

GEOTHERMAL PROJECTS AND NATIONAL PARKS IN KENYA

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ABSTRACT

Prominent geothermal systems of Africa are associated with the Great Rift Valley located in the eastern part of Africa. It intersects Djibouti, Eritrea, Ethiopia, Kenya, Tanzania, Zambia, Malawi and northern Mozambique. There is a western segment that passes through Uganda, Rwanda and Burundi. All these countries have some geothermal potential. It is only in Kenya and Ethiopia that exploitation of geothermal energy for power generation has been attempted. The North African countries including Egypt, Tunisia, Algeria, Libya and Morocco have low temperature resources not associated with the African Rift system. These resources have been used primarily for agriculture and bathing. Tunisia is a leader for greenhouse heating and irrigation.

Electricity generation from geothermal in Kenya started in 1981 with construction of Olkaria I station. The current output in Kenya is 130MW which is about 11% of the country's effective capacity. There is a plan to increase the generation by an additional 576MW by 2026.

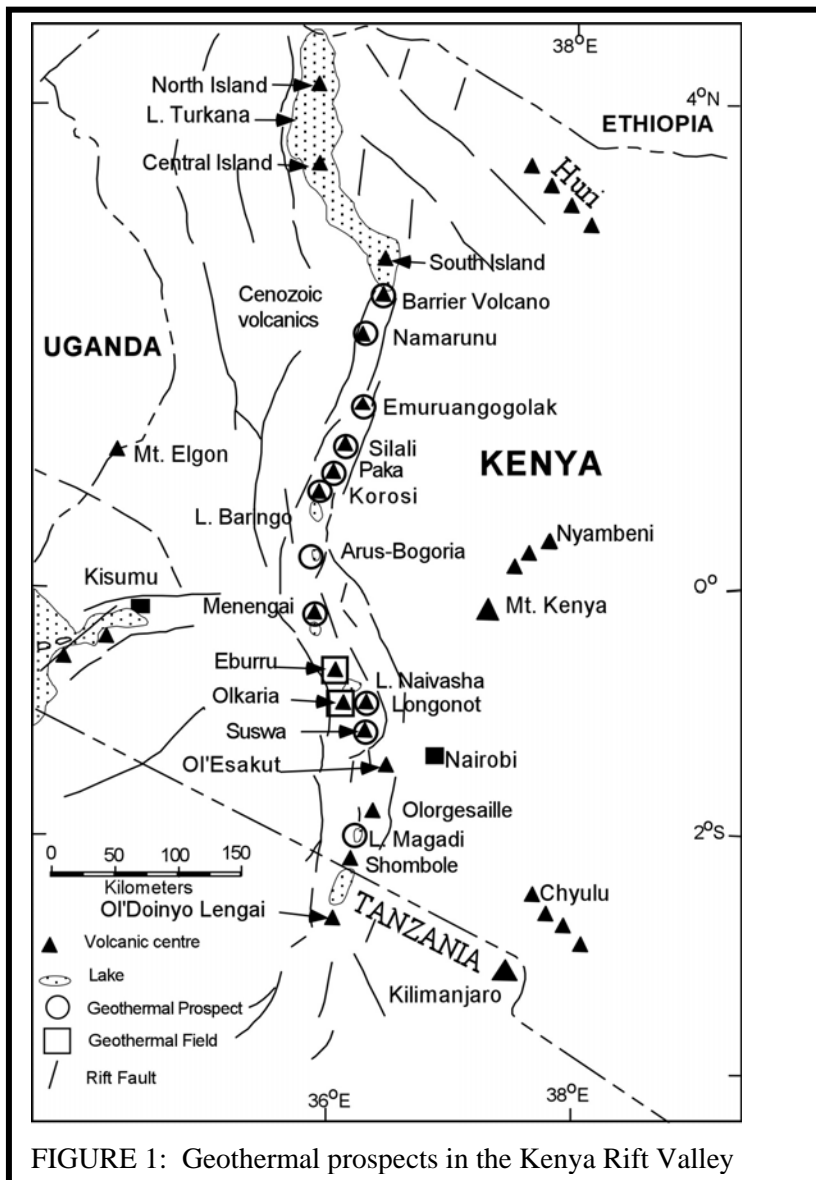
The current geothermal capacity is located in Olkaria Geothermal field mainly within Hell's Gate National Park. Kenya has over the years gained experience in managing the environmental issues associated within this development. This has proved that geothermal development can coexist with wildlife with maximum benefit from both resources. Kenya would like to replicate this success in other geothermal sites some of which are located in either National parks or Game Reserves.

1. INTRODUCTION

Most of the East African countries rely on biomass as the primary source of energy. Electricity accounts for between 10 and 30%. The electrical energy is predominantly from hydropower (70%), followed by fossil fuel thermal. Geothermal development can offer an excellent opportunity for saving foreign currency, cushion the supply variations and meet ever increasing power demand. It also offers renewable, indigenous and environmentally friendly alternative to more traditional sources.

Kenya and Ethiopia have so far produced power from their geothermal resources. In addition Kenya, Tunisia and Algeria have used geothermal for agricultural and recreational purposes. However, exploration for geothermal has been carried out to varied degrees in Djibouti, Eritrea, Uganda, Tanzania, Zambia and Malawi.

Kenya relies on three major sources of energy. These are biomass (68 %), petroleum (22 %) and Electricity (9 %). Hydropower (57 %) dominates the electricity sub-sector, followed by fossil- based thermal (32 %) and then geothermal (11 %). Wind, solar, biogas, micro hydro account for less than



1% In 1986, Kenya recognised that geothermal power offered a competitive price and introduced it into the National Power Development Master plan.

Most of the geothermal prospects in Kenya are located in mountainous remote places in National Parks and Game Reserves. These parks and reserves have vast riches of wildlife and scenic landscapes that are readily sought by both local and foreign tourist. Olkaria Geothermal Field, which is the most developed field in Kenya, is located in a Park. Tourism is the third foreign currency earner for Kenya. On the other hand, Kenya needs to develop its indigenous geothermal resources to fuel its other economy. In order to achieve these two objectives, the Government decided to encourage the co-existence of both the wildlife and geothermal energy by encouraging the use of proper environmental management and conservation methods in the operations.

This paper discusses the experiences so far gained in geothermal development in Kenya most of which is from Olkaria within Hell’s Gate National park.

2. GEOTHERMAL RESOURCES POTENTIAL IN KENYA

About fourteen (14) geothermal prospects have been identified in the Kenyan Rift valley (Figure 1). Their geothermal potential is estimated to be in excess of 2000 MWe. Wells have been drilled in only Olkaria and Eburru but exploitation so far has only been done at Olkaria geothermal field.

The Olkaria geothermal resource is associated with the Olkaria volcanic complex which consists of a series of lava domes and ashes, the youngest of which was dated at about 200 years ago (Clarke et al., 1990). The geothermal reservoir is bounded by arcuate faults forming a ring or a caldera structure that is intersected by N-S and E-W and NW-SE faults (Figure 2).

Olkaria Geothermal Field is estimated to be about 80 km² and has been divided into seven sectors namely Olkaria East, Olkaria West, Olkaria Northwest, Olkaria Northeast, Olkaria Central, Olkaria Domes and Olkaria Southwest (Figure 3). Currently, Olkaria East, and Olkaria Northwest fields are generating 130 MWe. In Olkaria Domes field, which is the fourth field targeted for development, three exploration wells have been drilled and plans for appraisal drilling are at an advanced stage.

Detailed surface exploration was concluded in Suswa, Longonot, Eburru, Menengai, Lake Baringo, Lake Bogoria and Korosi prospects. Six exploration wells were drilled in Eburru. Surface exploration is currently being done at Paka.

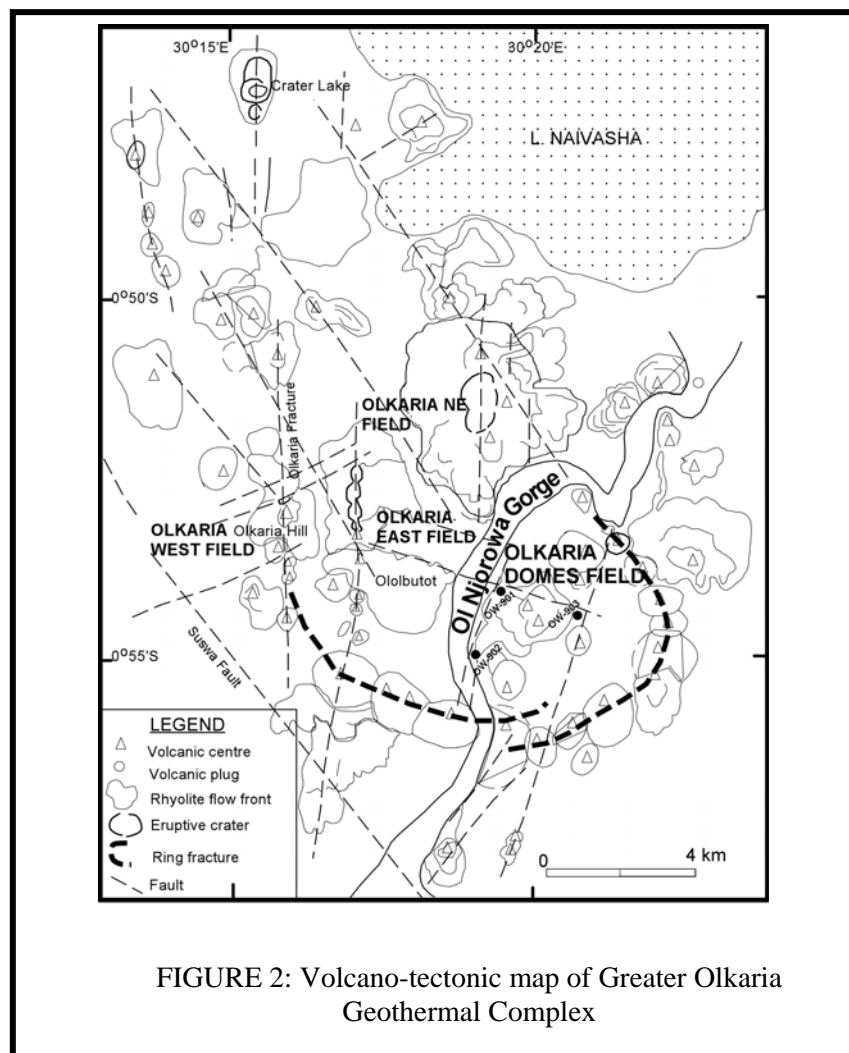


FIGURE 2: Volcano-tectonic map of Greater Olkaria Geothermal Complex

3. GEOTHERMAL UTILISATION

3.1 Electricity Production

Currently, geothermal energy is being utilised in Olkaria field only. Three of the seven Olkaria sectors namely Olkaria East field, Olkaria West field and Olkaria Northeast field (Figure 4) are generating a total of 130 MWe.

3.1.1 Olkaria I power plant

The Olkaria I power plant is owned by Kenya Electricity Generating Company Ltd (KenGen) has three turbo generating units each generating 15 MWe. The three units were commissioned in 1981, 1983 and 1985 respectively therefore the plant has been in operation over the last twenty four (25) years. Olkaria East field, which supply steam to Olkaria I power plant has thirty three (33) wells drilled. Thirty one (31) of them were connected to the steam gathering system 9 of them drilled as makeup wells. Currently, twenty six (26) of them are in production while the rest have become non-commercial producers due to decline in output over time and some of these are earmarked to serve as reinjection wells. Currently, the steam available from this field is more than what is required to generate 45 MWe and studies are underway to determine the viability of increasing generation.

3.1.2 Olkaria II power plant

Construction of 2 x 35MW Olkaria II geothermal power station started in September 2000 was completed November 2003. The project, which is publicly owned by KenGen, also included construction of 116km of 220kV from Olkaria to Nairobi and 3.5km 132kV transmission line connecting Olkaria I and II stations. The initial design had suggested 64 MWe but since the plant was built 10 years behind schedule, it took advantage of the latest technology. The plant is more efficient than the Olkaria I with a specific steam consumption of about 7.2 t/hr per MWe as opposed to the 9.2 t/hr for the Olkaria I plant. As a result of the efficient machines there is excess steam available in this field. Currently, KenGen is in the bidding process for the construction of a third 35MW unit to use excess steam from both Olkaria I and II fields.

3.1.3 Olkaria III power plant

Olkaria III project is the first private geothermal power plant in Kenya. A 20 year Power Purchase Agreement (PPA) was awarded to Orpower 4 Inc. by Kenya Power and Lighting Company (KPLC) under a World Bank supervised international tender for the field development of up to 100 MWe. The first phase of the project included drilling of appraisal wells and construction of a 12 MWe pilot plant.

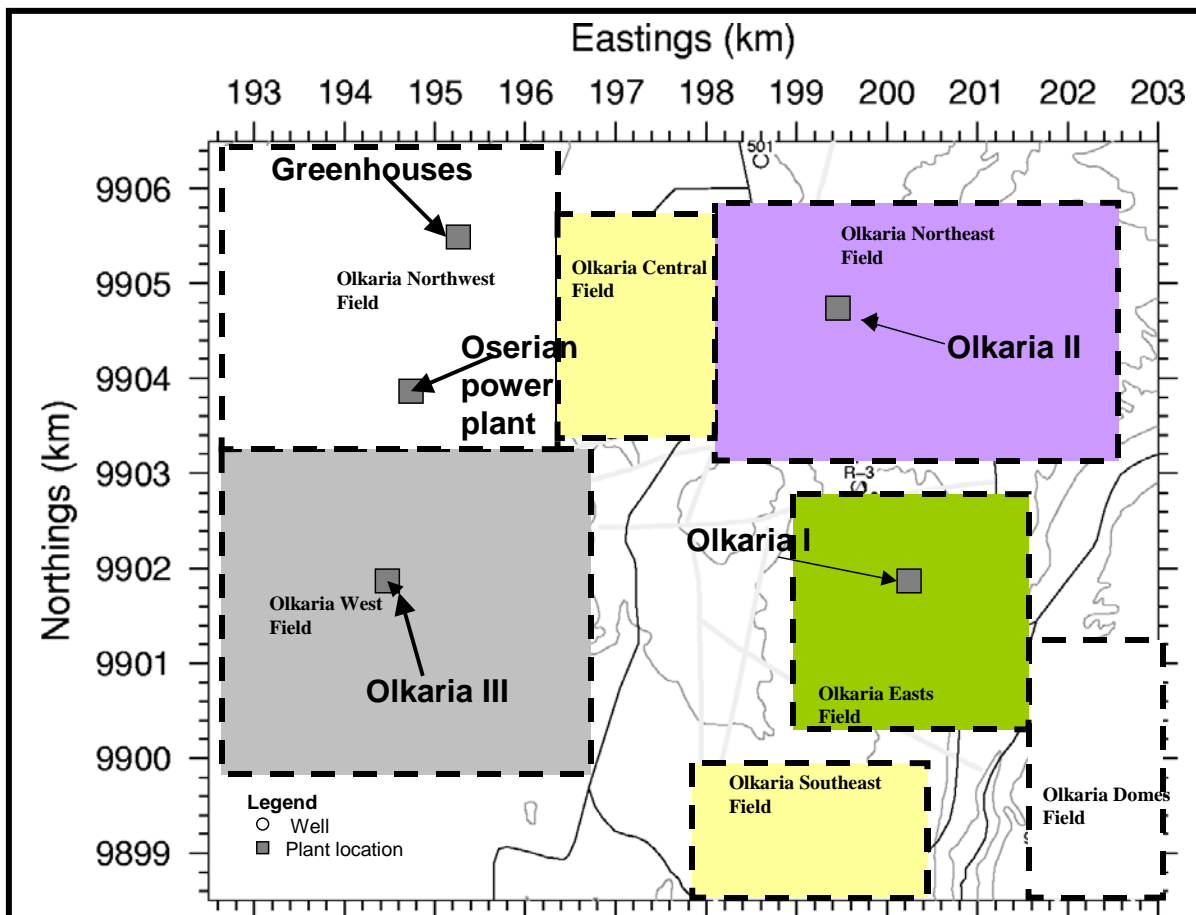


FIGURE 3: Olkaria Geothermal Area showing development blocks

The first 8 MWe was put on commercial operation on September 2000 and the other 4 MWe in December 2000. The appraisal and production drilling commenced in February 2000 and was completed by March 2003, after drilling a total of 9 wells and adequate steam was proved for total development of 48 MWe over the PPA period of 20 years. KenGen was contracted to do completion and heat-up tests in these wells. Both vertical and directional wells were drilled for appraisal as well as production with depth ranging between 1850 m – 2750m. To save on the drilling cost, each group of three wells were drilled on one pad. Production success rate of 100 % was achieved from the new wells. The 36 MWe power plant is expected to be in operation 2007/8 (Reshef and Citrin, 2003).

3.1.4 Oserian plant

Oserian Flowers Company has constructed a 2.0 MW binary plant Ormat OEC to utilise fluid from a leased well OW-306. The plant, which is supposed to provide electrical power for the farm's operations was commissioned in July, 2004.

3.2 Direct Uses

3.2.1 Greenhouse heating

The only commercial application of geothermal energy for direct use in Kenya is at Oserian Development Company. The company grows cut flowers and other horticultural crops in greenhouses for sale in the European market. The company installed a green house heating system in May 2003 using a 15MWt well leased from KenGen. Heating the green houses increases the plants' growth rate, reduce humidity and consequently decrease diseases. The carbon dioxide from the well is also useful for the flower photosynthesis. The system is currently heating 30 hectares and there is a plan to expand the heating if more heat would be available. Oserian is therefore planning to lease more wells from KenGen for this purpose.

3.2.2 Swimming pool heating

Hot springs have been used to heat spas in tourist hotels for example in Bogoria hotel which is located near the Bogoria prospect

3.2.3 Industrial processing

The Local community at Eburru geothermal resource condenses the steam from fumarole and uses the water for domestic purposes. They also use geothermal to dry pyrethrum.

4. DEVELOPMENT IN NATIONAL PARKS

The geothermal prospects that are located in National Parks or Game Reserves are Olkaria, Longonot, Lake Bogoria, and Lake Baringo. The rest of the prospects are in lands owned either by Government as forests, privately owned or in the hands of group communities. Menengai, although not a National Park, is very important to tourists and is included in these discussions.

As mentioned previously, Olkaria is the only field that is developed so far in Kenya and three stations are wholly in Hell's Gate National Park. Oserian station is in private land and the Olkaria IV will be located in a private land as well but close to the Park. This paper will discuss the experiences gained from Olkaria and it is hoped that these experiences will be applied in other prospects in the National Parks or Game Reserves in future. A government institution known as Kenya Wildlife Service (KWS) manages National Parks where as Game Reserves are owned and managed by Local Authorities and communities in which they are located.

4.1 Hell's Gate National Park

4.1.1 Background

Hell's Gate National Park is located south of Lake Naivasha as shown in Figure 4. When Units 1 and 2 of Olkaria I power station were commissioned in 1981 and 1982 geothermal development had been concentrated in a Government land. Some wells had been drilled in two privately owned land. KenGen then bought a total of 340 acres from the two landowners. The government allocated the rest of the land. A temporary camp called X2 had been established 5km away from Olkaria I station but within the park since the exploration started in 1970. However, another permanent housing estate was established about 13km away near Lake Naivasha when the Olkaria I plant was commissioned.

In 1984, the land belonging to the government including the one allocated to Olkaria I development was gazetted as Hell's Gate National Park. A farmer donated a portion of his land to the park to form its current size of 68km². The understanding was that KenGen was interested in steam

which is underground while the park would utilize the surface resource for the wild life. KenGen realised that for it to operate within the park, it needed to introduce an effective environmental management system. In 1985 it therefore established an environmental section in its geothermal establishment structure and employed environmental staff. Initially the staff worked under a consultant for several years.

Between 1992 and 1994, it carried a comprehensive Environmental Impact Assessment (EIA) for the purpose of Olkaria II development, which covered the entire Olkaria and its environs particularly Lake Naivasha (Sinclair Knight and Partners 1994). Based on the EIA a Memorandum of Understanding (MoU) was signed in September 1994 between KenGen and KWS and covered KenGen's operations in Hell's Gate and Longonot National Parks (KenGen and KWS, 1994). In 2000, KWS entered into a similar but separate agreement with Orpower4 because of its operations in Olkaria III power station. Both agreements are operational but KenGen/K MoU is currently undergoing some reviews.

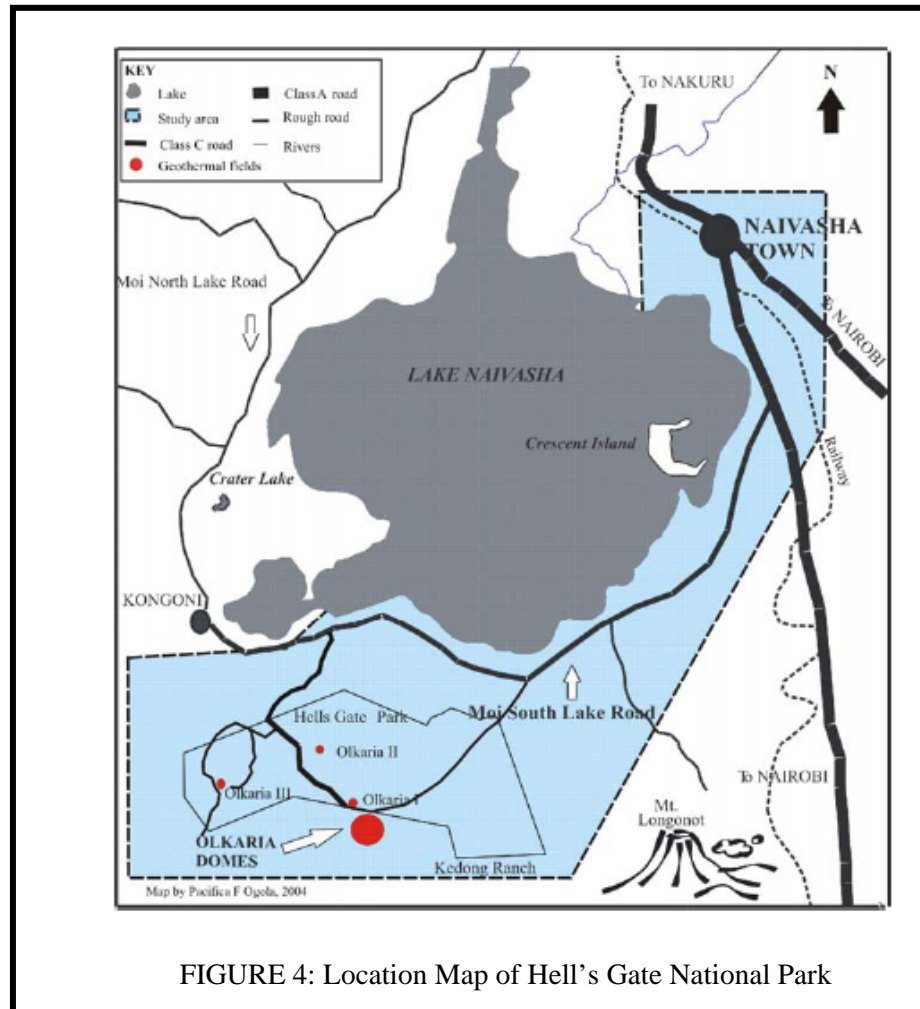


FIGURE 4: Location Map of Hell's Gate National Park

4.1.2 Features of the park

The area of the park is generally dry most of the time and the vegetation is grassland with shrubs dominated by *Tarchonanthus camphorates* (Leleshwa) bushes and several species of acacia the dominant one being *Acacia drepanolobium*.

Wildlife consist of eland, buffalo, lion, giraffe, zebra, leopard, impala, Grant's and Thomson Gazele, klipspringer, rock hyraxes and reedbeek. There are about 100 bird species some of which are raptors. This attracts very many ornithologists both local and foreign. One bird-hide is available for bird watching.

The Park has varied landscapes with rock cliffs and Volcanic plugs which are very popular with both amateur and professional climbers. There is a scenic gorge Ol Njorwa Gorge which was formed by erosion of Lake Naivasha when it breached on the southern side. It is the only park in Kenya open for walking and cycling and is popular with backpackers. There is one popular route where you enter the park through one gate and pass through open grassland full of animals then pass through Olkaria I and II power stations and naturally occurring steam jets and come out through the second gate. The route is about 35 km long.

There are several camp sites spread through out the park and provide scenic sundowners to the campers and views of Mount Longonot, the Aberdare mountain ranges and Mau Escarpment.

Neighbouring the park is a Maasai cultural centre with a community of about 50 people living in a typical Maasai homestead, *Boma*. At the center, one can buy Maasai curios and also enjoy cultural dances.

4.1.3 Memorandum of understanding

KenGen agreed to have a sound environmental management system by doing the following, among many other things:

- a) Reinject all future waste water;
- b) Remove all opportunistic plant species that may have been introduced during earthworks;
- c) Rehabilitate disturbed areas with locally available grass and tree species;
- d) Remove fences that obstruct animal movement;
- e) Provide bridges or pipe loops for free animal movement;
- f) Control speed on the park roads and avoid night vehicular movement unless for operations;
- g) Ban introduction of exotic animals;
- h) Educate staff and contractors on park rules and regulations and interaction with wildlife;
- i) Avoid cutting on slopes to reduce erosion and rehabilitate for erosion control;
- j) Tarmac roads serving the stations and wells;
- k) KenGen to continuously monitor noise and air emissions and to jointly monitor abundance of flora, fauna and birds and share the data.;
- l) Hold joint meetings to discuss and agree on expansion plans;
- m) Agree on road designs and harmonise road networks within the Hell's Gate and Longonot parks;
- n) Plant suitable trees to obscure the view of power stations;
- o) Remove any staff camps from the park;
- p) KWS and KenGen to enhance security and safety in the parks for visitors and staff;
- q) Construct future steam gathering systems with materials that blend with environment.

4.1.4 Park Management meetings

In addition to the KWS/KenGen meeting provided for in the MoU, KenGen is a member of the Hell's Gate and Longonot parks management committee. This committee comprises the two KWS officers in charge of Hell's Gate and Longonot parks, KenGen, Hotel owners, farmers around the park and other interested parties who are friends of the park including representatives of the local communities. The committee meets quarterly and discusses all issues relevant to the management of the two parks. They have a special account which well-wishers can donate funds to improve the park. The committee organises some activities that can earn the parks some money for their improvement including a curio shop. Money for several movies shot in the park have been used to improve the Park. In this meeting KenGen briefs the committee members' current geothermal activities and future plans.

4.1.5 Roads

When KenGen tarmaced the Moi- South Lake road into Olkaria Project, it improved communication for tourists visiting Hell's Gate Park tremendously. KenGen also assists KWS in maintenance of some of the earth roads within the park.

4.1.6 Visitors

There is a marked increase in tourists visiting the Hell's Gate park (Figure 5) some of whom are more interested in visiting the Olkaria I and II power stations rather than seeing the animals. The power stations have recorded about 2000 visitors a month on average. There are others that want to see both the animals and the power stations and even chose to camp near by. In our view, the power stations is a major attraction to the tourists and consequently benefits the park.

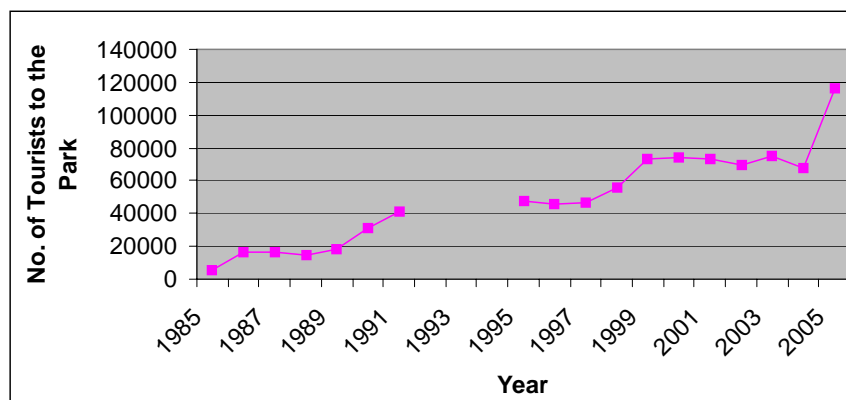


FIGURE 5: Total number of visitors to the Hell's Gate National Park (1985-2005)

4.1.7 Water supply

KenGen supplies water to the animals at various points so that they are not tempted to drink geothermal wastewater particularly during the dry seasons. Fortunately, all the wastewater ponds are generally fenced off from the animals.

4.1.8 Environmental management

As provided in a detailed paper elsewhere in these set of lecturers, it was very wise for KenGen to initiate good environmental management and introduce high environmental awareness in its operations early in the project. These management systems of rehabilitating the opened grounds, reinjection of waste water, provision of animal routes in the steam gathering systems, and control and monitoring of

noise and gas emissions have created the harmonious coexistence of the Park and geothermal development.

The EIA carried out in 1992-94 on which the MoU was based has played a significant role in the setting up of the environmental management. The findings of these assessment was incorporated in the designs of Olkaria II power station and its steam gathering system, gas monitoring, waste water management, noise reduction and transmission route. The adherence to the MoU and KenGen's strong believe and desire to follow and to surpass the guidelines has contributed to the success of this development. Through consultative meetings, KWS has been extremely cooperative in the Environmental management matters and has given useful advice. It is therefore believe that this should be encouraged in other places as well.

The Olkaria Project and Hell's Gate Park have been good sites for collaborative research with local and international institutions. The results form these findings have also contributed to the improvement of the Environmental management in the area.

4.2 Longonot National Park

Longonot National Park is Located to the east of Hell's Gate National Park about 85km North West of Nairobi. The park comprises Mount Longonot which is a central volcano with a crater at the peak. The mountain developed to the eastern edge of an old large caldera. The edge of this caldera is visible from the west and southern parts only. Because of its steep slopes, there are fewer animals found but bird life is high. The largest tourist attraction of this park is climbing up to to the crater and even circling it. Only the strong ones walk round the edge of the crater a distance of about 11km.

Longonot National Park was formerly a Forest Reserve under the management of Kenya Forest Department of the Ministry of Environment and Natural Resources. Tree planting was carried out to make this mountain a "real" forest but the efforts failed due to wildlife destruction. Due to the failure of converting the mountain into a wood forest, it was agreed that the area is turned into a National Park. This Park was gazetted in 1983. Total area of the Park is 52 square kilometres.

The dominant vegetation type comprises of dwarf shrub land and grassland. Dominant species are *Acacia drepanolobium* and *Tarchonanthus camphoratus*. The Park is quite open due to frequent bush fires. The wildlife species in Longonot National Park include, Reedbuck, Zebra, Eland, Lion, Cheetah and Buffalo. The Park has low wildlife numbers due to the nature of the vegetation and terrain. During the rainy season the animals are found in large numbers especially the Zebra. The numbers decline as the dry spell sets in due to reduced grazing materials. Zebra is the most abundant species in this ecosystem. No plant or animal has been identified as endemic in this Park.

Figure 7 shows the features of the Longonot mountain, park boundaries and the proposed exploration wells sites (KenGen 1998). The area of geothermal interest is found in caldera south of the mountain massif. Exploration drilling is planned to take place in 2007. If the resources can be confirmed here, the development will concentrate on the lower part of the mountain in order not to interfere with the scenic view of the mountain. It may be necessary to employ directional drilling as much as possible to reduce the number of the drilling pads created and also access to under the mountain below the crater. All the experiences gained in the interaction of the Hell's Gate park will be used here and will be covered by the existing MoU.

4.3 Menengai Crater

Menengai Crater (Figure 6) is located just north of Nakuru town. Like Mt. Longonot, Menengai crater also attracts many visitors although it is not a park but trust land because of the beautiful scenery when at the top. However, unlike Longonot, one can drive to the rim of the crater. School children and University students are the main visitors of this area. Tourists who visit Lake Nakuru Park also do visit

this area. Part of the crater is gazetted as a forest reserve and is under the management of Kenya Forest Department. The other part is trust land. Currently Nakuru county council is in the process of securing this area so as to earn revenue from the visitors by charging a fee for each visit. Already some organized groups have started putting up some tented camps for visitors.

The vegetation of the area within and outside Menengai caldera rim consists of bushed woodlands with common plant species being, *Euphorbia candelabra*, *Tarconanthus camphorates* and *Acacia* species. The gazetted forest consists of plantations with *Eucalyptus* species being the dominant.

There are very few wildlife species in the area as a large part is farming land and no open areas for grazing exist. The animals found here include Leopards, Zebra, Baboons and Monkeys.

According to the scientific results of the area, the recommended drilling sites are found in the Crater floor itself. It is anticipated that if a station was built there, it would more interest to the visitors as the view from the top of the crater would be scenic.

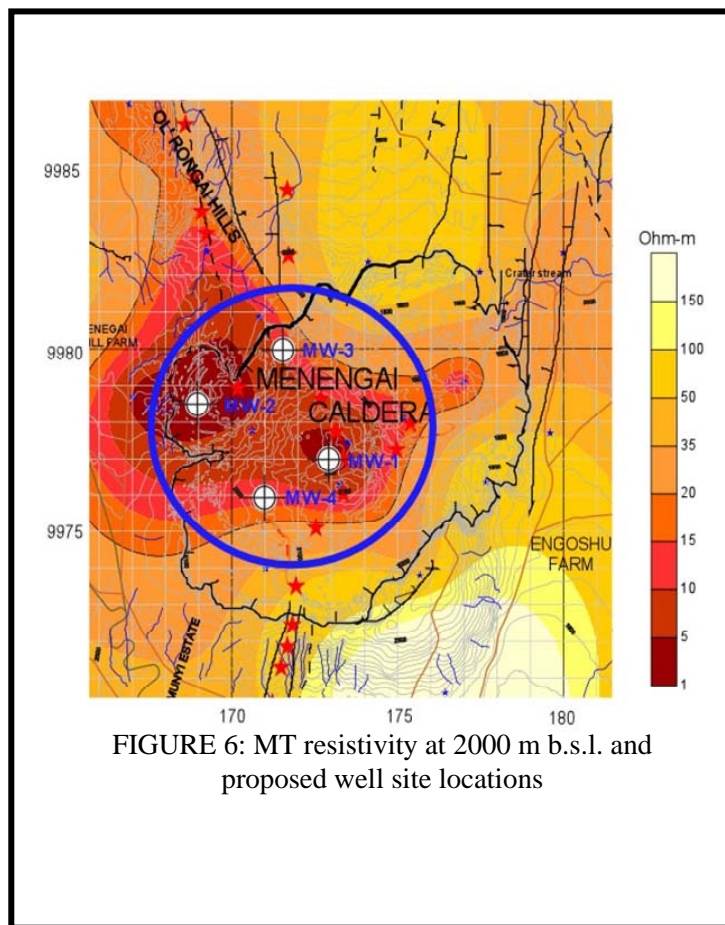


FIGURE 6: MT resistivity at 2000 m b.s.l. and proposed well site locations

4.4 Lake Baringo

The Lake Baringo area (Figure 7) is very dry and of low productivity. Vegetation is characterized by bush acacia especially *Acacia reficiens*, *Acacia mellifera*, *Acacia nubica* and *Acacia tortilis*, semi-deciduous woodlands and grass.

Within the geothermal prospect area is the 'Lake Baringo Conservation Area' which was gazetted in 1994 and is currently managed by Baringo County Council. The Council in collaboration with the local community has also established a Reptile Park at Kampi Samaki. Wildlife in and around the Lake includes Reptiles (Crocodiles, snakes, tortoise), Hippopotamus, zebras and baboons and many bird species including ostriches. This game attracts many tourists who support the local and regional economy. The lake is famous worldwide for its ornithological sanctuary with more than 480 different bird species.

The lake has had many local and international tourists due to rich wildlife. The number of visitors fluctuates according to season with the peak being in the months of July and October (KenGen and GoK, 2005).

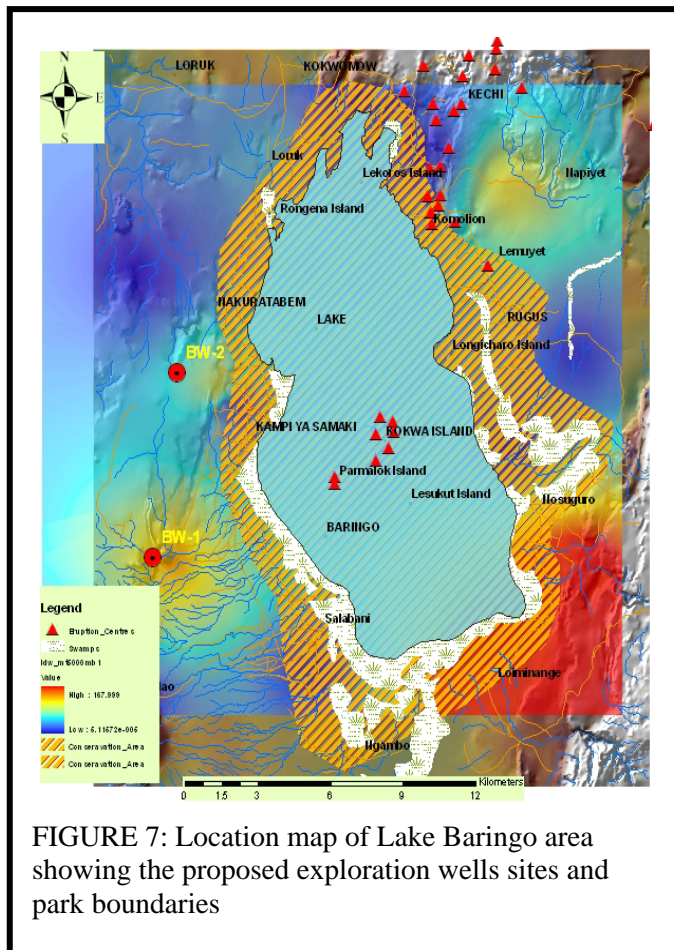


FIGURE 7: Location map of Lake Baringo area showing the proposed exploration wells sites and park boundaries

4.5 Lake Bogoria Game Reserve

Lake Bogoria and part of its catchment area is rich in fauna hence has been protected as 'Lake Bogoria National Reserve' (LBNR) and covers an area of 107 km². It was gazetted in 1973 and is currently managed by Baringo and Koibatek County Councils. Recently the LBNR was designated as a third Ramsar site after Lake Nakuru and Naivasha. The lake is saline and covers an area of 34 km². It is rich in biodiversity, hosting about half of the world's population of lesser flamingos (*Phoeniconaias minor*). It is also a habitat to other bird species including greater flamingos (*Phoeniconaias ruber*), black-necked grebe (*Podiceps nigricollis*), ostriches, fish eagles and several migratory species. Due to its avifauna richness, it has been designated as an Important Bird Area (IBA). The mammalian fauna in LBNR include zebras, gazelles, buffaloes, several primates and the only relatively accessible population of greater kudus. In addition to its rich biodiversity, Lake Bogoria has numerous hot springs including spectacular geysers.

The vegetation is mainly thorny bushland dominated by the species of *Acacia*, *Balanites* and *Commiphora* with patches of riverine woodland containing *Ficus capensis*, *Acacia xanthophloea* and *Acacia tortilis*. In the lower slopes of the Siricho Escarpment, *Combretum* and *Grewia* thickets dominate.

Lake Bogoria is internationally important as a main feeding ground for a large percentage of the world's population of the lesser flamingo (*Phoeniconaias minor*). The high productivity of the blue-green algae, *Spirulina platensis*, coupled with the presence of freshwater at several places results in a

concentration of the lesser flamingo in large numbers, at times over two million, to give the appearance of large shimmering pink sheets across the lake. Kenya holds between a third and a quarter of the total world population of the lesser flamingo

There are no mammals inside Lake Bogoria but a small variety of animals exist in the adjacent areas. They include the rare Greater Kudu (*Tragelaphus strepsiceros*) and many other antelopes such as gazelles and impala. Other mammals found in LBNR are zebras and buffaloes. The Greater Kudu population is reported to be on the decline, as a result of the demand on their horns, which are used by the locals for ritual purposes. The zebra population is reported to have increased tremendously in the recent past.

Tourists and visitors to the Reserve are stakeholders, in search of recreation, education and research. They include both local, national, and international tourists and visitor. Over 50,000 school children and researchers visit Lake Bogoria annually to understand and appreciate the unique physical geography of the Rift Valley, an important topic in the geography syllabus in Kenyan schools. The visitors fluctuate according to seasons with the peak being between the months of July and September (Figure 8).

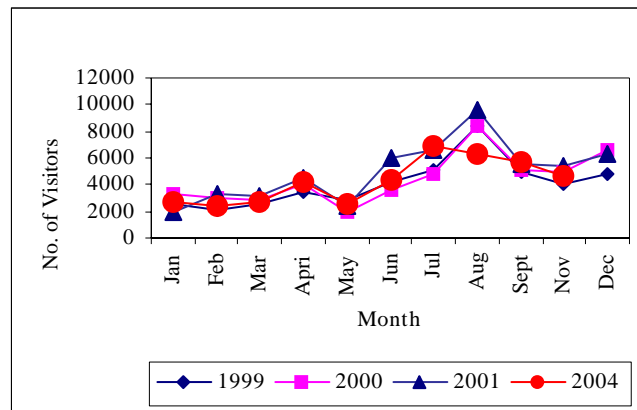


FIGURE 8: Visitors to Lake Bogoria National Reserve

5. CONCLUSION

Given the frequent African drought that affect the hydropower, variation of fossil fuel prices in the world market and the rapid increase in demand for more power, geothermal offers an indigenous environmentally friendly alternative to some Eastern African countries. The slow development of geothermal resource has been due to lack of knowledge, availability of cheap hydropower and lack of funds and manpower.

Many geothermal resources are located in game parks and other conservations areas. The success achieved in the development of the resource at Olkaria, in a national park, demonstrates that both can coexist by carefully using sound environmental management systems and monitoring. Cooperation of all the stakeholders is extremely vital. Kenya's success and the large geothermal potential of upto 7000MW in the Eastern Africa rift system, should motivate other countries in the region and elsewhere to pursue this development. Initiatives like Carbon Credit under the global framework of renewable resources and climate change augmented with other sources of funding can accelerate geothermal resource development.

Commercial direct uses of geothermal energy should be encouraged in countries with low enthalpy resources. For example Oserian Development Company in Kenya has benefited from the use of

geothermal heat leased from KenGen for heating their green houses. As a result, KenGen is looking into the possibility of providing hot water for agricultural and recreational purposes to other farms and hotels nearby.

Geothermal power stations have been successfully developed in Olkaria field within Hell's Gate National Park. With sound environmental management systems, properly designed operation systems can be used to mitigate most of the envisaged impacts. The developments of the geothermal projects do enhance the attraction of the parks and increase revenues. They also offer many other socio-economic benefits to the communities in which they are located. The experience of Olkaria will be replicated in many other geothermal prospects located in National parks, Game reserves, prohibited areas and private land.

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