Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Optimization of Water and Two-Phase Components in the Openhole Section for Extraction Strategy in Leyte Geothermal Production Field

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Keywords: enthalpy, extraction, two-phase, optimization, openhole

ABSTRACT

The Tongonan or Leyte Geothermal Production Field (LGPF) is a liquid dominated reservoir that has been on production since 1983. However, with continuous extraction, reservoir pressures declined particularly in the central sections of the production field. Most of the wells in the center the field have become two-phase or steam-dominated, while the wells near the periphery of the field remained liquid dominated.

Part of the resource management strategy in sustaining steam supply to power plants is the drilling of deep wells at the periphery of the reservoir in order to spread out mass extraction to other parts of the field and thereby allow pressure recovery in the drawndown central portion of the field. Available data from the newly drilled wells help us understand the reservoir condition, and has led us to investigate other parameters (permeability, physical and chemical data) which could have affected well output. Preliminary evaluation showed that the major difference is the discharge enthalpy of the wells, which depends on the contribution of the two-phase and water components in the reservoir. It was observed that wells with high mass flows having medium enthalpy are able to produce higher output compared to wells with low enthalpy.

The result from this study will be considered in the preparation of well designs particularly on the setting depth for the production casing shoe (PCS) to take into account a more balanced extraction from both two-phase and liquid part of the reservoir for a more sustainable well life. The result of this study was also compared with output prediction for new wells based on the discharge characteristics of offset wells with comparable percentage of openhole section above water level. Amongst others, well performance may still vary depending on the structures, reservoir temperature and pressure, and fluid chemistry of the reservoir where the well is drilled.

1. INTRODUCTION

Tongonan Geothermal Production Field (or Leyte Geothermal Production Field, LGPF) had been operating since 1983 initially with the 112.5MW Power Plant, and later increased to a total installed capacity of 476 MW. With the increase in mass extraction, the original mid-enthalpy wells became dry as a result of the experienced significant pressure drawdown. Steam availability increased as an initial response to the pressure drawdown as liquid feeds started to boil. However, the increase in steam was short-lived as the re-injected brine started to make its way to the production sectors and resulted to silica deposition in the wellbore and formation. With the pressure drawdown, brine returns, mineral depositions, wellbore blockages aggravated by some casing problems related to the high Total Suspended Solids (TSS) and age of the wells, steam started to continuously decline starting 2002.

As part of the Leyte steam augmentation project (LSAP) of EDC, about 20 production wells were programmed for drilling starting 2008. These wells are located mostly on the periphery of the field but some are within the center of the production area. One of the main objectives of drilling these new wells are to tap the deeper liquid zones of the resource to ease extraction from the drawndown steam region and to the liquid component discharge. Watery discharge will lessen the erosive effects of discharge from dry wells which cause thinning of casings and surface facilities.

The total actual MW output of the LSAP wells almost reached the total targeted output (~98%). However, a closer look at the details of the individual well performance showed that some wells exceeded the target while others were did not meet target expectations.

2. REVIEW OF DATA

The new wells drilled in LGPF since 2008 were analyzed in this study. The online outputs of some of the wells are low despite the high permeability and high temperatures encountered because of the low enthalpy discharges of the wells. The massflows are very high at fully open conditions with wellhead pressures (WHP) lower than the commercial WHP.

The effect of water level on the output performance of a well given certain permeability are shown in Table 1. Representative wells drilled in 2010-2012 were included in the table to show the correlation of each parameter.

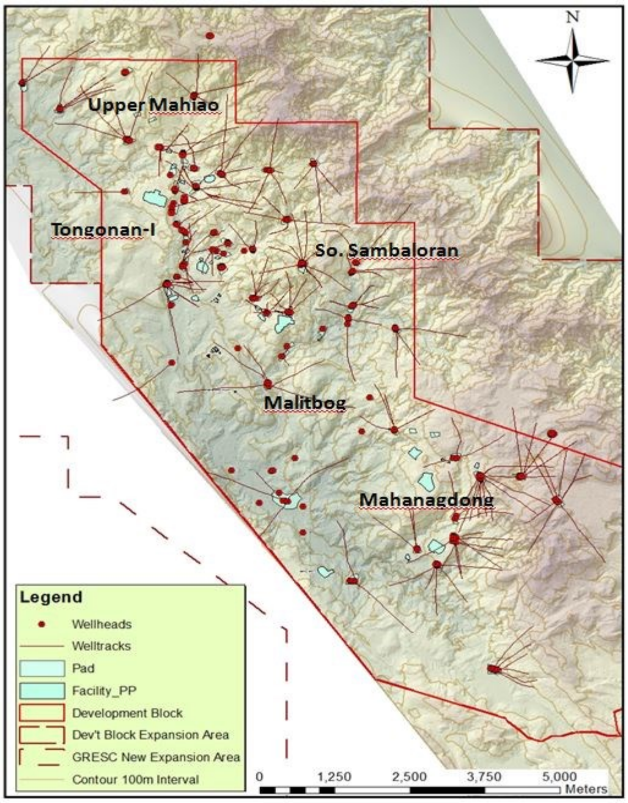

Figure 1: Leyte Geothermal Production Field Map

Table 1: Openhole Waterlevel Evaluation in LGPF

Well	Output (MW)	Enthalpy kJ/kg	Openhole above WL (m)	% openhole	Inj. Index (li/s-MPa)	Kh da-m	Max Temp (°C)
W1	10	2783	650	46	-	-	256
W2	9.1	1930	-108	0	24	2	277
W3	9.0	2463	1062	78	133	24	281
W4	8.5	2451	1106	85	125	19	311
W5	7.9	2785	317	90	58	27	311
W6	7.0	2779	800	89	32	5	321
W7	6.6	2370	728	76	45	2	314
W8	5.0	2785	312	39	107	24	296
W9	4.0	1857	409	36	28	5	300
W10	3.5	1240	400	31	57	15	242
W11	3.3	1976	210	26	51	3	286
W12	3.3	2552	329	44	9	5	233
W13	2.7	1920	135	22	16	2	201
W14	2.6	1156	350	28	48	3	246
W15	2.4	1123	-119	0	113	15	282
W16	2.0	1264	204	17	110	48	266
W17	2.0	1127	-241	0	65	9	265
W18	1.5	2788	150	17	197	-	260

High enthalpy wells produce high output (7-10MW) given high percentage (>40%) of openhole section above water level.

Temperature of wells in this study have all met the minimum temperature requirement in the openhole section at >220°C. Hence, temperature at openhole hole sections is not an issue during drilling these wells.

Results of the evaluation of the individual well performances showed that the well design should not only target high permeability and high temperatures but should also take into consideration the water level in the area. At the current state of the Tongonan geothermal resource, targeting to drill a 3.5km well would put the 1-1.5km openhole section below the water level and would yield a low enthalpy well. This low enthalpy well will have significant pressure drop from the feed zone as it goes up the wellbore resulting to lower maximum discharging pressure and difficulty in attaining the target commercial WHP. Oftentimes, the bottom liquid zones cease to contribute to the discharge as the well is throttled to reach the target WHP resulting to minimal output.

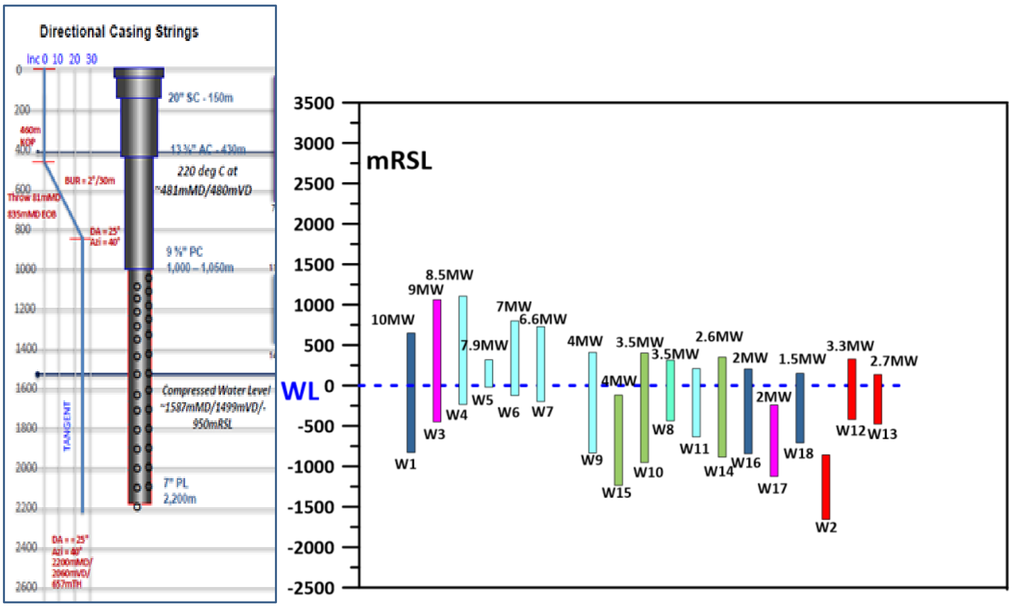

Figure 2: PCS Setting depths and waterlevel of newly drilled wells

The direct relationship between the well's output and the length of openhole section above water level is shown in Figure 2. This implies that increasing the channel of the two-phase zone is an advantage in attaining promising output. The available data on the water level of the area will equally lead to the best well design.

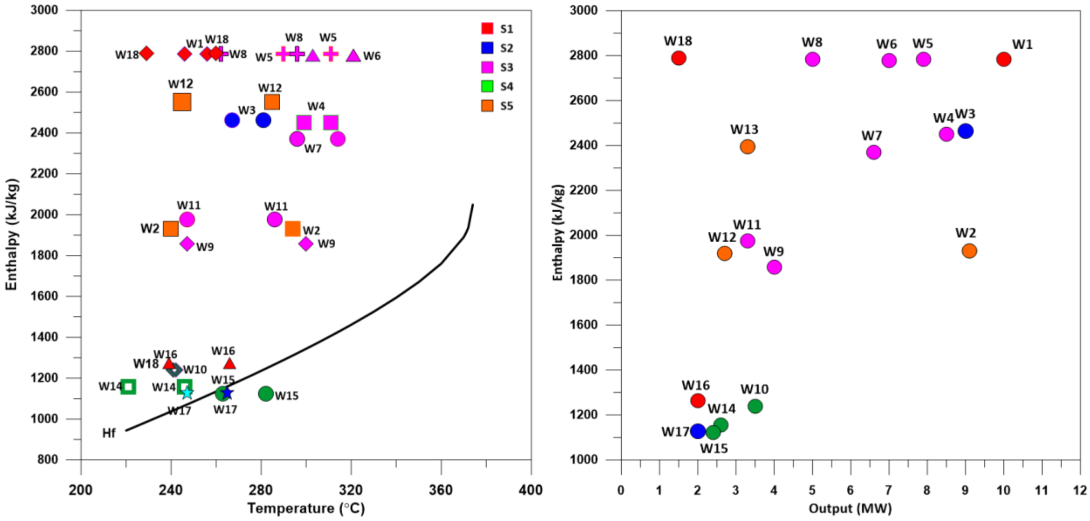

Figure 3: Crossplot between downhole Temperature/Output and discharge Enthalpy

All wells with liquid feed have low outputs and are clustered at the liquid enthalpy line of the openhole temperatures as shown in Figure 3. In order to achieve the objectives of getting higher output and less erosive fluids, an enthalpy of 1800-2200kJ/kg is ideal in addition to high permeability and high temperatures. With H>1800-2200kJ/kg, the well will have a high chance of easily attaining the commercial WHP and will have enough water component to lessen the erosive effect of the suspended solids going with the discharge.

3. DATA ANALYSIS

Linear regression under R commander was performed on well parameters. All the possible factors that may affect the output of the well were correlated to investigate the relationship between two variables. As regression was performed on all the factors, it was noted that the % openhole above water level has a significant effect to the well's output with a (Coefficient of Determination) R^2=0.9684 which suggests that 97% of the variation in the output of the well can be significantly explained by the variation in predictors to the model. The higher the R^2 , the more useful is the model. A correlation of the wellbore data revealed that percent openhole above water level (length of openhole above waterlevel vs. total length) and well output are significantly related.

Table 2: Regression Analysis

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Coefficients:
                   Estimate Std. Error t value Pr(>|t|)
(Intercept)       0.2162163  3.5809556   0.060 0.954192
X.openhole        0.0709489  0.0096985   7.315 0.000748 ***
Inj..Index        0.0002272  0.0526275   0.004 0.996723
Kh               -0.0383892  0.0222497  -1.725 0.145053
max.Temp          0.0024143  0.0111195   0.217 0.836691
inj2              0.0001785  0.0003050   0.585 0.583758
factor(Flow.1)1   0.8925884  0.7301465   1.222 0.276004
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Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.668 on 5 degrees of freedom
Multiple R-squared:  0.9684,     Adjusted R-squared:  0.9305
F-statistic: 25.54 on 6 and 5 DF,  p-value: 0.001336
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3.1 Statistical Data

The Coefficient of Determination, $\mathbf{R^2}$ will help determine how good is the model in fitting actual well data. Based on the $\mathbf{R^2}$ only 97% of the variation in the output prediction can be explained by the model. Hence, the are other factors that can affect well output, *e.g.* reservoir-related factors, *etc*. Validation and updating of the model using recent data is also recommended.

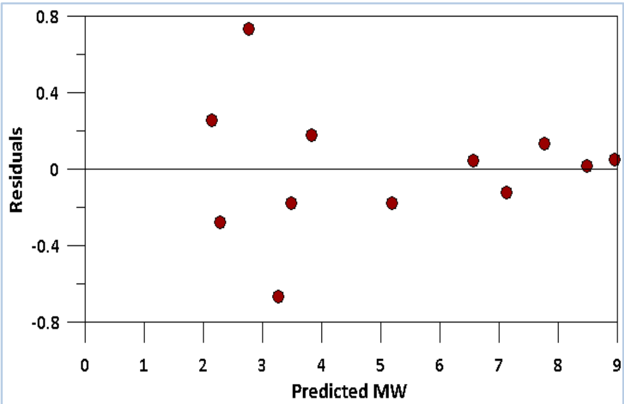

Figure 4: Plot of residual vs predicted output

The residuals vs. the predicted output indicates no distinct pattern, centered around zero and has a good spread which implies that the model is unbiased and confirms its validity as shown in Figure 4..

4. RESULTS AND DISCUSSION

In general, wells with higher percentage (>40%) of openhole section above the water level generate higher output. In the case of wells W1, W4 and W16, the length of openhole section above the water level is at least 45% resulting to an average output of 8.7MW, which surpassed the target output of 5MW for newly drilled wells. While wells W9, W10, W12 and W17 with openhole sections above the water level less than 40%, have only generated an average output of 2.5MW (about 50% of the target output).

Plotting the results, the correlation between the output and the water level of a well showed that the longer the openhole section (>50% of total length) tapping the two-phase fluids above the level, the higher the output (6-10MW) (See Figure 5). Outlier in the plot are wells W15, which has significantly higher temp (>300°C), localized drawdown (moderate permeability), and W18 which has shallow water level (data not yet stable, 1-DS). Overall, the above correlation may not be directly applicable to other fields given other factors such as permeability of structures, reservoir temperature and pressure, and fluid chemistry affecting well performance.

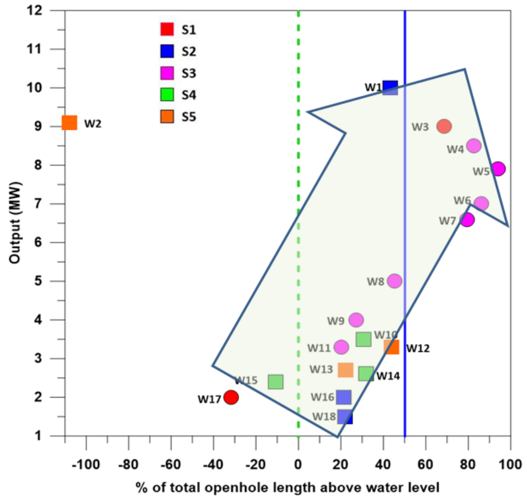

Figure 5: Output with Respect to % Openhole above WL

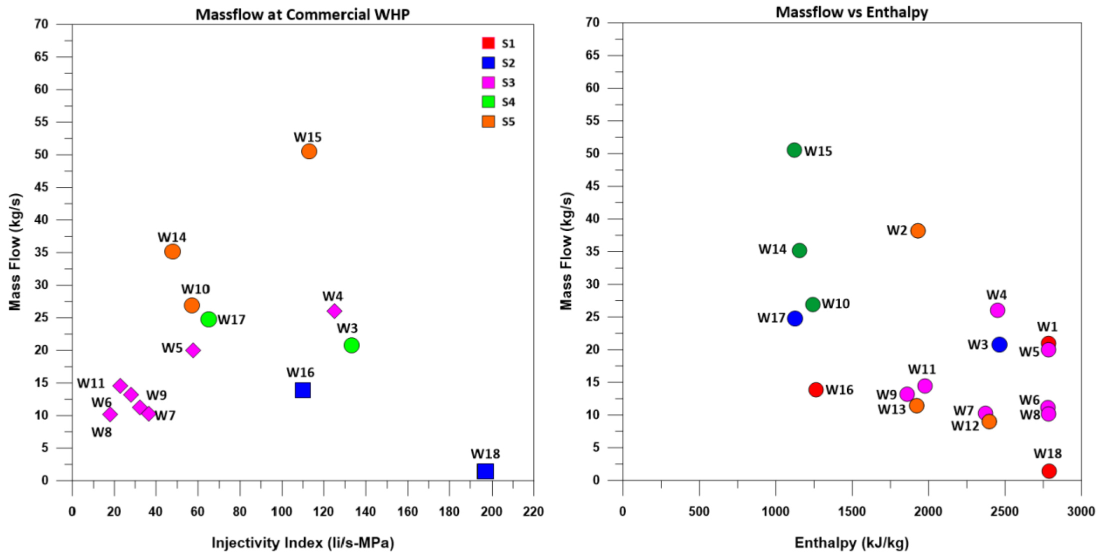

Figure 6: Crossplots between Massflow/Injectivity Index and Massflow/Enthalpy

No direct correlation between enthalpy, injectivity index (or transmissivity, kh) and massflow.

5. CONCLUSION/RECOMMENDATION

This study for Tongonan wells was able to find a correlation between the percentage of the openhole section above water level and well output. The longer the openhole section tapping the two-phase fluids yields the higher the output. The correlation may not be directly applicable to other fields given other factors such as permeability of structures, reservoir temperature and pressure affecting well performance. For future well designs (drilling new well), aside from targeting high temperatures and high permeability, wells should tap longer length of openhole section above water level to provide enough water flow for lubrication (to mitigate erosion).