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30 Years of Tongonan-1 (Leyte, Philippines) Sustained Production

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ABSTRACT

Tongonan-1 in Leyte, Philippines has achieved a milestone for sustainable production for 30 years. Reservoir management played a key role in the continuous power generation and in conquering the challenges since the commissioning of the Tongonan-1 power plant in 1983. The series of challenges in its 30-year history has been a source of lessons and the reason for the sound production and injection strategies that have been implemented.

Cooler injection returns, blockages, erosion and pressure drawdown are among the challenges that have been met squarely by the early and present resource managers. Technological knowledge and developments in field management, geochemistry and reservoir engineering were crucial in analyzing and addressing these challenges. Likewise, experiences in targeting M&R wells proved to be significant in achieving the sustained production.

1. INTRODUCTION

The Leyte Geothermal Production Field (LGPF), located in the province of Leyte in the Eastern Visayas region of the Philippines, is known as one of the largest liquid dominated reservoir in the world. It is comprised of two distinct hydrothermal systems - Tongonan to the north and Mahanagdong to the south, separated from each other by the low permeable Mamban block.

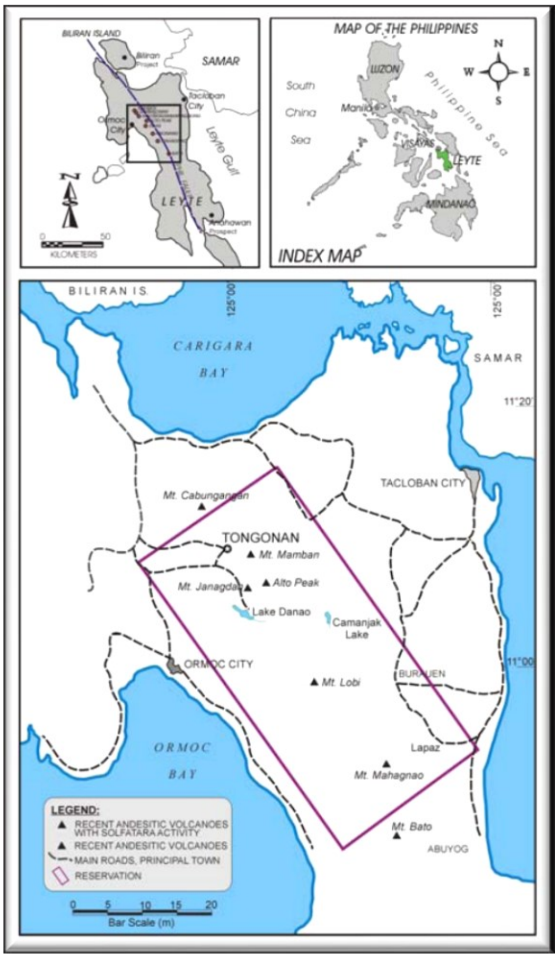

Figure 1: Location Map of the Leyte Geothermal Production Field

The Tongonan geothermal system encompasses four (4) sectors – Upper Mahiao, Tongonan-1, Malitbog and South Sambaloran, over a total resource area of 15km^2. The Tongonan baseline hydrological flow model identified a convective upflow centered in the area bounded by wells in Upper Mahiao and Tongonan-1. Major outflow was identified towards the Malitbog sector and some minor outflows towards the north, northwest and northeast directions in Upper Mahiao. Noteworthy of the field is a natural recharge in the form of a cooler fluid in the eastern region of the Upper Mahiao sector.

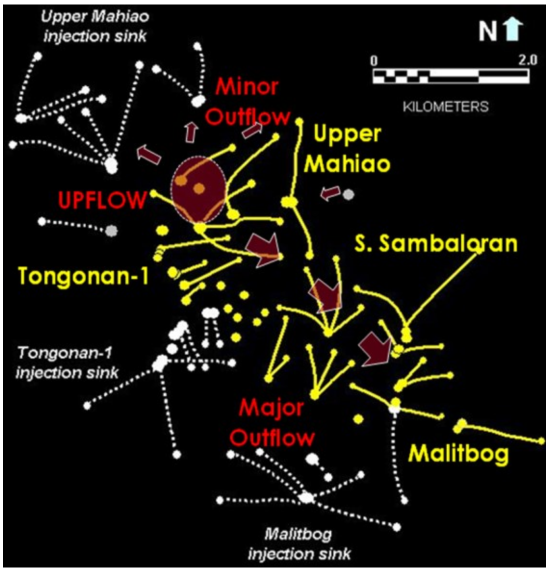

Figure 2: Tongonan Hydrological Flow Model

The experience of LGPF in the geothermal industry has come over from a long journey and can be considered one of the pioneers in this ground. Field surveys started as early as in the 1950's where the Commission on Volcanology completed a geothermal feasibility study that led to conception of the PNOC-EDC in the 1970's, tasked to develop the geothermal resources in the country.

This paper will focus on the journey of the Tongonan resource, where it all began for EDC, making the 30 years of Tongonan-1 Power Plant sustainable production possible – and the rest is history.

2. TONGONAN RESOURCE RESPONSE TO PRODUCTION

Commercial operation in the Leyte Geothermal Production Field started with the commissioning of the 112.5MW Tongonan-1 power plant in 1983. Twelve production wells were initially hooked - up to the system to provide the steam supply requirement of the power plant. Mass extraction in the Tongonan resource further increased with the commissioning of additional power plants - 232MW in Malitbog and 132MW in Upper Mahiao during operational expansion in 1996 to 1997. This also leads to the increase in brine injection to the resource.

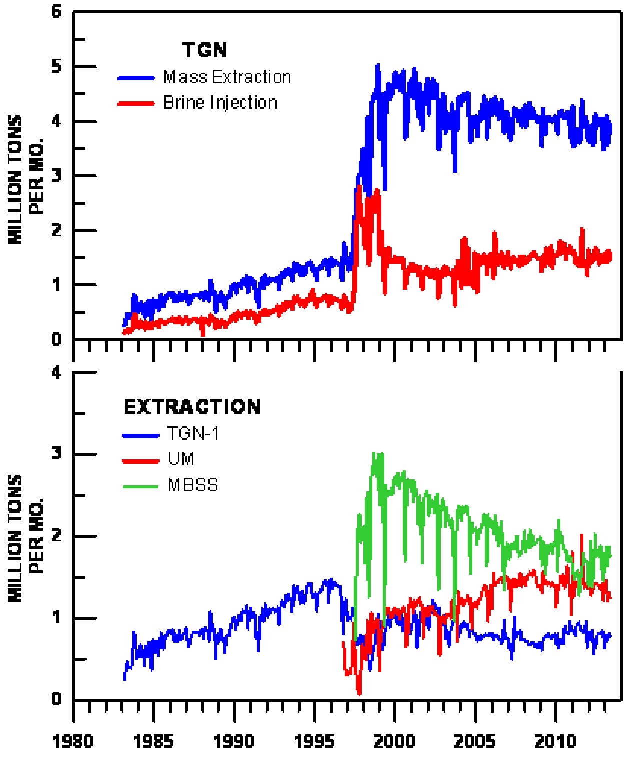

Figure 3: Tongonan Production History

Initial response of the Tongonan field after the start of large-scale production showed a large decline in the reservoir pressure between the periods of 1996 to 2002. Likewise, discharge enthalpy of most production wells across the Tongonan field began to increase, transforming liquid producing zones to highly two phase producers. However, discharge enthalpy declined in dry area encroached with injection returns and is most notably at the wells in proximity to the injection sinks. Injection management strategies were then implemented that stabilized field enthalpy in Upper Mahiao, Tongonan-1 and Malitbog sectors. Also, the drilling of new deep low enthalpy wells affected field enthalpy trends.

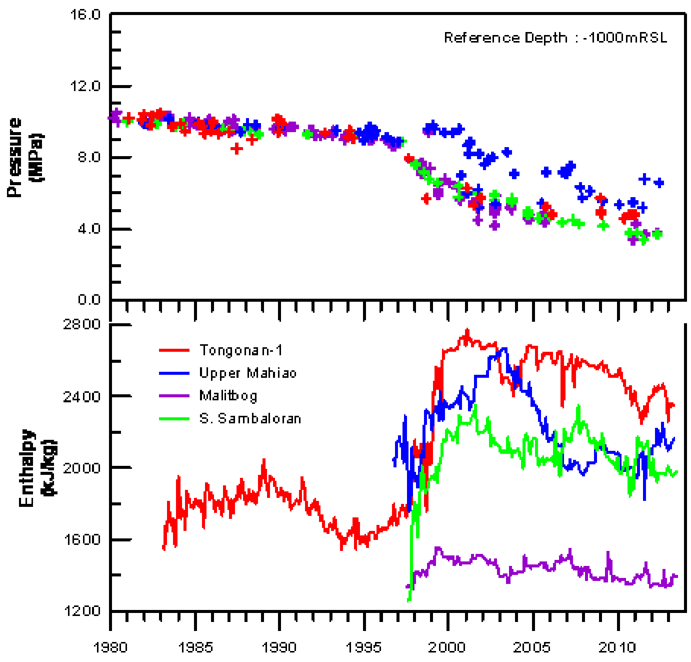

Figure 4: Tongonan Pressure and Enthalpy with Time

The pressure decline during increase in commercial operation resulted to secondary reservoir processes that affected steam supply of production wells with time. These encouraged solids problem – erosion, surface scaling and wellbore blockage. It also enhanced flow of cooler fluids from the outskirt to the production sectors such as brine-condensate returns in the north and groundwater inflow in the east of the Upper Mahiao, brine from Tongonan-1 injection sinks, and groundwater inflow in the east and west of MBSS sectors. Dried wells encroached with brine mists have silica deposition in the formation. Feed or output sharing was also observed in some wells. Feed refers to the source which maybe a fault or structure intersected wherein geothermal fluids enter the well thru the permeable zone/s for production. Feed or output sharing are observed in wells drilled in an area with close distances from each other. Such is the incident in one of the production pads in the Malitbog-South Sambaloran sector wherein after cut-in of a new well, existing online wells showed decline in their output. The observed total decline in output was almost equivalent to the output of the new well suggesting output sharing between the wells in the pad likely due to the high intra-formational permeability and close distances between their permeable zones. While in the Upper Mahiao sector, output sharing was best observed between the two wells in the same pad. During output measurements, the output of one well will decline in an amount equivalent to the increase in the output of the other well, and vice-versa. It was discovered during evaluation that the two wells shared a common structure in the openhole section and were drilled relatively close to each other.

Below is the summary of reservoir process observed in the production wells of the Tongonan geothermal field.

Reservoir Process	Tongonan - 1	Upper Mahiao	Malitbog – South Sambaloran
Silica Scaling	✓	✓	
Solids Problem	✓	✓	✓
Brine Returns	✓	✓	✓
Condensate Returns		✓	
Peripheral Groundwater Inflow			✓
Feed / Output Sharing		✓	✓

Table 1: Summary of Tongonan Reservoir Processes

Hydrological connection between the injection sink and the production sector become apparent in all the Tongonan sectors. Recharge of cooler peripheral fluids has become prevalent in the east of the South Sambaloran and in the eastern section of Malitbog sectors. The western part of the South Sambaloran sector has also exhibited signs of relatively cooler fluid incursion. Another reservoir process which contribute mostly to decline in production well steam flow is possible silica depositions either in the formation or wellbore. Majority of the production wells observed to have this condition are those located in the periphery of "dried-up" zone and injection sink. Silica deposition is enhanced by continuous flashing and casing breaks. Some dry wells began discharging significant suspended solids that caused erosion damage to some FCRS facilities. Cases of mixing production well with dry and watery discharges have caused deposition / scaling along their common branchline.

3. RESOURCE CHALLENGES AND RESOLUTIONS

Resource management in the Leyte Geothermal Production Field is a great challenge given the condition of the reservoir from long term utilization. The major challenges encountered to sustain production are presented as follows,

(1) Steam Availability
(2) Injection Management
(3) Critical Wells
(4) Age Categorization of Wells
(5) M&R Pads Development and Planning

Some management strategies to address these concerns are the implementation of optimization of steam supply distribution to maximize generation, brine injection transfer and conversion/development of non-utilized pads, monitoring of wells considered critical due to casing break and erosive-corrosive nature, and sequencing of future M&R pads developments to be tapped for production. Wells that have been in the service for above 25 years, with already minimal output and poor casing condition, have also been identified for possible replacement of future drilling.

Generating the current temperature contours in Tongonan geothermal field was a challenge since most data from old wells were no longer obtainable due to continuous expansion of the upper two-phase layer and inaccessibility to bottom due to wellbore obstructions such as mineral or casing / liner damage. However, new wells drilled deep in the Tongonan-1 sectors have still tapped the >300°C zone which is within the upflow region of the system. Latest temperature data showed that most of the production wells in the Tongonan sectors are still within the 280°C contour. Temperature declines towards the identified outflows of the resource and temperature dents observed at the injection sinks in Upper Mahiao, Tongonan-1 and Malitbog areas are now more evident.

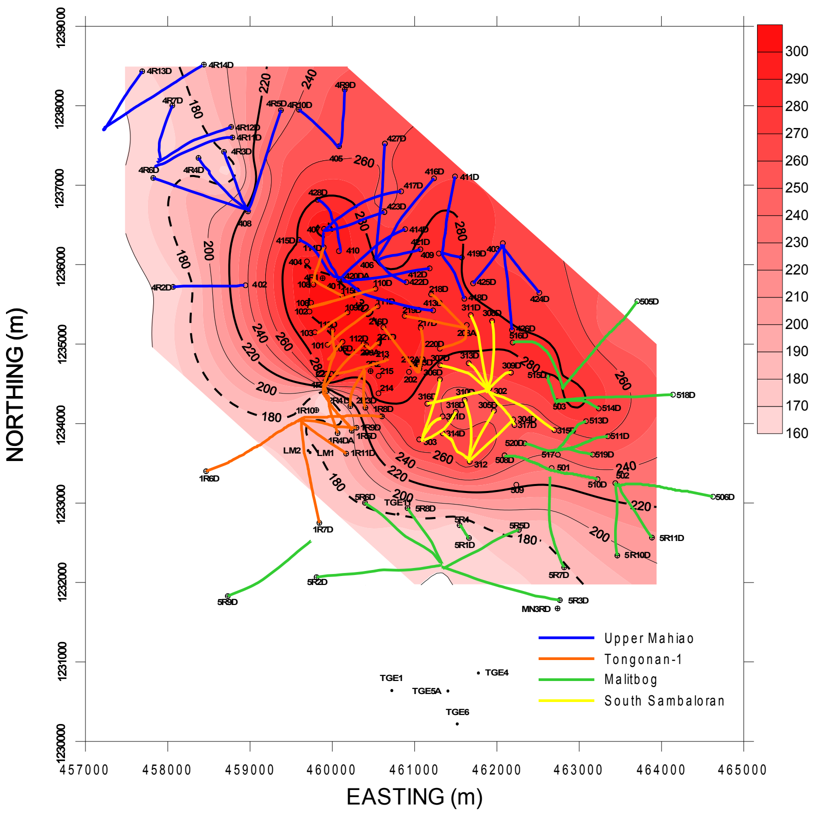

Figure 5: Tongonan Temperature Contour

In the same way, update on the pressure contour has shown lowest downhole pressure at ~5MPa to enclose the central production sectors of Tongonan-1 and South Sambaloran. High downhole pressures are still observed in northern periphery of the Upper Mahiao sector and along Malitbog wells where recharge is available either in the form of injection returns or groundwater inflow.

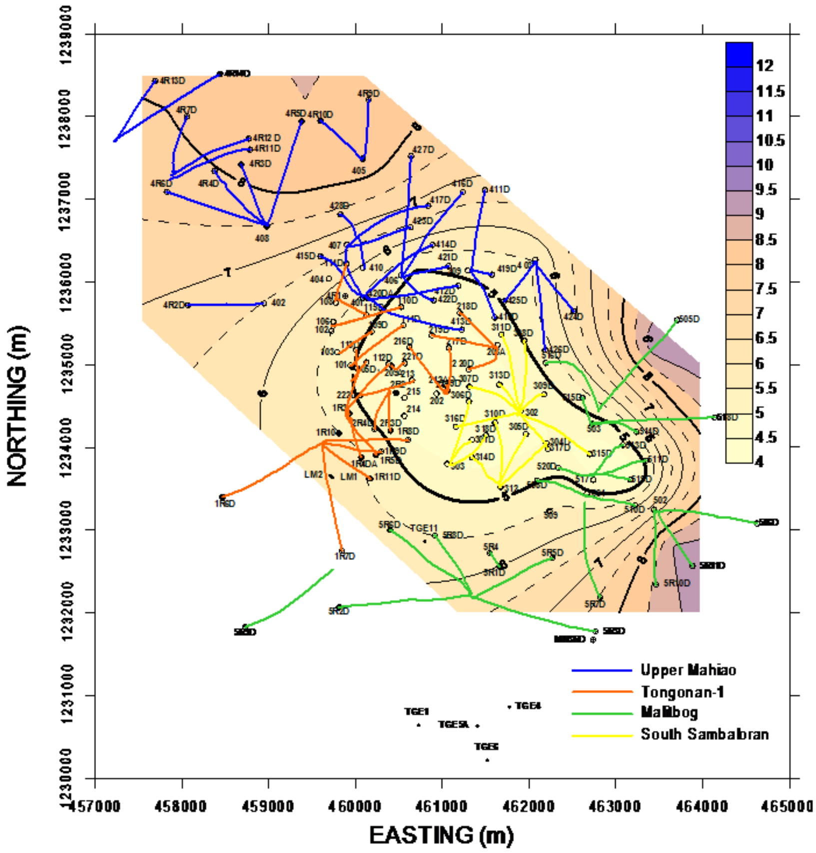

Figure 6: Tongonan Pressure Contour

4. FUTURE OUTLOOK

Continuous extraction and commercial expansion of the Tongonan Geothermal Field resulted to decline in pressure and boiling of the central production field. At the start of utilization of the three sectors, boiling occurred in the reservoir as evidenced by the sudden surge of steam flow as initial response and then followed with a sharp decline. Field-wide extraction has enhanced inflow of peripheral cooler fluids, brine returns and mineral deposition in the drawn-down area which contributed to the steam flow decline. However, the rate of decline was arrested when mitigating measures such as optimized brine loading and strategic injection locations were implemented.

Aside from the strategic injection utilization, drilling of M & R wells and work-over of old wells were also undertaken to sustain steam supply to the power plants. Amongst the latest interventions is the Leyte Steam Augmentation Project (LSAP). LSAP started in 2008 with the aim of drilling 19 production wells and 2 injection wells to replace steam decline and augment steam available. Drilling of LSAP wells with a target output of 105.5MW achieved 98.4% success after obtaining a total of 103.8MW after completion in 2011.

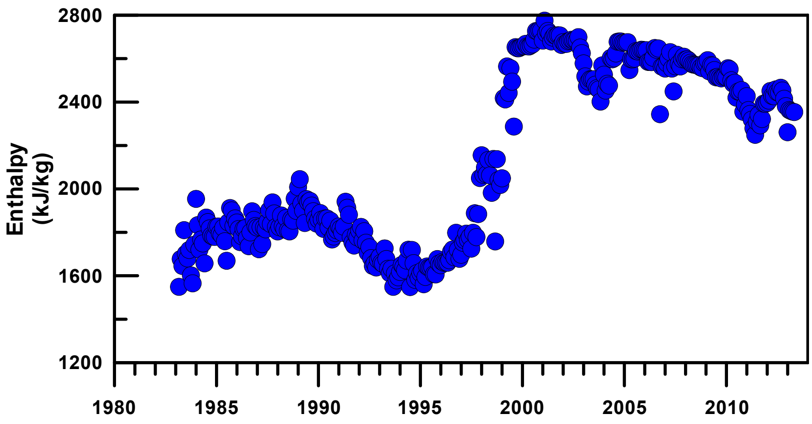

Figure 7: Tongonan-1 Field Enthalpy Trend

In Tongonan-1 alone, the field experienced initial sudden surge in enthalpy during commercial expansion in 1996-1997 due to pressure decline which resulted to initial increase in steam fraction from drying up of the wells. The increase was not sustain due to secondary reservoir processes such as blockages and cooler fluids inflow which in turned decrease the steam production. However, when resource management strategies were implemented beginning of 2002, the Tongonan-1 sector was able to sustain steam supply requirement to the power plant making it operational until now even after about thirty years of utilization.

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