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Geothermal Projects Site Selection - Zambian Case

Musenge Chomba, Oscar Sinkala and Ziye Tembo

ZESCO Limited, Stand No. 6949, Great East Road, P.O Box 33304,

Lusaka, Zambia

mchomba@zesco.co.zm osinkala@zesco.co.zm ztembo@zesco.co.zm

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ABSTRACT

Although there is no evidence of recent volcanic activity in Zambia, there are numerous hot and mineralised springs. Most of them related to relatively young faults affecting Karroo rocks, and some of them related to the rift system of East Africa.

Historic work includes a countrywide reconnaissance study and the installation of a geothermal pilot power plant at Kapishya. The reconnaissance study of fifty (50) hot or mineralised springs or groups of springs was conducted between 1971 and 1974. Measurements of water temperature, discharge and radioactivity were made, the geological setting was studied, and samples of water and chemical deposits collected for analysis. More detailed investigations were made at a few springs of outstanding interest. (Legg, 1974).

However only three geothermal sites (Kapishya, Lubungu and Chongo) have been prioritized in the first phase of the studies. The methodology applied in the selection of geothermal sites to be considered for assessment of power generation included the following aspects: Physical, Social Economic and Technical suitability of the area

1. INTRODUCTION

The use of geothermal energy for electric power generation has become widespread because of several factors. Countries where geothermal resources are prevalent have desired to develop their own resources in contrast to importing fuel for power generation. In countries where many resource alternatives are available for power generation like Zambia, geothermal should be a preferred resource as a base load alternative because it cannot be transported for sale, and the use of geothermal energy can support highly affected hydropower plants by the poor rainfall pattern during the 2014 to 2017 period.

Zambia belongs to the south-western branch of the East African Rift System (EARS) that propagates from the south-west Tanganyika Rifts through the Mweru Rifts into Zambia. The western branch develops from Uganda throughout Lake Tanganyika, where it joins the Eastern branch, following the border between Rwanda and Democratic Republic of Congo (DRC) (Legg, 1974).

The western branch is characterized with low enthalpy and much less active in terms of volcanism although both branches are seismically and tectonically active today. Although there is no evidence of recent volcanic activity in Zambia, there are numerous hot and mineralised springs. Most of them are related to relatively young faults affecting Karroo rocks, while some are related to the rift system of East Africa. The springs in the country are described under seven geographical groups: Northern, Mansa-Copperbelt, Western, Eastern, South-eastern, Choma and Lochinvar Group. (Legg, 1974).

Historic work of geothermal in Zambia includes a countrywide reconnaissance study and the installation of a 200 kW geothermal pilot power plant at Kapishya. The reconnaissance study of fifty (50) hot or mineralised springs or groups of springs was conducted between 1971 and 1974. Measurements of water temperature, discharge and radioactivity were made, the geological setting was studied, and samples of water and chemical deposits collected for analysis. More detailed investigations were made at a few springs of outstanding interest. (Legg, 1974).

From a list of 50 potential geothermal sites, seven (07) sites were prioritized for further studies. Further analysis resulted in only three sites (Kapishya, Lubungu and Chongo) being considered for power generation assessment. The methodology applied in the selection of geothermal sites to be considered for assessment of power generation included the following aspects: Physical, Social Economic and Technical suitability of the area.

2. STUDY AREAS

2.1. Kapishya Geothermal Site (Northern Province)

Kapishya hot springs are located on the western shore of Lake Tanganyika, 8 km north of Nsumbu in the Northern Province of Zambia. The site can be accessed by boat through Lake. The springs are located where a major fault of Lake Tanganyika trough cuts the impervious porphyritic igneous rocks. The hot springs consist of four large springs and numerous smaller springs with the maximum recorded temperature of 85°C in the main spring. Legg (1974).

Although the spring waters are relatively dilute, rocks in the vicinity are covered with encrustations, mainly of calcium carbonate with less sodium and potassium sulphate and chloride. The total discharge in May 1971 was of the order of 25 L/s.

Some of the springs give off large amounts of gas with a slight sulphurous smell, and the area is moderately radioactive, with the level of gamma radiation being approximately double that over porphyry outcrops 100 m to the west. Legg (1974).

2.2. Lubungu Geothermal Site (Central Province)

The Lubungu hot spring is located approximately 1 km north of the Kafue River within the Kafue National Park and about 92 km by road to the north-west of Mumbwa. The spring is isolated from the developed part of the park by the Lunga River Legg (1974). The maximum surface temperature recorded in December 1971 at Lubungu is 77°C. Chapman (1972).

The spring occurs in an area of medium-grained and strongly tourmalinised pink granite, probably a roof phase of the Kafue Hook granitic intrusive complex. The Lubungu Fault occurs a short distance to the west of the spring, and appears to form the eastern boundary of a northward-trending graben containing down faulted metasediments of probable Upper Katanga age. Legg (1974).

The fault zone is marked by intense tourmalinisation and hematisation, giving rise to a prominent and very persistent ridge. A minor, east-northeast trending fault branches from the Lubungu fault near the confluence of Kafue and Lunga river, and is marked by the patchy development of metasomatic magnetite, hematite and tourmaline, and by alteration and brecciation of the granite. The Lubungu hot spring appears to occur on the northern edge of this fault or shear zone. Legg (1974).

2.3. Chongo Geothermal Site (Muchinga Province)

Chongo hot spring, located in Muchinga Province about 1.5 km north-west of Nabwalya area in the Luangwa Valley. Its relative isolation makes it difficult to access. The hot spring is classified under the Eastern geological group and is the hottest and largest in the valley. It is found at the base of a prominent scarp, without marshy surroundings, making it easy to approach and observe Legg (1974). The maximum surface temperatures recorded at Chongo is 87°C.

The main spring rises from beneath coarse scree material at the base of the scarp, which probably marks a fault in Karroo sandstones. Sandstones seen in outcrop along the base of the scarp are commonly strongly brecciated, and have abundant quartz veins trending north-east, parallel to the line of the scarp Legg (1974).

The main spring is flanked by smaller hot seepages rising also from below scree, and 200 m to the south-west a muddy, densely grassed mound with warm seepages on its crest, occurs. Rocks in and around the springs are covered with abundant encrustations, and soils on the flat land west of the scarp show efflorescence during the dry season. Little gas is emitted from the spring, but there is a slight sulphurous smell. The spring is moderately radioactive, with a radiation level of twice the local background.

3. SITE SELECTION METHODOLOGY

The methodology applied in the selection of geothermal sites to be considered for assessment of power generation included the following aspects: Physical, Social Economic and Technical suitability of the area. This method is described briefly in the following section. (Noorollahi et al, 2007). A schematic diagram of the method used in the decision-making process is illustrated in Figure 1.

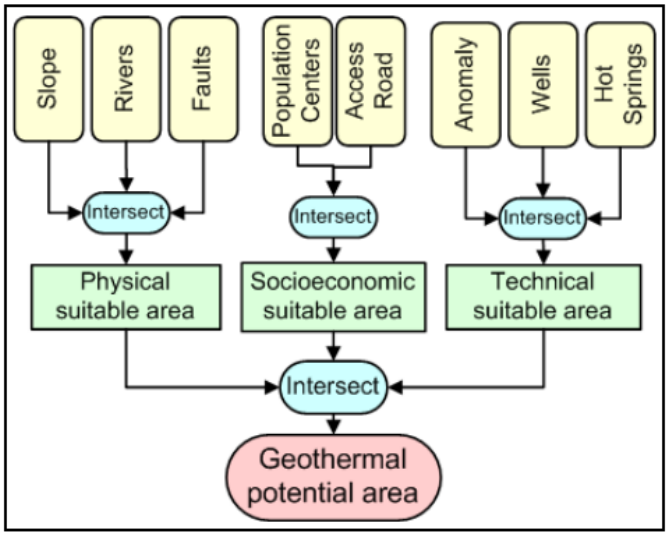


Figure 1: Illustration of the Model used in Decision Making Process for Site Selection

3.1. PHYSICAL SUITABLE AREA

3.1.1. Slope (Topography)

Slope refers to how steep the surface of the land is. Steep slopes are a limitation for GPP development, not only because of the cost and transportation, but also water that can find pathway from the drain to flow on the surface. Basically the slope

limitations for any development are slight if the slope is less than 8%, moderate if the slope is 8-15% and severe if the slope is greater than 15%. Topographic maps and Digital Elevation Models (DEMs) were used to analyze the slopes within the proposed geothermal site using software such as Global Mapper and ArcGIS.

3.1.2. Water Sources (Rivers or other Water Bodies)

River proximity and limitations refers to the location of rivers for recharge and also potential for flooding around GPP in the study area. In other words, the area not far away from the river, stream or big tributary drainage with their buffer can be assumed as a suitable area for GPP. The table below summarizes the estimated distances of the site from the water bodies (Rivers, Streams and Lakes)

Table 1: Proximity of Geothermal Site to Water Body

S/No.	Site Name	Closest Water Body	Distance from Water Body (m)
1	Kapishya	Lake Tanganyika	500
2	Chongo	Luangwa river	270
3	Lubungu	Kafue and Lunga River	200

3.1.3. Faults (Geological structures)

In geology, faults are discontinuities (cracks) in the earth's crust that have been responsible for many destructive earthquakes. Blewitt et al. (2003) indicated that at a regional scale, geothermal plumbing systems might be controlled by fault planes. Therefore fractures and faults play an important role in geothermal fields, as fluid mostly flows through fractures in the reservoir rocks. To avoid risk-taking of faults, a reasonable distance buffer size should be applied by using the ArcMap Buffer tool and a certain area should be selected as potential hazard area based on faults and fractures. Geological maps of the potential geothermal sites were critically analyzed to identify associated surface geology and structures.

3.2. SOCIAL ECONOMIC SUITABLE AREA

Socioeconomic study and conditions are usually hard to identify and investigate, as they are related to the human beings and their characteristics, which usually differ widely within the same community and from one community to another. In the study area among the socioeconomic parameters to be considered are population center and access road that can affect the GPP site selection process. In general, a stake-holders engagement plan (SEP) is employed in geothermal site selection process as summarized in the following sub-sections.

3.2.1. Populations Centers

The location and distribution of Villages, single buildings, agro nomads camping, livestock farming, stadium and sport centers, burial grounds, etc. considered as population center data layer should considered and assess the effect that the proposed site will impose. To avoid the socio and Environmental impact on the selection of a GPP site, a reasonable buffer size should be applied around these features to make the population center data layer.

3.2.2. Access Roads

One of the important parts of every socioeconomic study is the condition of road network. Access route analysis starts with remote sensing tools like Google maps, telephone interviews and a physical drive is undertaken to ascertain and confirm access to a particular site.

3.3. TECHNICAL SUITABLE AREA

Like all forms of electric power generation, both renewable and non-renewable, geothermal power production process has some technical requirements. This paper presents the most important requirements including anomaly zone, well locations and hot springs as categorized in the technical data set in GPP site selection model.

3.3.1. Anomaly zone

Geothermal fluids can be transported economically by pipeline on the Earth's surface only a few tens of kilometers, and thus any generating or direct-use facility must be located at or near the geothermal anomaly zone. To find the GPP suitable area based on the anomaly zone in Zambia buffer size should be applied which surround the anomaly zone feature. By the means of using clip tool in ArcMap only the buffer of anomaly zone around certain magnitude in land size should be selected as a factor map and suitable area for GPP siting model.

3.3.2. Wells location

It is always important to locate well in the proposed project area. To avoid selecting areas so near to the well pads a reasonable buffer size should be given to the wells features to make the restricted wells map.

3.3.3. Hot springs

Hot springs are evidence of a subsurface heat source and the temperature of springs has correlation with amount of heat flow. Those locations where hot springs rise to the surface are geothermal potential prospected areas because it is assumed that the probability of the occurrence of a geothermal resource is higher than that in the surrounding area.

3.3.4. Proximity to Electrical Power Grid

The proximity of the potential site to the national grid is cardinal for site selection as it influences the project cost.

In the 80s, the Zambian government with support from the Italian government undertook studies to map out all the geothermal resources in the country. The studies identified over 80 hot springs scattered around the country. Among the 80 sites, seven (07) sites were prioritized for further studies according to surface temperatures as follows:

Table 2: Prioritized Potential Geothermal Sites based on Surface Temperature

Site Name	Location	Surface Temperature (°C)
Chongo	Mpika District	87
Kapishya	Kaputa District	85
Lubungu	Mumbwa District	77
Mupiamanzi	Mumbwa District	73
Chinyunyu	Chongwe District	73
Kasho	Lufwanyama District	72
Chikowa	Mambwe District	64

ZESCO has further prioritized Kapishya, Lubungu and Chongo geothermal sites from the seven for further studies regarding the potential for power generation.

4. CONCLUSION

In this paper the geothermal power site selection process in Zambia involves, investigation and identification of available physical data which include; slope, river and faults, socioeconomical data such as population centers, access roads and technical data consisting anomaly zone, wells locations, hot springs and proximity to the national grid. All of the involved digital maps provided in the 1: 25,000 scale with the precision of 10 meter.

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