Bird Species | Wind | |
| Wind | Horses | |
| Well Production | Monkeys (Howlers and | |
| Water slide (Hacienda | White-faced monkeys) | |
| Buenavista) | Various Bird Species | |
| | Overflying airplanes | |
| | People | |
| | Thunder | |

## Land Uses

During the Field investigation, four general land use practices could be determined: Open pastures, forested areas, high grassland area and a tree plantation. The maximum, minimum and average $L_{A90}$ is reported in each of these different land use sectors (Table 3).

**Table 3.** Environmental noise levels ($L_{A90}$) in different land use sectors on the southern slope of the Rincón de la Vieja Volcanic Complex.

| Land Use | N | Min | Max | Avg | 50-65 dB-A | >65 dB-A |
|---|---|---|---|---|---|---|
| Forest | 37 | 36.93 | 72.63 | 53.98 | 13 (35%) | 8 (21%) |
| Open Pasture | 12 | 33.92 | 53.61 | 43.82 | 1 (8%) | 0 |
| Tree Plantation | 1 | 46.37 | 46.37 | 46.37 | 0 | 0 |
| High Grasslands | 6 | 44.83 | 73.72 | 58.09 | 2 (33%) | 2 (33%) |

Of the 56 observation points located in the field, 37 of them are in forested areas. The $L_{A90}$ recorded within this land use area ranged from 36.93 to 72.63 with an average value of 53.98 dB-A. Of these, 13 are in the 50-65 dB-A range and 8 exceed the 65 dB-A limit.

Twelve observation points are in open pastures. The $L_{A90}$ recorded within this land use area ranged from 33.92 to 53.61 dB-A with an average value of 43.82 dB-A. Of these, only one is in the 50-65 dB-A range. All others are less than 50 dB-A.

One observation point is located in a *Bombacopsis quintata* tree plantation. The $L_{A90}$ recorded within this land use area is 46.37 dB-A.

Six observation points are located in a high grassland area. The $L_{A90}$ recorded within this land use area ranged from 44.83 to 73.72 dB-A with an average value of 58.09 dB-A. Of these, two fell in the 50-65 dB-A range and two others exceeded the 65 dB-A limit.

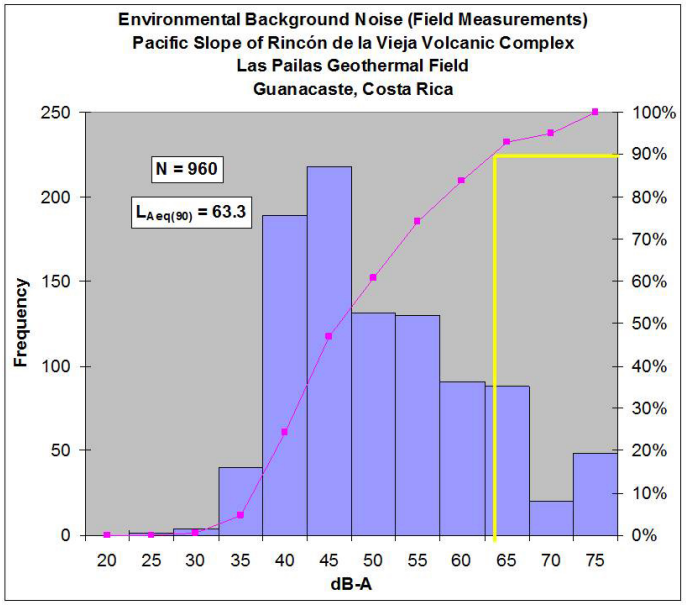


**Figure 4.** Raw environmental background noise obtained during the field sampling session from September 2008 to June 2009 on the Pacific slope of the Rincòn de la Vieja Volcanic Complex. $L_{A90}$ = 63.3.

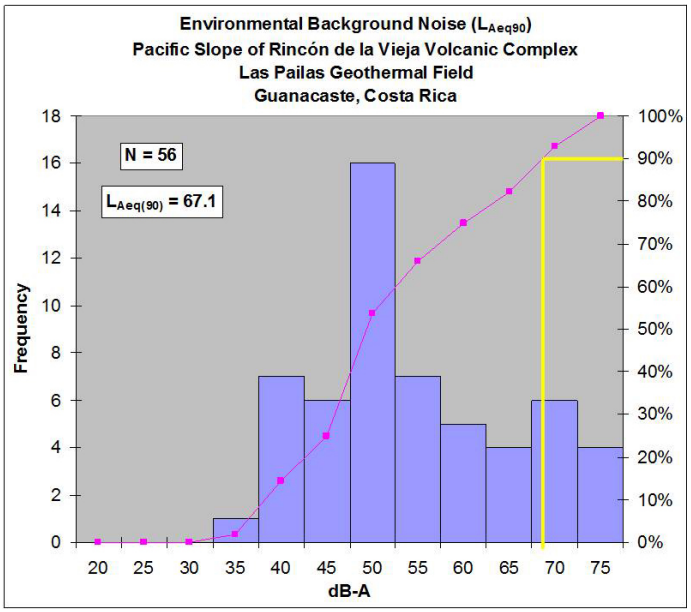


**Figure 5.** Calculated $L_{A90}$ values at each of the individual observation points on the Pacific slope of the Rincón de la Vieja volcanic complex from September 2008 to June 2009. $L_{A90}$ = 67.1.

## Topographic Aspect

Numerous measurements of topographic aspect were taken at each observation point and based on the field data it was determined that the slopes basically fan from the southeast to the southwest, however the majority of the slopes are south facing (Figure 6).

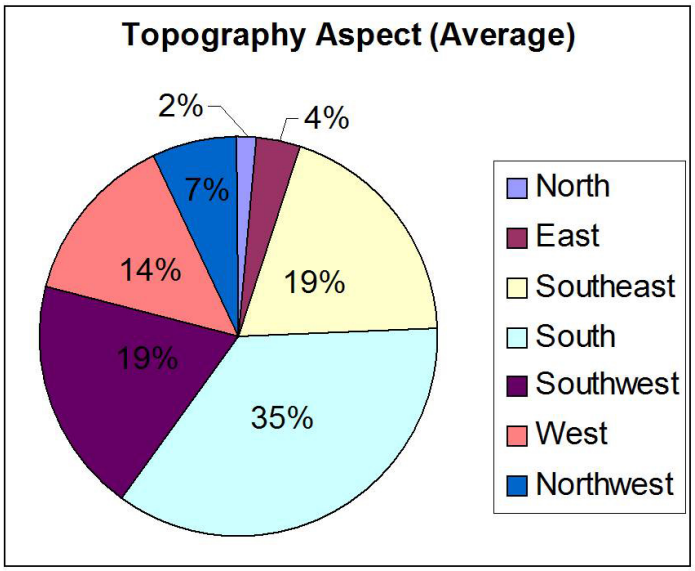


**Figure 6.** Topographic aspect as measured in the field area on the Pacific Slope of the Rincón de la Vieja volcanic complex.

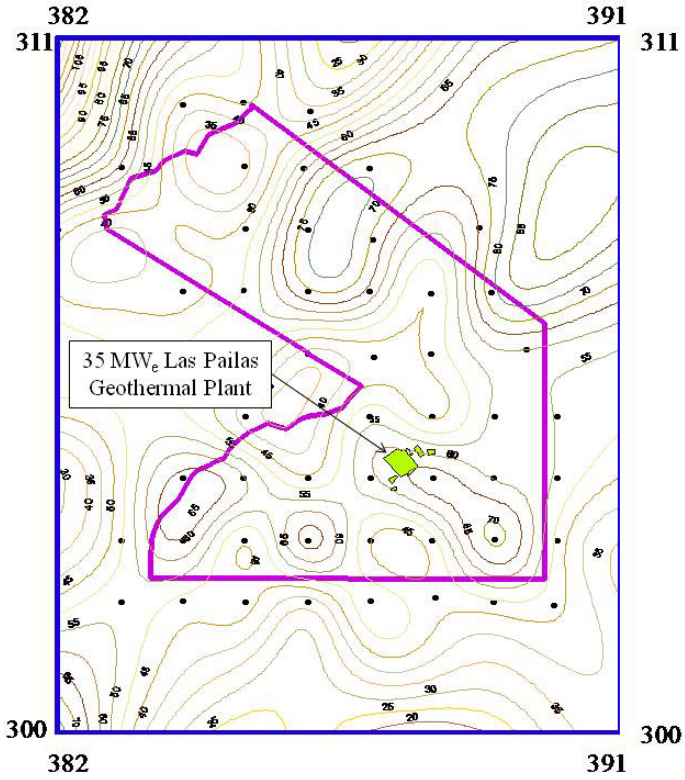


**Figure 7.** Environmental noise ($L_{A90}$) contours. The location of the Pailas Geothermal Plant is shown by a green box and is located within an area where the baseline $L_{A90}$ is between 60 – 65 dB-A.

## Final Remarks

Based on the field data collected in this investigation, the Environmental noise level ($L_{A90}$) at and around the Las Pailas Geothermal field is 67.1 dB-A where the highest values were measured in forested areas and high grasslands while the lowest values were measured in open fields and a tree plantation.

The 35 MWe Las Pailas Geothermal Plant is located within an area where the naturally occurring baseline $L_{A90}$ is between 60 – 65 dB-A.

However, the Las Pailas Geothermal Plant is an industrial area that will be a new point source of noise on the southern slope of the Rincón de la Vieja volcanic complex and by law the 35 MWe powerhouse shall not generate more than 75 dB-A during daytime or nighttime hours while under normal operation.

The nearest population centers to the Las Pailas Geothermal Plant are Curubandé (6.5 km SW) and the Las Parcelas settlement (4 km SE) and due to their distance from the powerhouse they may not be impacted by any noise contamination at all from normal operation of the Las Pailas geothermal plant.

However, due to their proximity to the geothermal plant and borehole field, the two mountain lodges within the Project Area (Hacienda Guachipelín and Rincón de la Vieja Lodge) may be mildly affected by the noise generated at the 35 $MW_e$ Las Pailas Geothermal Plant and surrounding borehole field.

A noise mitigation plan has been proposed to deal with the noise that will be produced by the Las Pailas 35 Mwe power plant.

Among the possible methods of noise atenuation are the construction of natural vegetative barriers, artificial barriers and the use of combined silencers.

Environmental noise level measurements need to be continued at and around the 35 MWe Las Pailas Geothermal plant once it comes on-line to ensure that the maximum permissible noise limits are not exceeded by normal operation.

Ronald Di Pippo, in his book Geothermal Power Plants (2008) writes that "an unabated , wide open geothermal well discharging vertically into the atmosphere produces a noise level of 71 – 83 dB(A) at a distance of 900 m." This can be compared to a noisy busy street which may have a noise level of about 80 – 90 dB-A (Brüel and Kjær. 2000).

## Conclusions

The majority of the environmental noise sources at and around the Las Pailas Geothermal Project are naturally occurring and in general are within the 50 dB-A range ($L_{A90}$) although some such as occasional howler and white-faced monkey calls, some particular bird species, wind, rivers and ravines generate high sound pressure levels (up to 75 dB-A).

Places where the topographic gradient is inclined towards the Las Pailas Geothermal Project (TS-020, TS-027, TS-012, TS-011, TS-013, TS-015, TS-021, TS-025, TS-026, TS-027 TS-031, TS-032 and TS-033) may be more affected by the noise that will produce the first 35 Mw power plant to be installed at Pailas Geothermal Field, as well as the open grasslands and intervened secondary forest in the north central and southwestern sectors of the area currently under development.

The secondary forest to the north and northwest of the Las Pailas Geothermal Project may serve as a noise buffer to the powerplant.

Although preferential wind direction patterns were not considered in this field investigation, they might also impact noise propagation from power plant and therefore should be studied and evaluated.

Once the power plant is constructed and operating, it is suggested that noise monitoring of the area with a minimum of a 900 meter radius around the power plant and each deep borehole pad be established to determine the effects of the power plant and future operations at the well pads may have on the environmental noise baseline established in this report.

## Acknowledgements

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