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Recent Expansions of Power Plants in Guris Concession in the Germencik Geothermal Field, Turkey

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ABSTRACT

The Germencik geothermal field is located in the western part of the Buyuk Menderes Graben (Western Anatolia). The field was discovered in 1967. It is a liquid dominated reservoir, with reservoir temperatures up to 276 ^oC, whose main feature is the high CO_2 content about 2.1% by weight.

GURIS Construction and Engineering Co. Inc. became the operator of the field and constructed a 47.4 MW_e double-flash power plant in 2009. The early production performance of the field indicated a great potential for further developments. The electrical generation potential of the GURIS lease (which is around 36 km^2) was initially estimated to be about 200 MW_e based on a volumetric resource assessment.

Data obtained from about 70 wells drilled in the Guris lease since 2009 have indicated the existence of the 200 MW_e and possibly more generation potential. Compilation of data related to geology, geochemistry, drilling and well test results, detailed production and injection histories-rates, wellhead pressures and temperatures of the active production and injection wells, and downhole pressure-monitoring data was succeeded and integrated to form the conceptual model of the field underlying the GURIS concession area. Our in-house lumped parameter model is utilized to model the production rate-reservoir pressure history and an almost perfect match is obtained.

Four power plants have been recently installed in the concession area and producing electricity; Efe-2, Efe-3 and Efe-4 each with 22.5 MW_e capacity and Efe-1 with 47.4 MW_e capacity. The total capacity has already reached to 162.3 MW_e. GURIS intends to develop the field and to extend the power plant capacity in the near future up to 232 MW_e.

Results obtained on assessment of the energy production potential of geothermal resources within the GURIS's area in Germencik, mainly through production performance and reservoir modelling, and of the feasibility of continued and increased production are discussed in this paper.

1. INTRODUCTION

The Germencik geothermal field is located in the western part of the Buyuk Menderes graben, about 40 km from Aegean Sea. Germencik is surrounded by further geothermal prospects as shown in Figure 1.

Nearly 300 geothermal resource areas have been identified in Turkey. The Germencik field is one of the largest and most developed resources discovered in Turkey so far. The commercial development of geothermal power in Turkey has led to installations of power plants with a combined capacity of 601 MWe as of the end of 2015. As shown in Figure 2, most of this development has occurred in the last decade, basically due to privatization in geothermal sector and improvements in regulations.

The Germencik field was discovered by MTA (General Directorate of Mineral Research and Exploration) in 1968. It is identified as a water dominated hydrothermal system with a temperature up to 276 ^oC, and CO_2 content about 2.1% by weight. Guris became the operator of the field and constructed a 47.4 MWe power plant, Gurmat 1, and put it on line in February 2009. Up to now, more than 70 wells drilled. The locations of the wells drilled in the field are shown in Figure 3.

The early production performance of the field indicated a great potential for further developments. The electrical generation potential of the Guris lease (which is around 36 km^2) was estimated to be about 200 MWe based on an initial volumetric resource assessment and then later this is further supported by the production performance of the field. Four power plants have been recently installed in the concession area; Efe-2, Efe-3 and Efe-4 each with 22.5 MWe capacity, and Efe-1 with 47.4 MWe capacity. The total capacity has already reached to 162.3 MWe. Guris intends to develop field and to extend the power capacity up to 232 MWe in the near future.

This paper discusses some of the recent findings and developments in the field, describes the observations and results of the analyses done on the production performance and reservoir pressure data response to production since the project start-up.

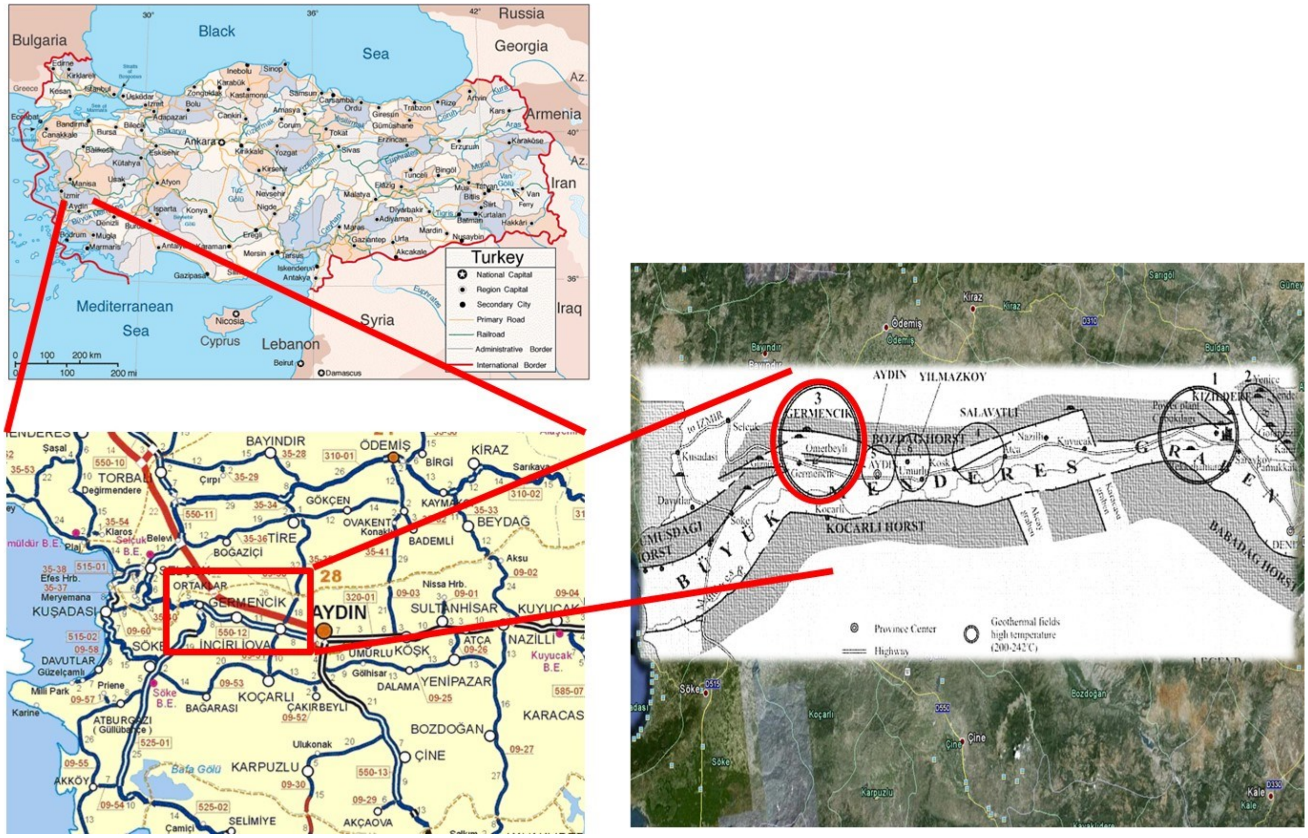

Figure 1: Map showing the location of the Germencik Geothermal Area within the western part of the Buyuk Menderes Graben about 40 km from Aegean Sea.

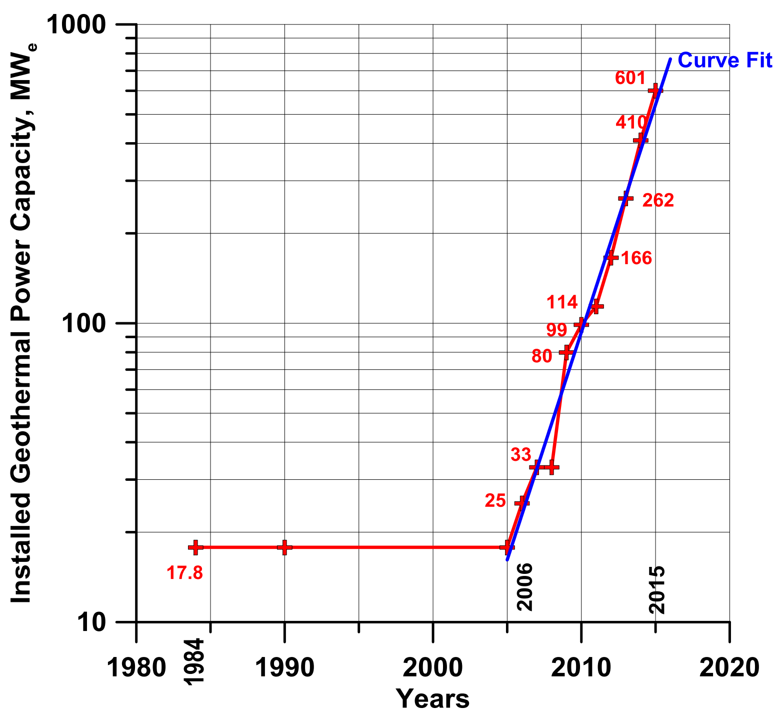

Figure 2: Growth of installed geothermal power capacity in Turkey.

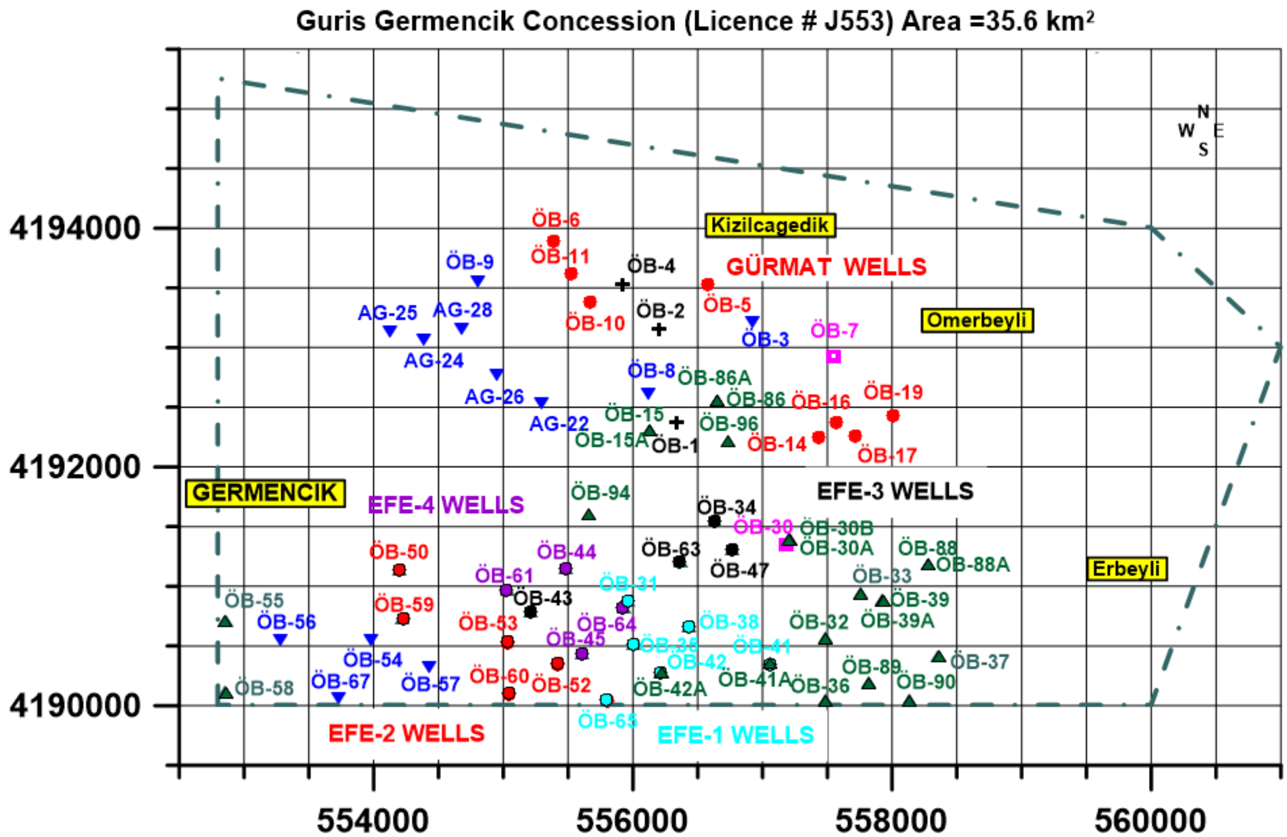

Figure 3: Well locations in the Guris lease and distributions according to power plants.

2. DYNAMIC PRESSURE-TEMPERATURE PROFILES AND WELLHEAD PRODUCTION TESTS

2.1 Dynamic p-T Profiles

Dynamic p-T profiles in geothermal wells are taken as a part of well completion. Particularly temperature profiles are analyzed and studied to identify the fluid entry depth and temperature. The bottom (deeper) parts of the temperature profile is also analyzed for better understanding of the trend and characteristics of the convective or conductive behavior of the bottom hole extensions of the wellbore. Vertical temperature profiles below the production zone can show decreasing or decreasing trend depending on with and without the temperature reversal below the reservoir (Sanyal et al., 2004).

If the temperature increases below the production zone, it indicates a conductive zone and possibly a deeper and higher temperature zone or a deeper reservoir with higher temperature.

Interpretation of the deeper parts of the temperature profiles indicates a deep convective hydrothermal system on the southeastern part of the field and it extends with vertically upward movement of the reservoir towards the central part of the concession area. The upflow of the geothermal system containing compressed water rises vertically from greater depth on southeast to shallower depth on the central part of the lease.

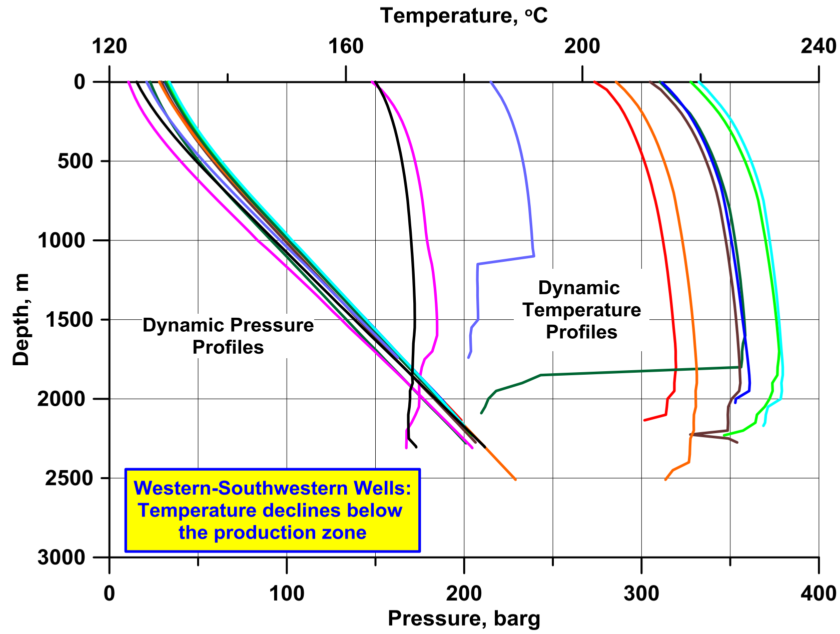

Figure 4: Western-southwestern wells showing temperature declines below the production zone.

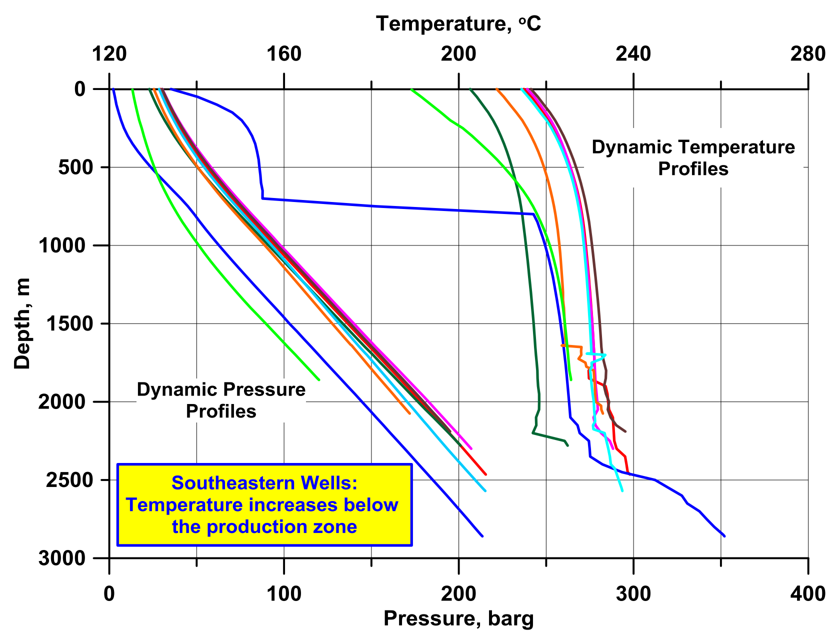

Figure 5: Southeastern wells showing temperature increases below the production zone.

Figure 6 shows the dynamic pressure and temperature profiles for the well OB-90. The profiles are typical of a well with compressed water entering the bottom hole and then the formation of the two-phase occurring in the wellbore. The wellbore contains a liquid column, identified by hydrostatic gradient and relatively constant temperature, above which is a flashing column with a lower pressure gradient and decreasing temperature profile.

An in-house wellbore flow simulator was used to analyze the dynamic flow tests. The purpose was to understand the flowing phase behavior, to estimate the amount of CO_2 dissolved in geothermal water, the depth where the flashing occurs, and to determine the flow rate-wellhead flowing pressure relationship.

Analysis of the dynamic-temperature profiles indicate that two-phase flow exists in the wells. The flashing point depths are determined. To prevent the calcite deposition in wells, an inhibitor is injected into the production wells.

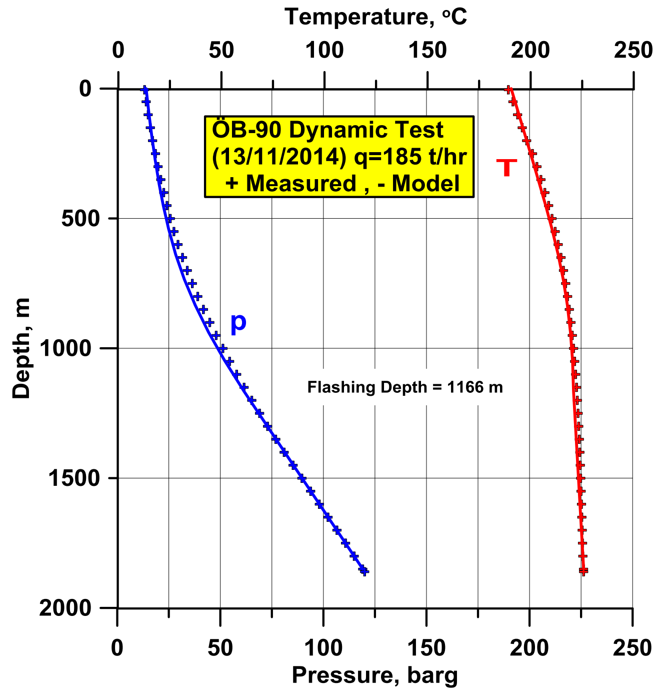

Figure 6: The dynamic pressure and temperature profiles for the well OB-90.

2.2 Wellhead Production Tests

The wellhead production (productivity) test is conducted to develop the wellhead flowing pressure-mass flow rate relationship. It is utilized to estimate the wellhead pressure response as flow rate is changed.

The production tests of all wells in a field can give an estimate of total (apparent) production capacity of the field. Figure 7 illustrates the production test results in the form of the output curve of mass flow versus wellhead pressure for majority of the production wells in Guris concession area.

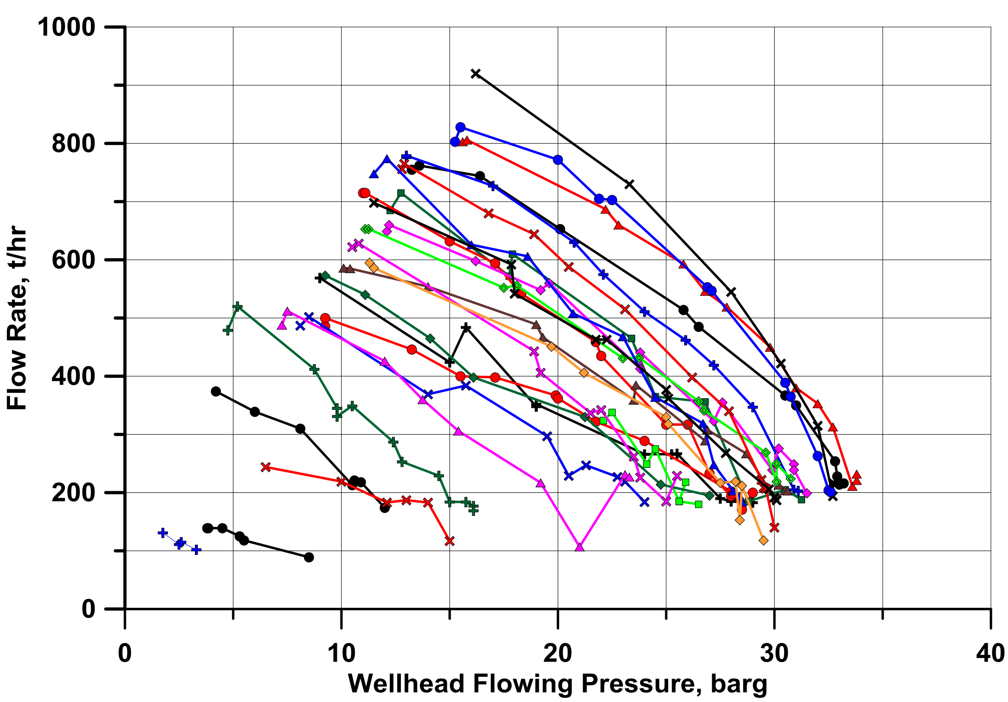

Figure 7: Production test results for wells.

3. PRODUCTION AND RESERVOIR PERFORMANCE - MODELING

3.1. Production Performance

The Germencik geothermal field has been produced over 6 years since February 2009. Figure 8 illustrates the historic production and reinjection data for the Guris concession area between April 2009 and November 2015. About 80% of the produced fluid has been reinjected into the reservoir successfully. There are no indications of reservoir cooling due to reinjected brine or natural recharge. Net production rate in Figure 8 represents the net mass flow rate defined as the difference between the production rate and the reinjection rate.

Reinjection of all separated brine is foreseen as crucial in the present and future development of the resource, mainly for the purposes of mass balance preservation and reservoir pressure maintenance, but also for environmental reasons.

One of the main issues that need to be resolved in order to optimize future reinjection in concession area is where the reinjection should be located. Some of the present reinjection well locations are now questioned due to the observation of decline in CO_2 content of the produced water indicating an early breakthrough of water from near reinjection wells. This appears to be a result of the nature of the heavily explored parts of the geothermal system containing reinjection wells close to production wells, which causes the decline of CO_2 content in the water discharged from produced wells. In a compressed liquid reservoir such as Germencik, the net mass loss of the reservoir caused by exploitation is supplied by decompression of water and decline of the partial pressure of noncondensable gas (CO_2). The ideas of reinjecting on the margins of the most productive part of the system rather than in-between production and relocating reinjection wells further away from the production wells are being discussed by the management.

Reservoir pressure has been regularly monitored in the concession area since the beginning of commercial operations in 2009. Pressure was measured in some observation wells. To capture the reservoir response with the addition of the new power stations, continuous reservoir pressure monitoring equipment were installed in observation wells within the production area. Reservoir pressure is continuously monitored at OB-7 from Febr. 2009 onwards.

Reservoir pressure data show a strong correlation with the net production rate, having initial high pressure decline followed by a transition to a stable pressure. The reservoir pressure decline has been estimated at 11-12 bars from the initial stage (February 2009). The pressure stability has been interpreted as due to a strong natural recharge leading to a steady-state established by the reservoir material balance.

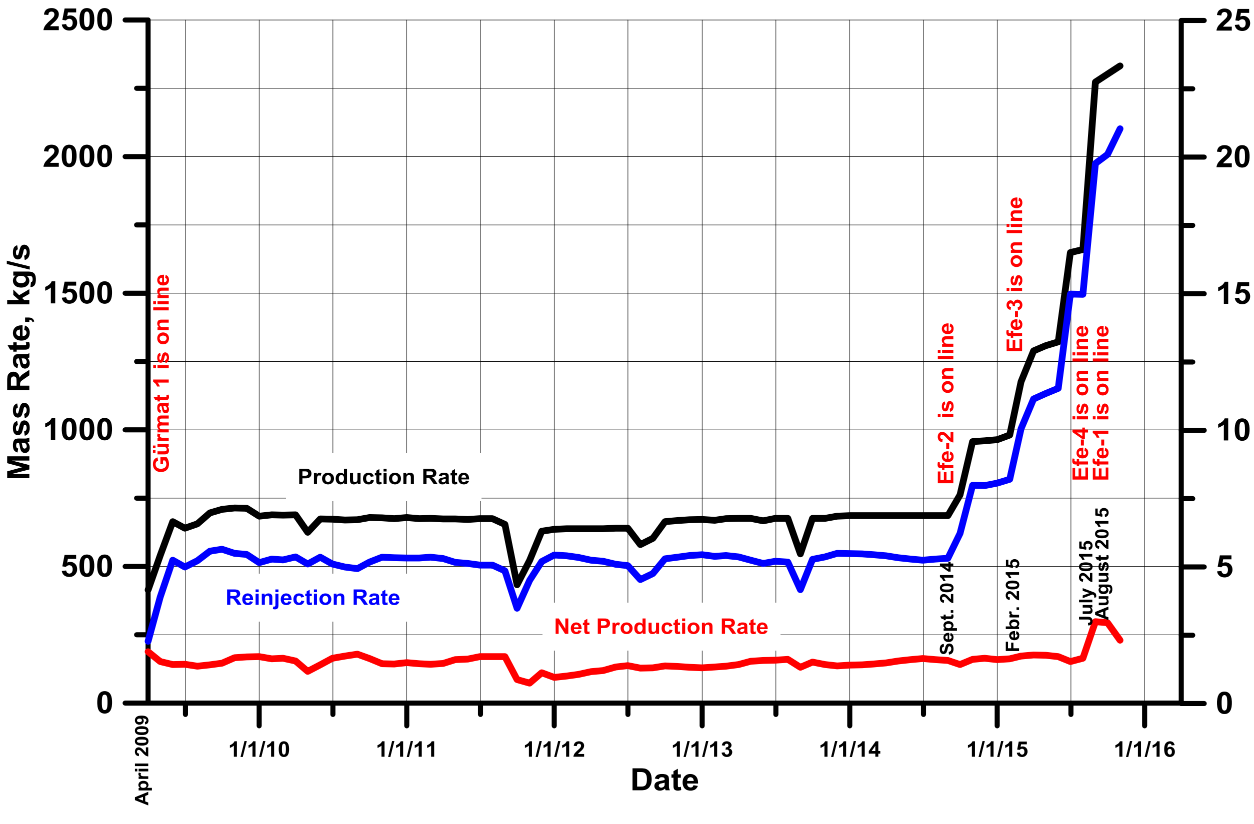

Figure 8: The historic production and reinjection data for the Guris concession area between April 2009 and November 2015.

The match to observed pressure drops in OB-7 between February 2009 and Nov. 2011 is shown on Figure 9 (Tureyen et al., 2014). A lumped parameter model (Sarak et al., 2005) was run with the aim of matching the measured pressure data obtained from observation well OB-7. Pressure in OB-7 is measured at 125 m depth (at an elevation of -54 m above sea level), and the initial pressure drop on 15.02.2009 is assumed to be zero. Mass flow rate represents the net mass flow rate defined as the difference between the production rate and the reinjection rate. Measured data are denoted by the black diamonds, while calculated pressure drops are represented by the solid red line. Reservoir pressure data showed a strong correlation with the increased production, showing initial high pressure drop followed by a transition to a stable pressure drop rate. As seen on Figure 9, the model has been able to match the OB-7 observation pressure very well. The difference between measured and calculated pressure data is very minimal throughout the production history.

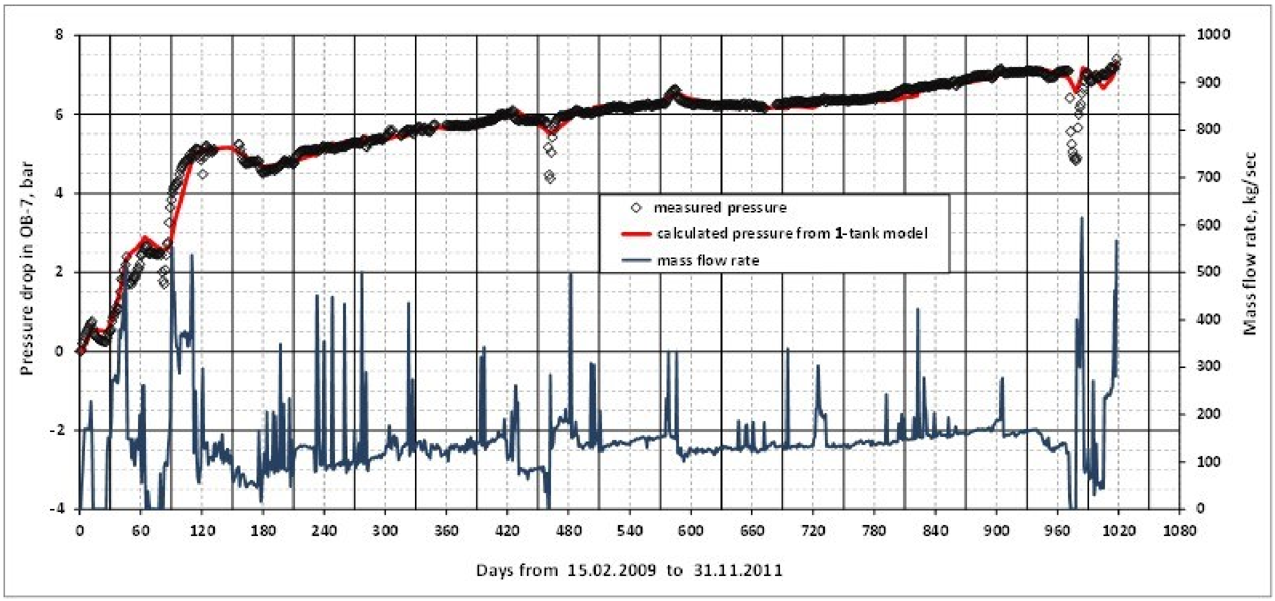

Figure 9: Matching of pressure response at Well OB-7 (Tureyen et al., 2014).

Results of the history matching of the data between February 2009 and Nov. 2011 (Figure 9) were considered to be excellent, as very good matches between measured and calculated were achieved. According to the results obtained from the lumped parameter model, a very strong natural recharge exists and the parameters determining reservoir pressure performance are production rate, reinjection rate, and natural recharge. Our in house lumped parameter model (Tureyen et al., 2014) was set up to match and interpret the continuous pressure data response of the observation well OB-7. The resulting match was then used for forecasting purposes.

3.2 Forecasting the Pressure Response

The forecast for the reservoir pressure in OB-7 was simulated using the current rates of all the production and injection wells and testing the effect of changing the production rates. The results are shown in Figure 10.

Our forecast results show the general reservoir pressure decline rate may be stable and reaches to steady state conditions indicating a very strong natural recharge support.

4. CONCLUSIONS

The Germencik geothermal field has been produced over 6 years. The production has been sustainable. No general cooling of the field has been observed so far. The present production of the field can be largely increased and be maintained without increasing the pressure drawdown substantially, provided that the ratio of the reinjection rate to the production rate is kept high, about 90%.

The model of the Guris lease of the Germencik Geothermal System has been revised based on all available geological information, temperature and pressure data, various reservoir and wellbore testing and monitoring data as well as information on the chemical content of the reservoir fluids. Most important are data from more than 70 wells drilled in the area since 2009.

The electrical generation capacity of the geothermal system was assessed. The resource can be split in two parts; a heavily explored part where extensive drilling has delineated the resource and long-time utilization experience exists and a less explored part where drilling has been limited and mainly indirect indications on an exploitable resource exists.

A great increase in electrical generation has occurred recently and is also expected within the next few years, with an associated drastic increase in mass extraction.

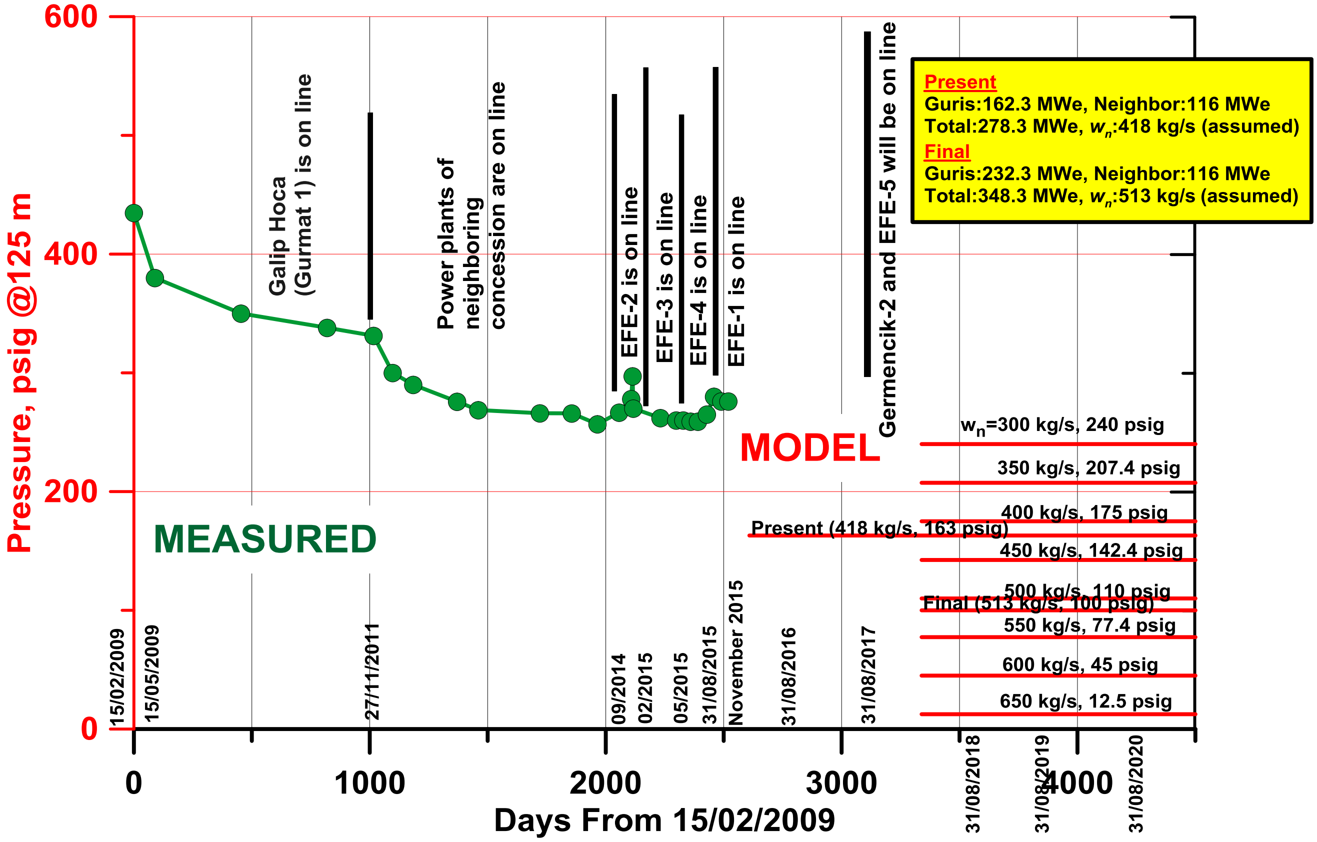

Figure 10: ÖB-7 Observation well measured pressure behavior and model results for future projection.

The generation capacity estimates and forecasting the reservoir pressure response for the Guris area are based on the results of three reservoir assessment methods; (i) volumetric potential estimates for both the heavily explored and less explored parts, (ii) the analysis of the productivity tests of the production wells, and (iii) the lumped parameter modelling of the pressure response.

Our study has revealed:

* The importance of a comprehensive monitoring program for geothermal systems being utilized, in particular production rate change and pressure decline monitoring

* The pressure response of the Guris area indicates substantial recharge to the geothermal system.

* The lumped parameter model, which has now been developed for the Germencik Geothermal System, is an indispensable management tool during long-term utilization.

* The experience in Guris lease area, where nearly 90% reinjection is applied, should be used to help planning future reinjection in Guris concession area in Germencik.

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