Preliminary Environmental and Social Impact Assessment of Karisimbi Geothermal Prospect, Rwanda

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ABSTRACT

In this paper a preliminary environmental impact assessment of geothermal exploration and development at the Karisimbi geothermal prospect located on the southern slopes of the Karisimbi Volcano in Rwanda is presented. The sites for drilling 3 exploration wells were chosen after scientific studies and taking into account the possible impacts on the mountain gorillas in the National Volcanoes Park. It is anticipated that noise created by the drilling and discharge operations of the wells during the testing period may have an impact on the mountain gorillas. Other impacts might include the unpleasant smell of hydrogen sulphide and poaching in the park. To minimize the utilization of fresh water, drilling fluid will be recycled and future drilling might use a mixture of fresh water and brine if the exploration wells are successful. A minimum of 4 wells will be drilled at each well pad to minimize environmental impact and the size of land required in this densely populated and high yield agricultural area. Exploration drilling will have socio-economic impacts and benefits on the local community and therefore an environmental and social impact assessment (ESIA) will be carried out prior to drilling. If exploration drilling is successful, then a full ESIA will be carried out as part of the feasibility studies.

1. INTRODUCTION

1.1 General Introduction

The Karisimbi geothermal prospect covers an area of 200km^2 in the Kabatwa, Bigogwe and Jenda sectors of the Nyabihu District and in the Bugeshi sector of the Rubavu District. Based on available geo-scientific data, the potential area has been narrowed down to 25km^2.

The prospect area is characterized by a hilly terrain with steep hills ranging from an elevation of 1460m to 4507m at the Karisimbi Summit. The region has four seasons and a moderate climate with an annual average rainfall of 1400mm. The four main seasons are: short dry from January to March, long rains from March to May, short rains from September to December and a long dry season from June to August. The average maximum temperature varies between 22^{0}C-26^{0}C while the average annual temperature ranges between 10^{0}C-15^{0}C.

The prospect area has fertile volcanic soil (andisols and andosols), which are used for growing a few cash crops (pyrethrum, coffee), food crops (Irish potatoes, maize, sorghum, corn and beans) and vegetables (cabbages, carrots and onions). The majority of the arable land is occupied by pyrethrum plantations owned and processed by the Rwandan Pyrethrum Society (SOPYRWA) for export and for production of insecticides. There are also small plantations of cypress and eucalyptus trees used for firewood in the region. Dairy farming is also practiced on a small scale and cows are kept in enclosed spaces to maximize on production and reduce soil erosion. The potatoes are supplied to the whole country and the neighbouring regions of Burundi and the DRC.

1.2 Environmental Geology

The rocks at Karisimbi are classified as Nephelinites which are of ultrabasic chemical composition typical of continental rift graben. The rocks are highly resistant to chemical alteration. The porosity of the rocks is very high and visible; it is estimated to be at least 25% (IGIP, 2004). The permeability of Karisimbi rocks has also been confirmed by Browne (2011) who explained the scarcity of ponds, lakes and permanent surface flow despite the high rainfall.

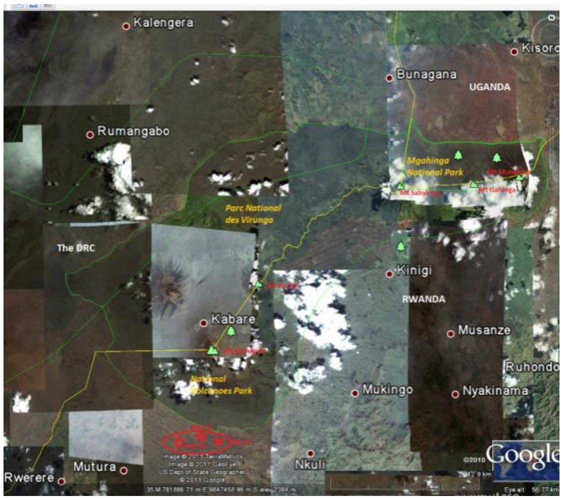

Figure 17: Location of drilling target, 3 national parks and 5 mountain volcanoes on Rwanda-DRC-Uganda borders

1.3 Results of Previous Studies

Preliminary surface investigations were started in the western, northern and southern provinces of Rwanda in 1981 by the French Bureau of Geology and Mines (BRGM). The result of this study suggested the Southwest (Bugarama) and Northwest (Gisenyi) as drilling sites for geothermal energy development with estimated reservoir temperatures above 100°C (Rancon and Demange, 1983). In 2004 the Government of Rwanda (GoR) renewed interest in geothermal exploration due to a severe drought that required the country to rely on expensive electricity generation from oil fired generators. A summary of the exploration work carried out is given below:

a) In 2006, Chevron carried out geochemistry studies in the Bugarama and Gisenyi geothermal prospects and estimated the geothermal reservoir temperatures to be more than 150°C (Newell et al., 2006).

b) In 2008, the Germany Institute for Geosciences and Natural Resources (BGR), in collaboration with the Kenya Electricity Generating Company (KenGen), the Icelandic Geo Survey (ISOR) and the Spanish Institute for Technology and Renewable Energies (ITER) carried out surface studies in the Gisenyi, Karisimbi and Kinigi areas (Jolie et al., 2009). The results from this study were as follows:
   - ✓ A high temperature geothermal system (>200°C) on the southern slopes of Karisimbi volcano;
   - ✓ A medium temperature geothermal system around Lake Karago (150-200°C); and
   - ✓ A heat source for the geothermal system at a depth of about 5km.

c) In 2009, KenGen acquired additional surface studies (geochemistry and geophysics) and base line EIA on the southern slopes of the Karisimbi Volcano (Mariita et. al, 2010). The results from this study were:
   - ✓ A workshop involving experts from Germany, Iceland and Kenya held in Kigali in February 2010 to discuss the findings and recommend drilling sites;
   - ✓ A higher resolution conceptual model used to identify targets for drilling 3 exploration wells;
   - ✓ Location of 3 sites for exploration drilling;
   - ✓ Estimated geothermal resource area of more than 20km^2;
   - ✓ Estimated geothermal potential of over 300 MWe; and
   - ✓ A preliminary ESIA.

d) In 2011, the Institute of Earth Science and Engineering based at the Auckland University in New Zealand carried out additional studies..

1.4 Legislative and Institutional Frameworks

ESIA in Rwanda is governed by the Environmental Law N^o 04/2005 of 08/04/2005 as enshrined in the constitution and ratified in several international conventions and treaties for the protection and conservation of the environment. The law determines the modalities of protection, conservation and promotion of the environment in Rwanda. The law also sets up the modalities for the establishment of the Rwanda Environment Management Authority (REMA) as an implementing agency. REMA was created by Law N^o 16/2006 of 03/04/2006 which determines the organization, functions and responsibility of REMA. However, to facilitate investments in Rwanda, ESIA review and approval was transferred to the Rwanda Development Board (RDB).

An ESIA study in Rwanda includes 5 steps:

a) Project application and registration,
b) Screening, scoping and terms of reference,
c) ESIA study and report,
d) Submission of an ESIA report; and finally
e) Decision making.

The whole process of getting an ESIA Certificate of Authorization (ESIACA) takes 34 days excluding the time for ESIA studies which varies depending on the magnitude and the size of the project. The developer is required to submit an annual monitoring and environmental auditing report (REMA, 2006).

2. PRELIMINARY ESIA STUDIES

2.1 Introduction

The Karisimbi geothermal prospect is part of Virunga volcanic region which is made up of three parks: NVP of Rwanda, Mgahinga Gorilla National Park (MGNP) in Uganda and Parc National des Virunga (PNVi) in DRC. This area encompasses six volcanoes: Karisimbi (4507m), Mikeno (4437m), Bisoke (3711m), Mgahinga (3474m), Muhabura (4127m) and Sabyinyo (3634m). The parks are managed by the National Park authorities in each country.

2.2 Fauna and Flora

The Virunga Volcanoes Range (VVR) is an area of afro-mountain forest which hosts mountain gorillas and other flora and fauna. The fauna depends on habitat types (mixed forest, disturbed woodland, bamboo and Hagena-Hypericum wood land). The region contains 45%-57 % of the endemic vertebrate species found in the Albertine Rift and 56% of the threatened amphibian species (Table 1) making it an important site for amphibian conservation (Owiunji et al., 2004). Over 800 species of flowering plants have been recorded in the VVR.

Table 1: Species Richness, Number of Albertine Rift Endemic and IUCN Threatened Species

Species	**Species richness**	**Endemic species**
Mammals	86	18
Birds	258	20
Reptiles	43	7
Amphibians	47	16
Plants	878	124
Total	**1312**	**185**

The increase in the estimated population size of 480 gorillas (2010) as shown in Table 2, represents a 3.7% annual growth rate from a previous census in 2003 of an estimated population size of 380 gorillas and has been attributed to a combination of ecological conditions and effective park management efforts (Gray et al., 2011).

Table 2: Summary of Gorilla Population According to the Country of Group Location in 2010

Country	**Habituated gorillas**	**Un-habituated gorillas**	**Total**
DRC	84	117	201
Rwanda	259	10	269
Uganda	9	1	10
Total	**352**	**128**	**480**

2.3 Water Resources and Quality

The hydrological network comprises of many streams, brooks, springs, ponds and Lake Karago. All streams and springs are concentrated in lowland valleys between steep mountains. Residents rely on rainwater harvesting for their water supply through water pans and gutters on their houses. About 30%-35% of the population has access to drinking water from the eleven water kiosks supplied with piped water. This section acts mainly as a catchment area.

Chemical analysis of the water from Lake Karago which is the largest in the area and the Nyirakigugu pond shows that the water is of good quality in accordance to the World Health Organization (WHO) guidelines for drinking water. Pesticides were not found in all samples analysed. Contamination by faecal coliform bacteria was noted in some samples and is attributed to lack of appropriate sanitation facilities and nutrients which most likely originate from agricultural fertilizer applications (Water Supply and Sanitation Services, 2010).

2.4 Socio-economic Environment

2.4.1 Population and Public Health

Rubavu and Nyabihu districts are among the most densely populated districts in Rwanda with an average population density of 535 inhabitants per km^2. The population growth rate is estimated at 2.8% per annum. The population lives in rural agricultural settlements, in family hamlets and in group settlements commonly known in the local language as "imidugudu" or villages (Table 3).

There are 15 health centres and 1 hospital in Nyabihu District. The common diseases are malaria, respiratory tract diseases, diarrhoea, skin rashes, amoebic dysentery, headaches and cholera. Most of these diseases are due to poor hygienic conditions, poor sanitation infrastructure at the household level, and poor water quality. A new policy on mutual health insurance has been set up and every citizen is required to pay RWF 3000 per year (equivalent of $USD 5) for a universal health care system. This policy facilitates access to health care for people from vulnerable groups like widowers and the very poor. Furthermore, there are plans to supply drinking water, improve hygienic conditions and work on birth control issues for the population in the northern regions. Sanitation facilities are limited - usually only a small pit latrine less than 3m deep - because of difficulties in digging into lava rocks. This causes the rapid transmission of contagious diseases. Septic holes that might pollute groundwater are used in schools and large institutions.

Table 3: Population, Health Centres and Hospitals of Sectors Bordering the Karisimbi Prospect

District	**Sector**	**2009 Population (density)**	**Health centres**	**Hospitals**
Nyabihu	Kabatwa	16,000 (450)	15	1
	Bigogwe	37,000 (840)		
	Jenda	31,000		
	Mukamira	29,000		
	Karago	27,000		

Source: Mariita (2010)

2.4.2 Education in the Karisimbi Area

The Nyabihu District has 87 public primary schools and 22 secondary schools apart from 9-year basic education schools (Table 4). There are 3 higher institutions of learning in neighbouring districts: the Kigali Independent University Campus - Gisenyi in Rubavu District, the High Institute of Agriculture and Animal Husbandry (ISAE) and the Catholic Institute of Higher Education (INES-Ruhengeri), both in Musanze District.

Table 4: Schools in Nyabihu District Bordering the Karisimbi Prospect

District	Sector	Schools and Universities		
		Nursery	Primary	High School
Nyabihu	Kabatwa	156	87	22
	Bigogwe			
	Jenda			
	Mukamira			
	Karago			

Source: Mariita (2010)

2.4.3 Tourism in the National Volcanoes Park (NVP)

The NVP was established in 1925 and it is within the Nyabihu, Rubavu and Musanze Districts. The park plays an important role in the economy of the country by attracting many tourists and researchers worldwide who come to see and trek mountain gorillas. The tourism activity is controlled by the Department of Tourism and Conservation of the Rwanda Development Board (RDB). Foreign visitors accounted for 92% of the visits in 2009. NVP is the busiest of the three parks in Rwanda accounting for 49% of park visits. The gorillas attracted 82% of the guests while other scheduled activities like mountain climbing, natural trails, golden monkey and Diane Fossey's tomb made up the rest (18%). Foreign tourists pay USD 500 EACH for a gorilla visit while East African residents and Rwandese nationals pay USD 250 and USD 30 respectively.

2.4.4 Infrastructure

Affordable public transport subsidized by the GoR is run by the National Office of Transportation (ONATRACOM). However, private transport companies provide their services on the main road at a price set by the Rwanda Utility Regulatory Agency (RURA). The main access road will be through the upgrade of an existing a 5km dirt road.

There is an existing network of electrical power lines which supply electricity to the residents of the Kabatwa area. However, like the rest of the country the main source of energy is biomass in the form of firewood or charcoal. The use of geothermal energy together with improved cooking stoves may drastically reduce the use of biomass. Geothermal energy could also be used in the processing of agricultural products like pyrethrum and potatoes thus creating jobs to improve the socio-economical development of the villages.

3. ACTIVITIES DURING EXPLORATION DRILLING

A description the activities to be carried out during and after drilling are given below. The activities include preparation of access roads, drilling of pads, water supply for drilling, camp site portable water and electricity supply.

3.1 Access Roads, Well Pads and Camp.

The 10km road connecting the prospect to the main tarmac road (Kigali-Rubavu) will be upgraded and widened with good drainage channels. Access roads will also be prepared to 3 wells pads which will be constructed such they can be used to drill 5 wells per pad. The well pads including the drainage pond will measure about 85x150m. The camp site and the storage area for drilling materials and accessories will cover an area of about 150x100m. The plan is to lease the land, remove the top soil, store it and then rehabilitate the sites if they are no longer required.

It is anticipated that heavy traffic will be experienced once the road is rehabilitated and this could cause accidents due to over speeding. The rig - mobilized and demobilized - could also cause accidents. A health and safety environmental management policy will be put in place and enforced during the exploration drilling.

3.2 Water for Drilling

A maximum of 2,000 litres per minute of water will be required for exploration drilling for about 6 months. Completion and injection testing may require up to 10,000m^3 per day (Nyakecho, 2008). The water will be pumped from Lake Karago to the Kabatwa village which is about 20km from the Lake. Water storage tanks will be constructed on the slopes of Karisimbi Mountain such that the water will flow to the drilling sites by gravity.

3.3 Drilling and Completion of Exploration Wells

The drilling program will include drilling, cementing and casing. It is anticipated that drilling in the reservoir zone will be mainly by water, air and aerated form. The casing design has been determined taking into account the anticipated depth to the production zone, rock properties, casing diameter, flow rate, expected temperature, well trajectory and the length of individual casing intervals (Finger and Blankenship, 2010).

After drilling each well, completion tests will be carried out. Well stimulations to enhance the output of the wells will also be conducted if required. This may include compressing the well to initiate discharge. Initially the wells will be discharged vertically for a short time to clean them.

4 POSSIBLE ENVIRONMENTAL IMPACTS AND MITIGATION

4.1 Environmental Impacts

Environmental impacts and mitigation measures due to geothermal exploration are generally well known but may vary from one location to another depending on local conditions. The major impact will be during exploration and appraisal drilling and will become significant in the power plant design and construction phase (Haraldsson, 2011). The major impact will be noise during drilling and testing and it is not well known how this would affect the gorillas which, as already mentioned are a big tourist attraction. Data from other geothermal fields indicates that the noise levels reduce to background noise at about 400m from the wells. The anticipated impacts and mitigation measures are outlined below:

4.1.1 Access Roads and Drilling Pads

The planned access roads will follow existing roads and tracks which will be complementary to upgrading the road network to increase accessibility to markets for the agricultural products. In a few places, it may be necessary to widen the existing road in order to facilitate the movement of the rig and heavy trucks. This may call for the acquisition of land from residents. The drilling pads have been located in farming areas with fewer people to relocate. Destruction of existing vegetation to pave way for the construction of access roads to drill site and site preparation will be minimized using existing tracks and by planting fast growing trees and grass which bind to reduce soil erosion. The drilling pads will be used to drill up to 5 wells to minimize land use and environmental impacts. After well completion the sites will be restored by putting back the top soil to prepare the land for its original use.

4.1.2 Noise

Drilling creates temporary noise (which in most cases does not exceed 90 dBA), fumes and dust which can disturb animals and humans living nearby. The level of noise may cause long term hearing impairment, hypertension, ischemic heart disease, annoyance and sleep disturbance if safety equipment is not used. As shown in Table 5, the noise shall not exceed 65 dBA at a distance of 0.8km from geothermal operations (Hunt, 2001).

Various measures will be taken during drilling including muffling, construction of earth embankments, use of ear muffs for residence who live less than 250m from the drilling sites and possibly temporary relocation. If a viable geothermal resource is found, then a buffer zone of trees may be planted to form a screen for sound absorption. During well discharge silencers will be used to reduce the noise level.

Table 5: Noise from Some Drilling Activities

Activity	**Noise level (dBA)**
Air drilling	120 (85 with suitable muffling)
Discharging wells after drilling	Up to 120
Well testing	70-110 (if silencers used)
Heavy machinery	Up to 90
Well bleeding	Up to 85 (65 if rock muffler is used)
Mud drilling	Up to 80
Diesel engine (to operate compressors and electricity)	45-55 (if suitable muffling is used)

Source: Hunt (2001)

The noise from discharging boreholes rarely exceeds 120 dB as evident from the noise data from two rigs and a discharging well (Figure 2). The recommended environmental noise limits for new developments are 55 dBA (day time) and 45 dBA (night-time) for residential, institutional and educational receptors while for industrial and commercial receptors the threshold limit is 70 dBA (day and night) (PERTAMINA Geothermal Energy, 2011). The data from Kenya clearly shows that the noise levels reduce to less than 45 dB (A) at a distance of about 250m from the wells.

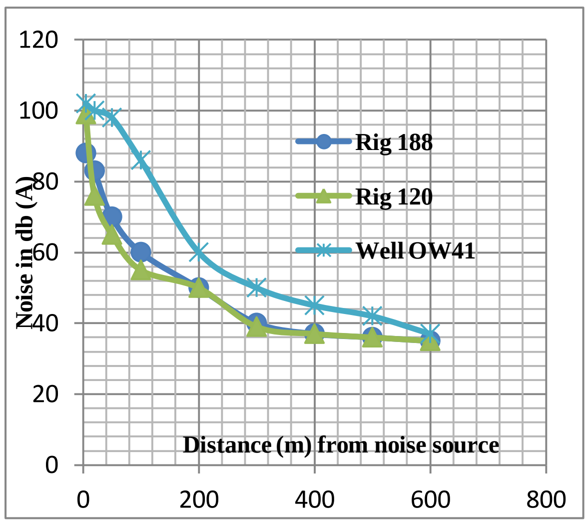

Figure 18: Noise level at increasing distance from drilling rigs and a discharging well at the Olkaria geothermal field in Kenya

4.1.3 Gas Emissions

The major gases emitted from geothermal wells and power plants are carbon dioxide (CO_2), hydrogen (H_2), nitrogen (N_2), Argon (Ar), hydrogen sulphide (H_2S) and methane (CH_4). H_2S dissolved in water aerosol such as fog can react with atmospheric oxygen to form sulphur dioxide (SO_2) which can lead to acidic rain. This is a photochemical reaction that takes place under dry sunny conditions. In wet weather it is usually washed to the ground and may form solid sulphur. H_2S is the greatest concern because of its unpleasant smell and toxicity (Table 6). Geothermal power plants do not emit NO_x, but geothermal gas may contain ammonia (NH_3) and trace amounts of mercury (Hg), Boron (B) and radon (Rn). Inhalation of mercury causes neurological disorders. It is proven that ammonia can cause eye irritation, nasal passage and respiratory tract infection at concentrations ranging from 5-32 ppm (Hunt, 2001).

Table 6: Human Health Effects at Various Hydrogen Sulphide Concentrations

Exposure		Effect/observation
$mg.m^{-3}$	Ppm	
0.011	0.00781	Odour threshold
2.8	1.988	Bronchial constriction in asthmatic individuals
5	3.55	Increased eye complaints
7-14	4.97-9.94	Increased blood lactate concentration, decreased skeleton muscle citrate synthesis activity, decreased oxygen uptake
5-29	3.55	Eye irritation
28	20.59	Fatigue, loss of appetite, headache, irritability, poor memory, dizziness
>140	>99.4	Olfactory paralysis
>560	≥397.6	Respiratory distress
≥700	≥497	Death

Source: WHO (2005)

Gas emissions will be monitored during the exploration drilling and well testing and suitable personal protective wear used. If a viable resource is found, then geothermal gas emissions will be reduced through appropriate re-injection of the brine and if required, abatement systems will be used to remove H_2S and Hg emissions from non-condensable gases.

4.1.4 Solid and Liquid Wastes

The primary wastes due to geothermal drilling operations are drill cuttings mixed with bentonite. These will be directed to circulation ponds. The ponds will filled and rehabilitated after well completion and testing.

Silica which is not considered an environment risk may be found in effluents or treated wastewaters that are the by-products of drilling. The silica if found may be dewatered and the silica sludge disposed of off-site. Water abstraction and use of drilling fluids will be minimized by recycling. Solid wastes like drill cuttings and mud generated during geothermal exploration drilling will be stored in a sump for disposal.

4.1.5 Aesthetics

Geothermal power stations and steam pipelines will be designed to blend with the ever green environment and dark volcanic soils in the vicinity of a national park (Figure 3). The long steam gathering pipelines will be avoided by drilling 5 wells on one pad. The only visual quality effects will be steam plumes, separators, power plants and transmission lines. The steam gathering pipes are usually mounted on stanchions, so that most of the area can be used for farming, pasture or other compatible use.

Figure 19: View of the Karisimbi area in February 2011

4.1.6 Land Subsidence and Landslides

Subsidence may occur if the geothermal reservoir is hosted either in a weak, porous sedimentary or pyroclastic formation and/or in a tectonically active zone. This may be a problem because the exploration wells have been targeted along fractures that could be zones of weakness and may be reactivated with time. For example at the Wairakei geothermal area in New Zealand, a horizontal movement of 75 mm/year and a vertical movement of 130 mm /year occurred in two of its zones (Bixley, 1984). The major problems caused by subsidence are steam pipelines from the production field to the power house and the channels carrying separated geothermal water to waste. A total area of $30km^2$ was subsiding at more than 10mm/year (Kagel et al., 2007).

The geothermal prospect area is a high relief and terrain area and therefore landslides could be a potential hazard. It is however anticipated that this will not be a problem because the geology is composed of competent volcanic rocks and metamorphosed sediments and granitic intrusions.

The risk of landslides can only be significant if there were to be a volcanic activity that creates mounts of volcanic rocks that may exceed the angle of repose and cascade downhill. The design and location of power plants will take this into consideration after carrying out detailed hazard mapping, groundwater assessment and deformation monitoring.

4.1.7 Seismicity

It is anticipated that geothermal development in Rwanda may cause microseismic activity during production and more extensively during reinjection. This may be severe when reinjection is stopped and stress adjustments occur. It is strongly suggested that the reinjection program should be designed in such a way that there is no interruption unless there is significant cooling of the resource. The prospect area is in a tectonically active rift zone with faults that can be reactivated. At present, most of the volcanic activity is associated with Nyiragongo active volcano in DRC (Figure 4). The microearthquake activity near Nyiragongo is controlled by a linear NW-SE trending structure probably related to active faulting. If a geothermal resource is proven, then a seismic monitoring network will be installed.

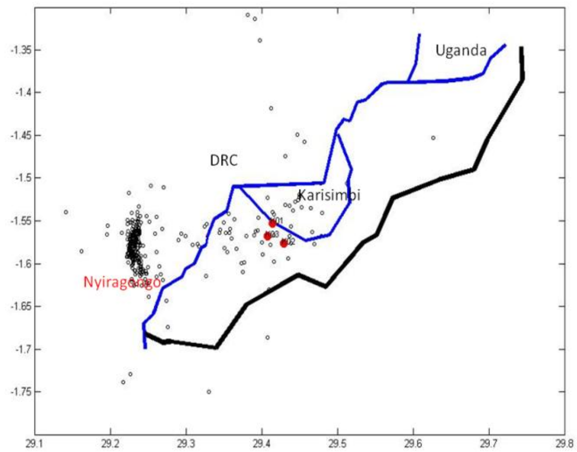

Figure 20: Location of microearthquakes. The Karisimbi area has fewer earthquakes than the active Nyiragongo area in DRC

4.1.8 Hydrothermal Eruptions

Hydrothermal eruptions constitute a potential hazard in geothermal exploration in liquid dominated high temperature systems. It occurs when the steam pressure in a near surface aquifer exceeds the overlying lithostatic pressure and the overburden is then ejected forming a crater of 5-500m in diameter and up to 500m deep. A hydrothermal explosion occurred on October, 13 1990 in the Agua Shuca fumarole area (El Salvador) and killed close to 20 people nearby (Barrios et al., 2011). The possibility of hydrothermal eruptions will be minimized through maintaining reservoir pressures by balancing abstraction, recharge and reinjection.

4.1.9 Social and Economic Impacts

The short term socio-economic impacts expected are minimum population displacement and lease of fertile agricultural land. If a geothermal resource is found there may be possible land acquisition and expropriation through guidelines of the National Land Law in collaboration with the district authorities. The most plausible benefits are job creation during the drilling period and improvement of roads. It will also be an opportunity for the local population to sell their agricultural products. The contractor will be requested to hire local employees except for tasks where local expertise does not exist.

Local authorities will be contacted before the general public becomes aware of the planned activities. The purpose of the project will be explained to all stakeholders. The meetings will emphasize the long-term benefits and mitigation measures to be undertaken. Close collaboration with the local population will be undertaken through provision of honest answers to issues of concern.

The long term benefits of geothermal development will come when the resource is confirmed. These benefits include: (a) increased power supply to the national grid which will replace expensive and environmentally unfriendly fossil fuel, (b) reduced electricity cost and promotion of business and economic growth (c) job creation and capacity building of Rwandese nationals in geothermal sciences and engineering, (d) improved infrastructure for development within the area and (e) the Government of Rwanda shall benefit from carbon credits because of reduction in carbon emissions (Mariita, 2010).

4.1.10 Public Health and Safety

Accidents can occur during various phases of geothermal activity including well blowouts, ruptured steam, turbine failures and fires. The contractors will have the responsibility of minimizing the likelihood of accidents to project workers whether directly employed or subcontracted as defined in the OHSE policy. All workers will be provided with protective equipment including:

a. Hearing protection - earplugs or ear mufflers.
b. Respiratory protection - respirators and/or breathing apparatus.
c. Eye and face protection - goggles, visors, spectacles, face screen etc.
d. Protective clothing - safety footwear, overalls etc.

4.1.11 Impact on Tourism and Mountain Gorillas

Exploration drilling will be carried out in the vicinity of the National Volcanoes Park and it is anticipated that noise may be a threat to mountain gorillas. H_2S could also be of concern because of its unpleasant smell. The responses of mountain gorillas to noise and H_2S smell are unknown because such a project has never been developed elsewhere in a Mountain Gorilla habitat. However, the experience form the Olkaria Geothermal Field in Kenya which is located within a park indicates that the primates and all the animals are resilient and adaptive to changes. This is a perfect example of a beneficial co-existence between a national park and geothermal development. At Olkaria, the park has greatly benefited from increased visitors to the geothermal field. Furthermore, given that the noise levels reduce to ambient noise at about 250m from the drilling sites, it is anticipated that the initial locations of the wells will have no impact on the gorillas.

The drilling activity will change the visual aesthetic value of the project area but this will not affect the National Volcanoes Park as all 3 boreholes will be in the vicinity of the park.

4.1.12 Impacts of Water Abstraction from Lake Karago

The abstraction of water for drilling from Lake Karago might have some impact on the water balance in the lake. However, the water studies indicate the lake level will not be affected after the artificial outlet channel was blocked. The long and short-term hydrological variability of Lake Karago will be recorded to ensure that water requirements for aquatic life are maintained.

4.2. Environmental Monitoring Plan

Environmental monitoring will be incorporated from the drilling phase. H_2S monitoring network will be installed and periodic audits carried out to ensure compliance with the OHSE policy. If the resource is proven, the number and location of monitoring stations will be increased to acquire data for air dispersion modelling. This will be used to evaluate the anticipated effects on local community and the gorilla habitat. The movement of the mountain gorillas will also be monitored to evaluate any effects due to the drilling activities. Monitoring of rainfall for chemical pollutants will also be carried out from the commencement of drilling activity to well testing completion.

5. CONCLUSIONS AND RECOMMENDATIONS

Environmental impacts of geothermal exploration and power generation and direct use are relatively small and generally manageable. Exploration drilling and monitoring will comply with the environmental legislation in Rwanda. Geothermal energy causes smaller emissions of CO_2, SO_x and NO_x comparable to other forms of energy but the long-term effect on the mountain gorillas is not known. It is however anticipated that the gorillas would adapt to the ambient noise and gases which are already in the air due to frequent volcanic eruptions in the area. During the exploration drilling phase, the Karisoke Research Center should monitor two social groups of mountain gorillas which are found nearest to the project area.

Exploration drilling has small socio-economic effects on the local community, such as land acquisition and resettlement of evacuated people. The immediate benefits to local people will include land compensation, job creation and the improvement of transport infrastructure.

If a viable geothermal resource is found and exploration drilling has only short-term impacts, the long term effects will be established based on the data from the exploration phase.

A joint monitoring team made up of representative from the Rwanda Environment Management Authority (REMA), Rwanda Development Board (RDB), animal behaviour specialists from the Karisoke Research Centre and the developer will be established prior to the commencement of drilling.

The local communities will be involved in the exploration phase of the project to minimize conflicts.

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