VOLUMETRIC RESSOURCE ASSESSMENT OF ASAL GEOTHERMAL FIELD, REPUBLIC OF DJIBOUTI

DAHER E. HOUSSEIN
Centre d'Etude et de Recherche de Djibouti, CERD, Djibouti

ABSTRACT

Three geothermal fields were identified in Asal geothermal field. Based on USGS volumetric estimation method together with Monte Carlo simulations is used to provide estimates of the probable power potential capacity of the geothermal system. The estimated power generation potential of all Asal high-temperature hydrothermal systems is between 115 and 329 MWe for a 25-year exploitation period.

Keywords: Asal, Resource, Assessment, Simulation

INTRODUCTION

Different methods used to assess geothermal resources are described by Muffler and Christiansen (1978) and Muffler and Cataldi (1978). These authors also discuss the theoretical background, assumptions and development of the equations used in these models. The most commonly used, particularly during the initial phases of a geothermal project mainly because of lack of sufficient data, is the volumetric method. Due to the simplifying assumption made, the volumetric method tends to be much less accurate than the numerical models.

from Mt and TEM survey made later in December 2007 (Arnason et al., 2008), three geothermal sufields is recognized in Asal area (Fig. 1)

The USGS volumetric method (Sabodh, 2010) is applied to the Asal area to get an initial capacity estimate. The purpose of this assessment is to estimate the electricity generation capacity for the region assuming a 25-year power plant life. Because most of the parameters assumed in the calculations are associated with considerable uncertainties, a Monte Carlo technique is used.

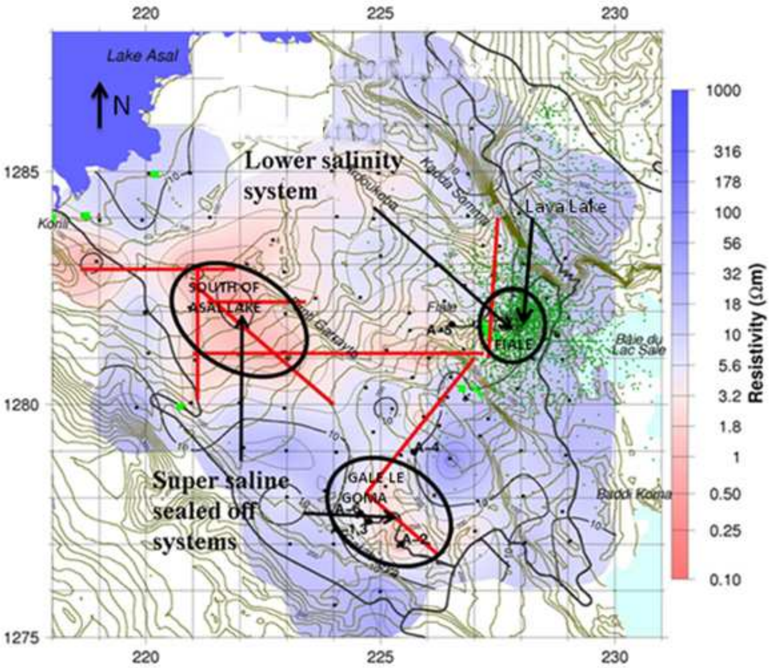


Fig. 1: Map showing the location of the three known geothermal systems (Gale le Goma, Fiale and South of Lake) in the Asal region. The figure also shows the resistivity at 3000 m b.s.l., inferred lineaments in low resistivity (red lines), seismicity (dark green dots) and geothermal surface manifestations (light green). The two super saline and sealed-off Gale Le Goma and South of

Asal Lake systems are indicated, as is the more open, lower salinity Fiale system under Lava Lake (modified from Arnason et al., 2008).

PARAMETERS USED IN THE MODEL

Based on the resistivity surveys conducted by ISOR (Arnason et al., 2008), the median estimated surface areas of the three geothermal systems, Gale le Goma, Fiale and South of Lake Asal, are 4, 4 and 3 km^2, respectively. From the temperatures profiles (Fig. 2) and the MT and TEM) data (Arnason et al., 2008), the thickness of these reservoirs is assumed to vary between 1500 and 2000 m.

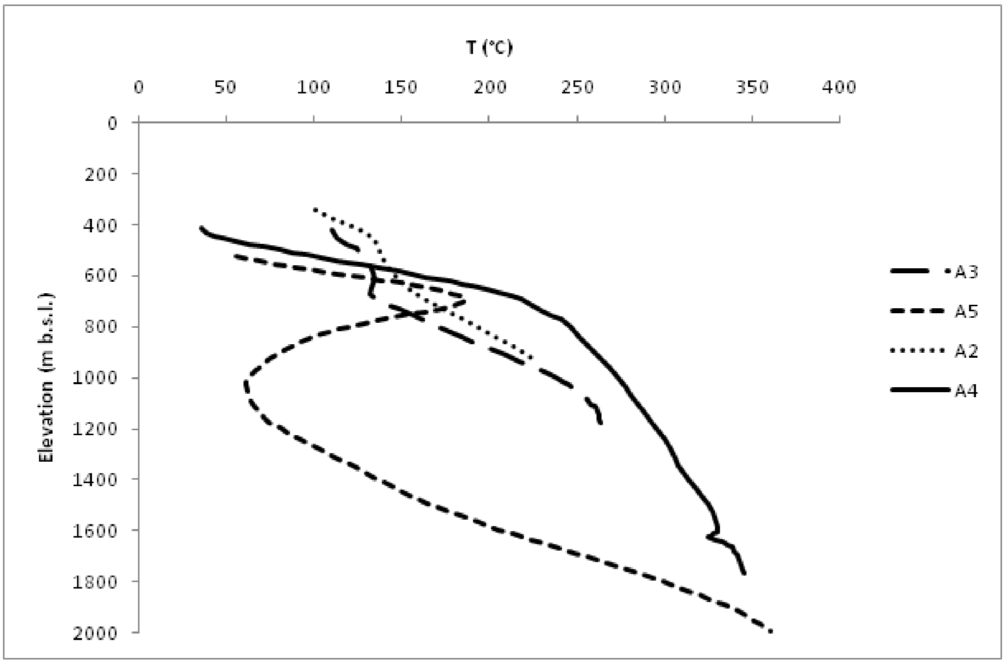


Fig. 2: Temperature profiles of Asal wells A2-A5.

In the calculations, a rejection (condenser) temperature (T_{ref}) of 40°C was selected (MIT, 2006). The reservoir temperature (T_{res}) was assumed to be homogenous, 280°C being the most likely, 265°C the minimum, 290°C the maximum for both Gale le Goma and South and 350°C the maximum for Fiale. This temperature range was based on the temperature profiles of wells A6, A3 and A4 drilled in the Gale le Goma area (Fig. 2).

Because of the high salinity of the fluid in the deep Asal reservoir, our calculations assume a fluid average density (ρ_{fluid}) of 890 kg/m^3 (Aquater, 1989) and a heat capacity ($ß_{fluid}$) of 4800 J/(kg°C).

The deep Asal reservoirs are considered to be composed mostly of metamorphic rocks (Aquater, 1989); therefore, the value for the heat capacity of the rock, $ß_{rock}$, is chosen to be between 0.8 and 1 kJ/kg°C, the values measured experimentally by Vosteen and Schellschmidt (2003). The porosity φ of the basalt rocks in the Asal area is of the order of 10% (Aquater, 1989). The average density of the rock (ρ_{rock}) is set at 2870 kg/m^3 on the basis of the gravity data collected by BRGM in 1979 (Aquater, 1989).

The geothermal recovery factor R_f, which represents the ratio of extracted thermal energy (measured at the wellhead) to the total thermal energy contained in a given subsurface volume of rock and water (Muffler and Cataldi, 1978), is assumed to be between 0.05 and 0.2, with 0.1 being the best guess. The electrical conversion efficiency (η) is taken to be 40%, like in the case of the Wairakei power plant (Thain and White, 1993). A 95% load factor L is used, based on 18 days of preventive maintenance per year.

All the input parameters used in the volumetric assessment are listed in Table 1.

Table 1: Most likely values and probability distributions for the patameters used to estimate power generation capacities in the different Asal geothermal fields

Input parameter	Units	Assumed distribution	Best guess	Minimum	Maximum
Area	km^2	Triangular	4 Gale	2	6
			4 Fiale	2	6
			3South	2	8
Thickness	m	Triangular	1500	1000	2000
Reference temperature (T_{ref})	°C	Constant	40		
Reservoir temperature (T_{res})	°C	Triangular	280 Gale	265	290
			280 Fiale	265	350
			280 South	265	290
Time period (Δt)	Years	Constant	25		
Recovery factor (R_f)	%	Triangular	0.1	0.05	0.2
Fluid density (ρ_{fluid})	kg/m^3	Constant	890		
Fluid heat capacity (β_{fluid})	J/(kg°C)	Constant	4800		
Rock density (ρ_{rock})	kg/m^3	Constant	2870		
Rock heat capacity (β_{rock})	J/(kg°C)	Triangular	900	800	1000
Reservoir porosity (ϕ)	%	Constant	10		
Conversion Efficiency (η)	%	Constant	40		
Load factor (L)	%	Constant	95		

RESULTS AND DISCUSSION

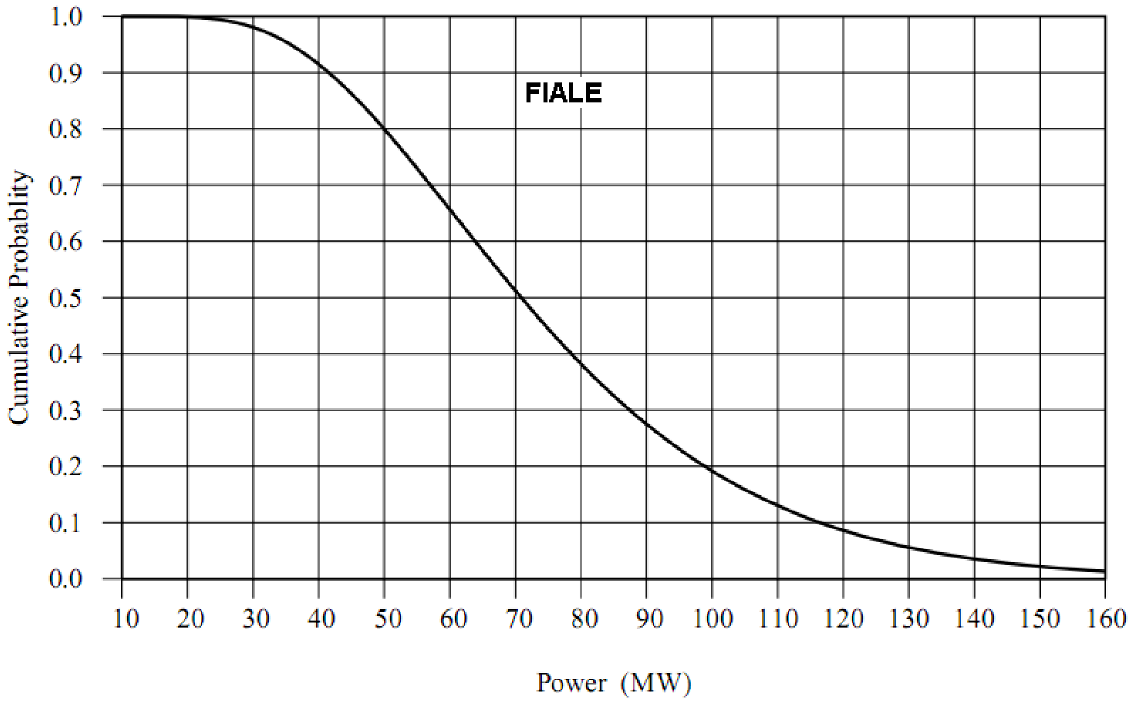
The results of the volumetric assessment of the electricity generation potential of the three geothermal fields in the Asal region are summarized in Table 2 and Fig. 3. These estimated generation capacities are only preliminary estimates since they are based on parameters with considerable uncertainties (in the South Asal Lake area, no wells have been drilled), particularly in the size of the reservoirs and in the assumed recovery factor.

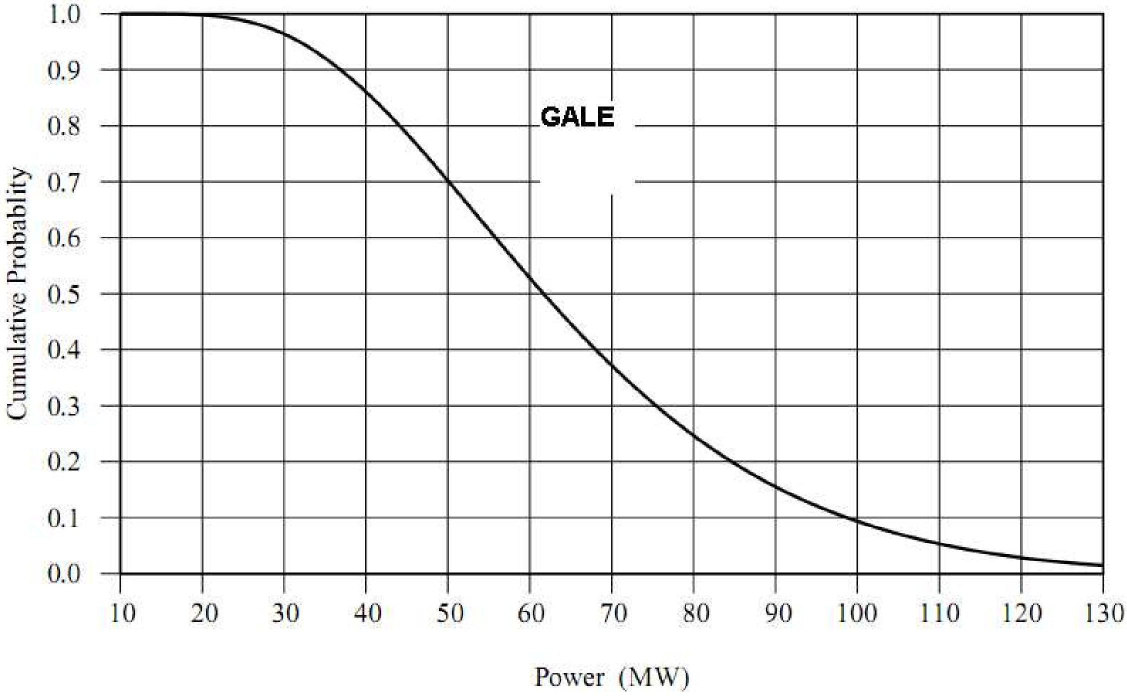
At the present time, the Fiale field is under development. A 50- MWe geothermal power plant might be installed there in the next few years. This size of plant might be realistic as the mean power capacity for the Fiale field is estimated to be 71 MWe and the 10% -90% confidence interval of the estimate is 42-116 MWe (Table 2).

Table 2 :Estimated power generation capacity of the three Asal geothermal fields based on the volumetric method and Monte Carlo calculations

Geothermal field	Estimated capacity (MWe)		
	Minimum	Median	Maximum
Gale le Goma	37	62	99
Fiale	42	71	116
South of Asal Lake	36	65	114
Total	115	198	329

Minimum, median and maximum are the P90, P50, and P10 values. Here Pxx indicates that there is a xx probability that the power generation capacity is at least the estimated value.





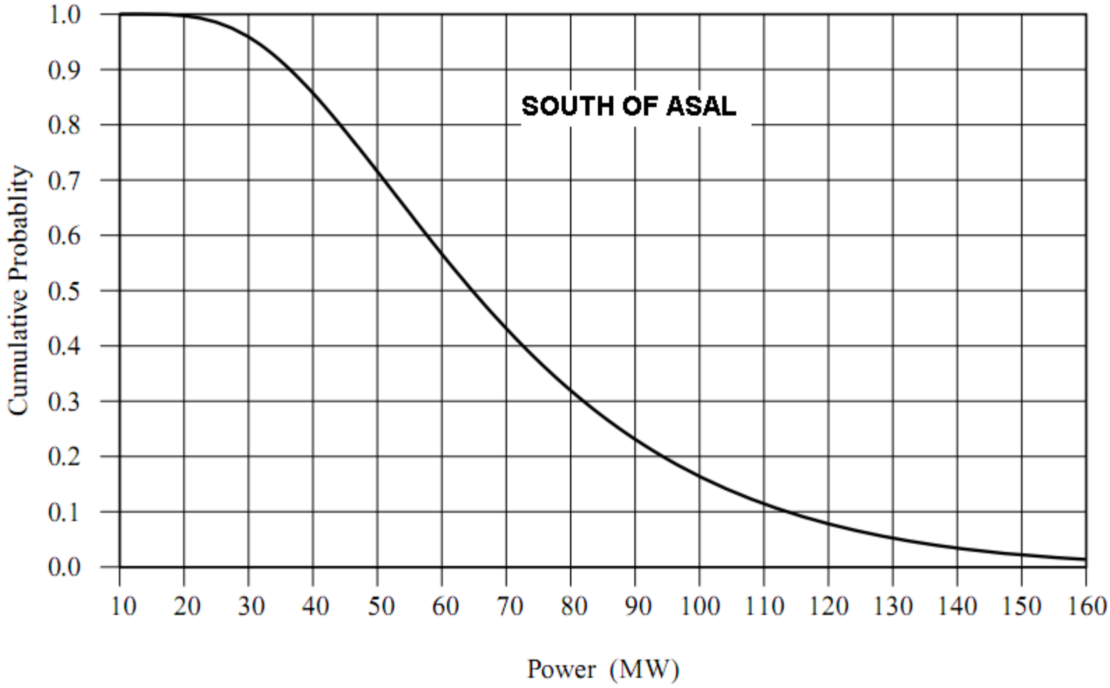


Fig. 3: Cumulative probability of energy reserves in three geothermal subfield of Asal area.

CONCLUSIONS

Using a volumetric method, the combined electricity generation potential of the three Asal geothermal systems is estimated to be between 115 and 329 MWe (Table 6). As more data on these areas become available, numerical studies should be performed to better determine electricity generation capacity of the Asal region.

ACKNOWLEDGEMENTS

Thanks to Reykjavik Energy Invest for allowing me to use data from the geophysical survey made in the Asal geothermal system. My appreciation goes also to Dr. Sabodh K. Garg for his help with calculations using volumetric method.

REFERENCES

Aquater, 1989. Djibouti geothermal exploration project Republic of Djibouti: final report. Aquater SpA, Lorenzo in Campo, Pesaro, Italy, 159 pp.

Arnasson, K., Eysteinsson, H., Vilhjalmsson, A.M, 2008. The Asal geothermal field, Djibouti. ISOR geophysical surface exploration. ISOR report 2008/019, 70 pp.

MIT, 2006. The future of geothermal energy: impact of enhanced geothermal systems [EGS] on the United States in the 21th Century. Massachusetts Institute of Technology , Cambridge, MA, USA. Available on World Wide Web at: *http://www1.eere.energy.gov/geothermal/future_geothermal.html*

Muffler, L.J.P., Cataldi, R., 1978. Methods for regional assessment of geothermal resources. Geothermics 7, 53-89.

Muffler, L.J.P., Christiansen, R.L., 1978. Geothermal resource assessment of the United States, Pure and Applied Geophysics 117, 160-171.

Sabodh, K.G., 2010. Appropriate use of USGS volumetric "heat in place" method and Monte Carlo calculations. Proceedings of the 34th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, CA, USA, SGP-TR-188.

Vosteen, H.D., Schellschmidt, R., 2003. Physics and Chemistry of the Earth 28, 499–509.