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Field Management Strategies for the 700 MW Greater Tongonan Geothermal Field, Leyte, Philippines

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ABSTRACT

Field management strategies were planned and implemented to support the 700 MW power plant steam requirement from the Greater Tongonan Geothermal Field (GTGF) operated by PNOC Energy Development Corporation. Short to medium term strategies like maintenance and replacement drilling, pipeline construction and development of new sites for both the Tongonan and Mahanagdong fields of the GTGF are implemented. For flexibility and to avail of the excess steam from the other sectors in supplying the five power plants of the GTGF, the steamlines were interconnected through the staged development of a “Steam Highway”.

In north Tongonan (Upper Mahiao), monitoring of potential condensate injection returns through chemical tracing is on-going. Injection wells were converted to production wells and further developed in two stages totaling 40 MW. Idle peripheral wells have been, or are programmed to be, connected. Additional capability from these measures is about 60 MW. In the central sector (Tongonan-1 and South Sambaloran), injection returns causing a decline in six wells will be minimized as injection will be transferred to a well drilled deep (~3000 m) into the resource. An additional 4 MW was gained by converting an injection well into production. Drilling of two wells is also programmed for long-term steam supply. A well drilled deep was targeted towards the less drawndown area. These will provide well replacement and add 35 MW more while arresting output decline due to injection returns. In the south (Malitbog), peripheral injection will disperse brine using an idle well coupled with the ongoing construction of an additional two-km pipeline with silica inhibition incorporated to prevent deposition in the long pipeline and wellbore formation. This will reduce injection returns and output declines in three affected wells. Another deep well to be drilled will provide an additional 8 MW steam capability.

In Mahanagdong, measures included condensate management from Mahanagdong-A plant with the additional construction of a three-km condensate line to the southernmost pad away from the production sector. Brine injection in Mahanagdong-B was also transferred to provide hotter recharge and block the migration of groundwater coming from Paril. A long-term strategy is the development of the Mahanagdong-F block of the resource with five wells programmed for drilling. Initially intended as M&R for Mahanagdong, it may also be a possible source for a 40 MW expansion plant.

1. INTRODUCTION

The Greater Tongonan Geothermal Field (GTGF) is the first and biggest wet geothermal steam field operated by PNOC-Energy Development Corporation (PNOC-EDC). It is located in the island of Leyte in central eastern Philippines, about 600 km southeast of Manila. It occupies 107,625 hectares of a geothermal reservation under a geothermal service contract obtained by PNOC-EDC from the Department of Energy. It hosts two distinct geothermal reservoirs, the Tongonan Geothermal Field (TGF) to the north and the Mahanagdong Geothermal Field (MGF) to the south, separated by the impermeable Mamban block (Fig.1). The TGF has four production sectors, namely: Upper Mahiao in the north, Tongonan-1 and South Sambaloran in the center, and Malitbog in the south; while the MGF has two production sectors, MG-A in the south and MG-B in the northeast. The GTGF derives production from intrusives within the Mahiao Sedimentary Complex through permeable structures mostly from northeast trending faults associated with the Philippine fault line, intersected by some 75 production wells drilled to a depth of between 1,000 to 3,000 m. The separated fluids (brine and power plant condensates) are disposed to 26 injection wells located both in-field and outfield, the latter in the periphery of the geothermal fields.

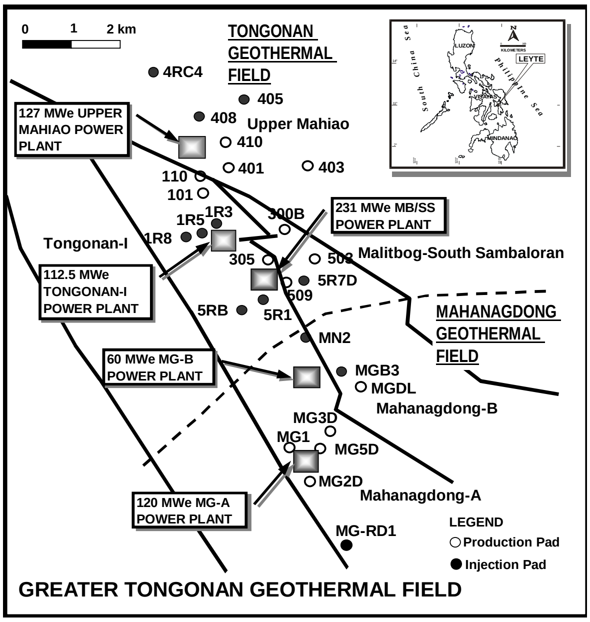

Figure 1: Location map of the Greater Tongonan Geothermal Field (GTGF).

There are five main power plants and four optimization plants generating around 700 MW gross power. It accounts for 60% of PNOC-EDC’s geothermal installed capacity of 1,150 MW and 38% of the entire Philippine geothermal power installed capacity of 1,850 MW. It contributes heavily to the national grid and is the main interconnection supplier to two major Philippine islands, Cebu (through the

Leyte-Cebu; 200 MW) and Luzon (though the Leyte-Luzon; 400 MW) by grid interconnection. In the future, it will also supply the Leyte-Mindanao grid interconnection.

The Commission on Volcanology first explored the TGF in 1952-1972 and, later, with assistance from the New Zealand government. By 1973-1976, exploration drilling was conducted and in 1977, the first geothermal pilot plant (3 MW) was operated. Development drilling ensued and by 1983, the first commercial geothermal power plant (112.5 MW) was commissioned supplying the Leyte-Samar islands. With the Philippines hit by a severe power crisis in 1990, the expansion development of the GTGF went into full swing with the construction and commissioning in 1996-1997 of four main and four optimization power plants under the Build-Operate-Transfer (BOT) scheme. It exports power to bigger electricity consumer islands of Cebu and Luzon through submarine cable wires by generation from the plants listed in Table 1.

Table 1: Power plants in GTGF (703 MW capacity).

Power Plant	Installed Capacity MW gross	Year Commis-sioned	Type
NPC T1PF	112.5	1983	Condensing
UM	127	1996	GCCU
MBSS	232.5	1996/1997	Condensing
MG-A	120	1997	Condensing
MG-B	60	1997	Condensing
Optimization	51	1997	OEC
Total	**703**		

2. GENERATION PERFORMANCE AND FIELD EXTRACTION RATE

The first power plant to operate in GTGF was the Tongonan-1 power plant, which was commissioned in 1983. The 3-unit Mitsubishi turbo-generators has a rated output of 112.5 MW. It generated an annual energy of 150 to 250 GWH in 1983-1984 at a low plant factor of 15 to 25% (Fig.2). It subsequently increased annual generation upon full commissioning in 1985 to 415 to 640 GWH (1985-1996) at a 40 to 65% plant factor. The plant generation was curtailed in 1997-1998 to 420-500 GWH due to the commissioning activities in the four main and four optimization expansion (BOT) power plants. Since 1999 to 2003, it even generated a higher annual energy of 725 to 740 GWH and at a higher plant factor of 65-75%. Since commissioning, it has generated a total of 9,400.3 GWH of energy.

On the other hand, the BOT plants started commercial operations in 1996 first with the 127 MW Upper Mahiao Geothermal Combined Cycle Unit (GCCU) and initially supplying the Leyte-Samar islands. In 1997, the first high voltage submarine cable interconnecting the GTGF grid with the Cebu and Visayas grids was completed. It allowed for the first time the BOT plants to export power to the bigger electricity-consuming islands through the 200-MW capacity Leyte-Cebu interconnection. With the completion of the 400 MW capacity Leyte-Luzon interconnection line the following year, GTGF went full steam, dispatching 850 and 1,820 GWH for Cebu and Luzon, respectively, from its BOT plants (Fig.3). For the next five years (1999-2003), GTGF increased generation annually, dispatching between 850 to 1000 GWH to Cebu and 3000 to 34000 GWH to Luzon. Since commercial operation in 1996, the total energy dispatched from the BOT plants reached 5,650 and 18,230 GWH for Cebu and Luzon, respectively.

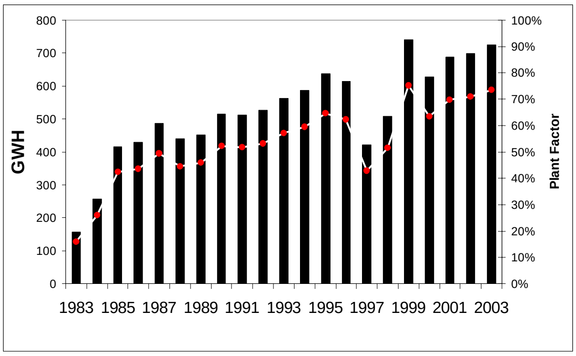

Figure 2: Tongonan-1 annual gross generation history in GWH (1983-2003)

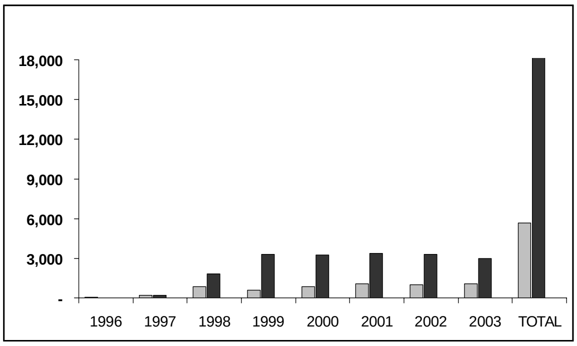

Figure 3: Expansion (BOT) power plants annual energy dispatched in GWH (1996-2003)

To sustain this generation performance, the field extraction rate also increased significantly. Figure 4 shows the production history in the TGF plotted as net fluid mass extracted for the period 1983-2003. With the 112.5 MW Tongonan-1 power plant as sole operating plant, the net mass extraction rate was ~0.5 million tons per month. This significantly increased to ~1.5 million tons per month in 1997-1998 after the commissioning of the 127 MW Upper Mahiao power plant. It further increased to ~2.8 million tons per month starting in 1998 after completion of the Leyte-Luzon interconnection and full commissioning of the rest of the BOT plants. It finally peaked in 2000-2001 at ~3.6 million tons per month with the commissioning of the 60 MW steamline interconnection that allowed the excess steam from TGF to supply the MGF total steam requirement.

3. RESERVOIR PROCESSES AS A RESPONSE TO FIELD EXPLOITATION

Changes in the geothermal reservoir come with the onset of commercial operations. The degree of change depends on the level of production and the ability of the reservoir to replenish itself of the withdrawn mass. In the case of the Tongonan and Mahanagdong geothermal fields, major changes in response to full exploitation started in 1997-1998 with the commissioning of the Leyte-Cebu and Leyte-Luzon grid interconnections. The changes in the reservoir of both fields are discussed in detail below.

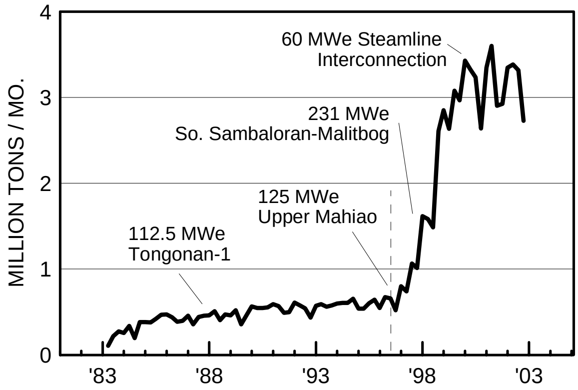

Figure 4: TGF production history (net mass extraction rate in million tons per month).

3.1 Tongonan Geothermal Field Response to Exploitation

The TGF has been exploited for twenty-one years with the initial operation in 1983 of a 112.5 MW power plant. By 1996-1998, the commissioning of new power plants raised the total generation to around 500 MW. By 2000, this increased further to around 550 MW when Tongonan started to augment the steam requirement of the neighboring MGF through a steamline interconnection (Dacillo, 2004; Guillen et al, 2003; Herras and Siega, 2003; Sarmiento, 2000). The increase in generation starting in 1996 brought about rapid changes in the reservoir that are mainly in-response to field exploitation.

The most prominent among the changes in the reservoir is the transformation of the discharge of the production wells, mostly from the central part or near the upflow region, from liquid-dominated to steam-dominated. Most of the wells located in the Upper Mahiao, Tongonan-1 and South Sambaloran sectors incurred sharp increases in enthalpy from 1600-1900 J/g to 2400-2700 J/g. These changes are attributed to the existence of a highly two-phase zone in the reservoir that has expanded as a result of increased production. The immediate effect was the increase in steam availability from these sectors that allowed the excess steam to be transported to the other sectors. The Malitbog sector on the other hand, remained liquid-dominated with little two-phase region forming at the top of the reservoir.

Figure 5 summarizes the secondary reservoir processes that are observed in Tongonan reservoir at present as a result of the fieldwide pressure drawdown. These processes are:

a. Condensate returns from the NW injection sink into the Upper Mahiao production sector when injection of ~300 kg/s power plant condensate started in 2003.

b. Injected brine returns from the Tongonan-1 in-field and Malitbog injection sinks. Although beneficial to the reservoir as it provides recharge, the rate of injection returns was controlled as it can potentially quench the upper two-phase zone in these sectors.

c. Inflow of cooler peripheral waters into the South Sambaloran sector from the southwest and northeast section of the field.

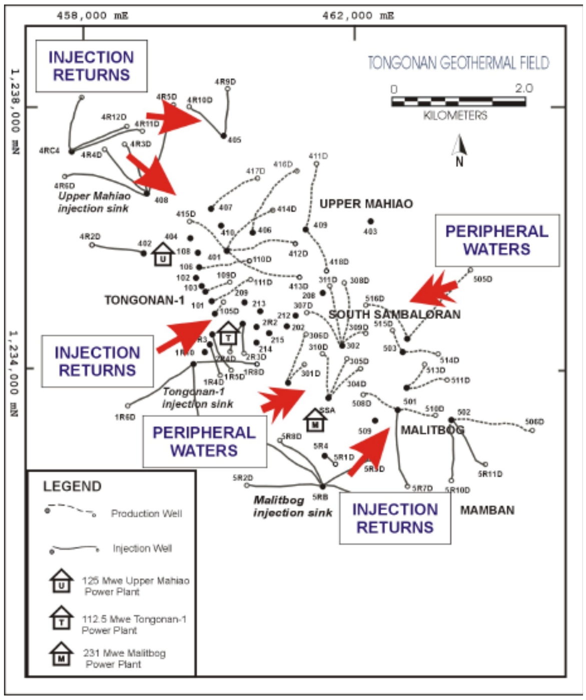

Figure 5: Map of Tongonan field indicating the present reservoir processes.

3.2 Reservoir Processes in Mahanagdong Geothermal Field

The Mahanagdong geothermal field consists of a deep geothermal system (~2000 meters VD) overlain by a shallow cold aquifer at the northwestern part of the field. Within four years of production, the depressurized production sector invited fluids from the over-pressured peripheral areas. These inflowing fluids include the injected brine and condensates from the northern and southern injection sinks and the cooler groundwaters from the northwest (Fig. 6). The entry of these fluids has reversed the increase in fluid enthalpy in some wells and caused fluid temperature declines in others, resulting to constraints in field steam production (Salonga, et al., 2004; Herras and Siega, 2003).

Aside from the entry of cooler, peripheral fluids, MGF has also encountered problems in calcite blockage formation in at least six production wells in the south. The deep fluids of these wells are saturated with calcite and, upon flashing inside the wells the fluids become supersaturated thus forming calcite blockages. Initially, mechanical work-overs were done to clear the calcite blockages, but due to the costs and risks involved, calcite inhibition was considered as a means of maintaining well output.

5. FIELD MANAGEMENT STRATEGIES

The following strategies were implemented to optimize steam availability from various sectors of GTGF.

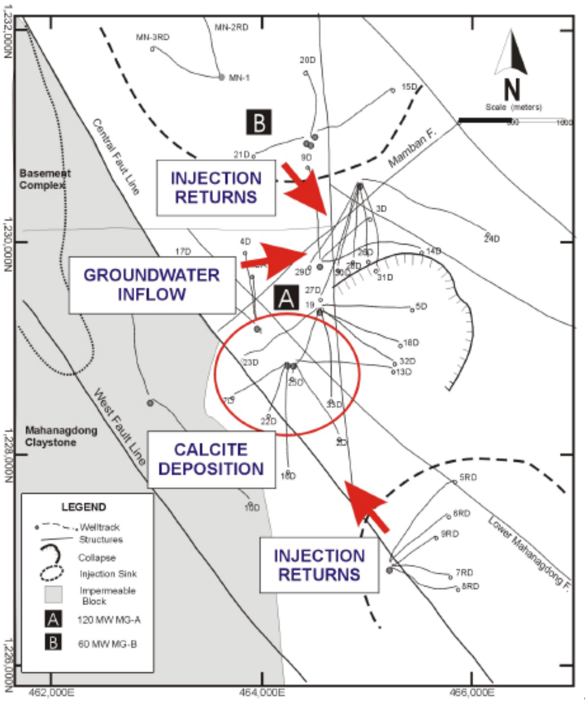

Figure 6: Map of Mahanagdong field indicating the present reservoir processes.

5.1 Steamline Interconnection

The MGF experienced field constraints after four years of exploitation. The combined effects of calcite blockages in production wells, returns of cooler injected brine and power plant condensates, and the incursion of cooler dilute groundwater affected field steam supply. In anticipation of the impact of the entry of cooler fluids from the shallow zone, and the injection returns and mineralization into some production wells, the excess steam available from the TGF was tapped as additional source of steam for Mahanagdong. This necessitated the construction of the 6-km Steamline Interconnection (SLI) pipeline connecting the steam supply from Tongonan to Mahanagdong (Fig.7).

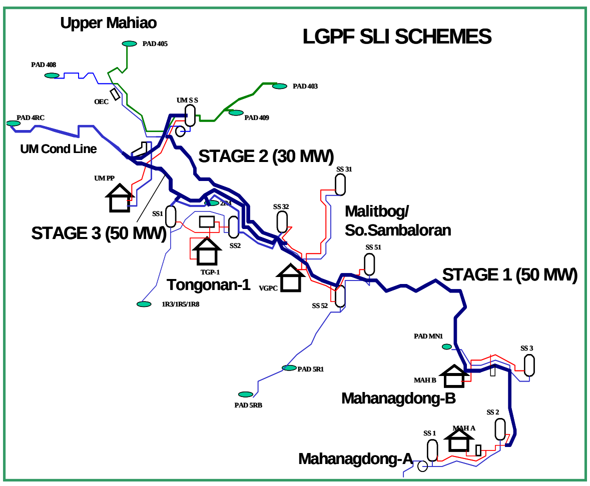

Figure 7: Schematic diagram of the LGPF Steamline Interconnection (Steam Highway).

This "Steam Highway" was developed in 3 stages: Stage 1 linked the Malitbog-South Sambaloran sector to Mahanagdong. Due to the pressure drawdown and expansion of the upper two-phase zone in Tongonan and Upper Mahiao sectors, more steam became available for the SLI. Also, with the reduced brine flow from South Sambaloran sector, 6-km of 20" and 36" brine injection pipelines were optimized by converting them into steam lines. The brine conduit was later transferred to a shorter, newly constructed 18" brine pipeline and the evacuated 20" and 36" brine lines converted to steam lines became the Stages 2 and 3 of the SLI, respectively (Table 2). The commissioning of the SLI allowed GTGF the needed flexibility in supplying steam to the five main and four optimization power plants from the six producing sectors and immediately replenished the steam supply in Mahanagdong. Also, excess steam available from a sector with a power plant on annual preventive maintenance shutdown (PMS) was supplied to the other power plants with on-going work-over in some producing wells or conducting repair and maintenance activities in its fluid collection and recycling system (FCRS). This in effect made the whole GTGF integrated into one of the single biggest geothermal piping network in the world.

Table 2: Steamline Interconnection (SLI) pipelines.

SLI	Year Commis-sioned	Pipeline Capacity (MW)	Sector Supplying Steam
Stage 1	2000	50	UM, T1PF, MBSS
Stage 2	2001	30	UM, T1PF
Stage 3	2003	50	UM

5.2 Injection Wells Conversion to Production

Wells intended for injection but drilled within the production field were later utilized as production wells instead of drilling make-up wells. This saved the company in terms of drilling 5 new make-up wells with a target capacity of 45 MW.

5.3 Utilization of Idle Peripheral Wells

During the development drilling of the TGF, some wells were drilled at the margins of the field to delineate the boundaries of the exploitable reservoir. These were, in turn, not hooked up to the system during the construction of the FCRS because it was then deemed not economically viable to construct long pipelines. With the recent steam and injection capacity requirements, these idle peripheral wells have been programmed to be hooked-up to the FCRS with an estimated capacity of 19 MW.

5.4 Injection Management Strategy

To monitor the effects of the injection brine and cold power plant condensates to the production well or the migration of peripheral groundwater fluids, chemical tracers, downhole measurement and bore output measurements were regularly conducted. This section discusses the injection management strategies formulated and implemented to abate the effects of these undesired reservoir processes.

5.4.1 Chemical Tracing

Tracer tests are conducted to establish flow paths, rate and magnitude of influx of cooler peripheral waters into the producing field. The information obtained from the tracer tests can serve as the basis for implementing injection and production strategies that would respond to the current state of the reservoir and ensure sustainable field production.

In the latest tracer tests conducted in 2003, two tests using Naphthalene Disulfonate (NDS) were conducted in TGF and MGF. For Tongonan, the main objective of the test was to determine presence of possible flow channel from injection wells at pad 4RC4 (Fig.8) to the production sectors of Tongonan. These injection wells were utilized starting January 2003 for the disposal of a large volume of power plant condensates (~300 kg/s) that could be detrimental to field production. Results of the test confirmed the hydrological connection between the injection wells and Upper Mahiao production sector.

For Mahanagdong field, the main objective is to assess the extent, rate and magnitude, as well as the structural channels of groundwater inflow from the west and injected brine and condensate from north and south injection sink. Geochemical investigation has highlighted the adverse effects of these types of inflowing peripheral waters to field steam production. Three types of NDS tracers were injected at three different injection wells, namely: a) MG21D to investigate the returns of hot injected brine from the north injection sink; b) MG5RD to investigate returns of injected brine and condensate from the south injection sink; and c) MG4DA to assess flow path and rate of groundwater inflow from the west section of the field (Fig.8).

Results of the test were able to identify the major structures channeling these waters and the rate and extent of inflow into the production sector of Mahanagdong. Based on the results, optimization of MG21D brine load to the north was recommended to minimize the fast return of brine and at the same time provide pressure support to lessen groundwater inflow to the production sector. In the case of the southern injection sink, it was recommended to optimize loading of other injection wells directed away from the production sector to minimize returns and to allow the injected brine to be reheated before it reaches the production sector.

5.4.2 Power Plant Condensate Injection Management

The Mahanagdong-A (MG-A) power plant condensate injection in MG9D was identified through geochemical monitoring to be one of the causes of the temperature and output decline in well MG3D in MGF. This was evident in the decline in mineralization and temperature based silica geothermometer in the well. It was decided to totally transfer the power plant condensate injection farther to the south in well MG8RD in Pad RD1 (Fig.9). This involved construction of new three-km condensate injection pipeline with installed condensate pumps since the injection pad in RD1 is higher than the MG-A power plant. The transfer of the power plant condensate injection in 2003 away from the production sector resulted in the arrest of temperature and output decline in MG3D and stabilization of its chemistry.

In Upper Mahiao, as a result of the NDS chemical tracing and the observed decline in mineralization in Pad 405 production wells, the power plant condensate injection load (300 kg/s) in wells 4R12D and 4R11D nearest to the production sectors were reduced and transferred to well 4R7D directed away from the production sectors. In addition, the production wells drilled towards the injection sink (4R9D and 4R10D) were either shut or throttled to minimize draw-in of injected power plant condensates.

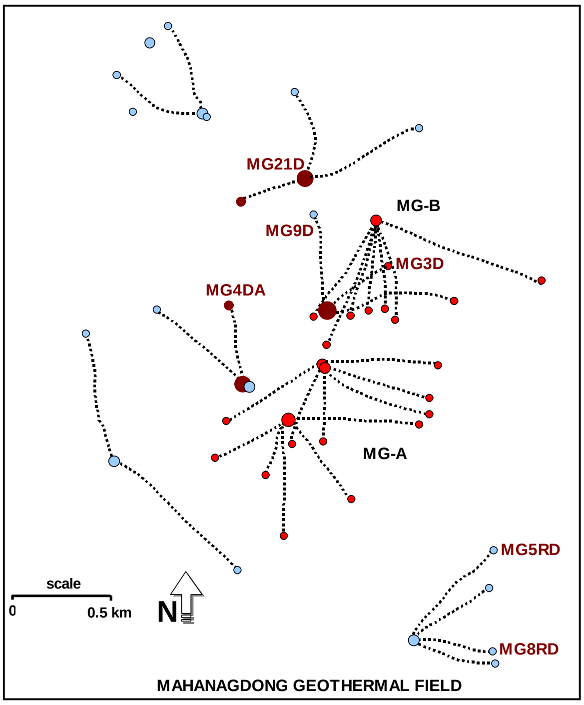

Figure 8: Locations of NDS tracer, brine and power plant condensate injection wells in Mahanagdong.

5.4.3 Brine Injection Dispersion

Brine injection returns were observed to be affecting production wells' output in three sectors, namely (1) in Tongonan-1 from injection well 2R4D, (2) in Malitbog from injection wells 5R1D, 5R4 and 5R7D, and (3) in MG-A from injection wells in Pad RD1.

In Tongonan-1, brine injection returns observed in wells 2R2, 214D and 215D identified through increases in waterflow, output declines and increases in mineralization, will be reduced with the transfer of bulk brine load (230 kg/s) currently injected in wells 2R4D and 1R8D to a well to be drilled deep (~3000 m) into the resource and directed away from the production wells. This hopes to provide sufficient reheating of the injected brine before it returns to the production sector and still provide recharge and pressure support through the in-field injection.

In Malitbog sector, brine injection returns observed in wells 509, 501 and 511D, identified through increases in waterflow, declines in output and increases in mineralization, will also be reduced with the dispersion of bulk of the brine load (275 kg/s) currently injected in wells 5R1D, 5R4 and 5R7D to peripheral wells 5R10D and 5R11D in Pad 502. This will involve construction of a two-km new brine injection pipeline with a silica inhibition system incorporated to prevent silica deposition in the long pipelines and inside the wellbore formation.

5.5 Scale Inhibition

Another major problem that affected steam availability and brine injection capacity is mineral deposition, primarily calcite in MGF and silica in the Malitbog sector of TGF. To prevent recurrence of these problems, scale inhibition technology were developed in-house by PNOC-EDC using calcite inhibitor and brine pH modification (Baltasar, et al, 1997).

5.5.1 Silica Scale Inhibition

Brine injected in Malitbog is oversaturated with respect to silica. As a result, the injection wells have recurring injection capacity declines. Minimal deposition occurring in the surface piping indicated that silica deposition is occurring in the wellbore formation.

Tests using pH modification proved effective in controlling silica scaling at low excess silica in the brine (~ 50 – 120 ppm silica; SSI = 1.10 – 1.18). A pilot set-up mimicking the pipelines and wellbore formation showed that in the brine pH modification test, no silica deposition occurred anywhere in the line. Visual inspections, petrologic analyses, formation weight measurements, flowrate measurements and brine chemistry monitoring were used in the tests. Also, brine pH modification was found to be the most cost effective mitigating solution to silica deposition in Malitbog. The industrial scale installation is due for commissioning in July 2005.

5.5.2 Calcite Scale Inhibition

Past methods of removing calcite blockages to recover well output in Mahanagdong wells is through mechanical clearing using a drilling rig. However, due to the costs and risks involved in conducting periodic mechanical clearing, the use of a chemical inhibitor in preventing recurrence of calcite blockage deposition inside the wells was considered.

A calcite inhibition system (CIS) was installed in two Mahanagdong wells. The CIS basically consists of a surface injection facility for the preparation and injection of chemical solution and a downhole injection facility to allow injection of the chemical solution inside the wellbore of a producing well below the flash point depth (Fig. 9). Based on well output monitoring, the decline rates in terms of total massflow in both wells with installed CIS has been reduced significantly from an average of 4.0 kg/s-month to less than 0.5 kg/s-month.

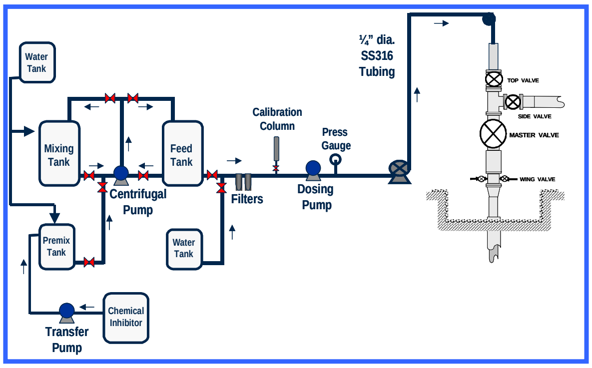

Figure 9: Schematic diagram of the calcite inhibition system (CIS) installed in Mahanagdong wells.

5.6 Well Work-Over and Acidizing

One of the major problems encountered in geothermal field operation is solid deposition inside the well casings or in the reservoir formation. The most common of these solid deposits are calcite and silica scales. The problems caused by these scale deposits are associated with changes in the production of the wells due to flow restrictions and subsequent reduction in well output. If mineral deposition occurred in the production casing or slotted liner only, the well is subjected to basic mechanical clearing to remove the blockage and recover its output or injection capacity. In TGF and MGF, typical work-over operations involves only mechanical clearing of blockages in which, most of the time, recoveries of at least 90% of the well's output resulted. Table 3 shows some of the wells worked-over and the changes in their output before and after the work-overs.

Table 3 Summary of production wells worked-over due to mineral blockage.

Well	Original Capacity (MW)	Pre-WO Output (MW)	Post-WO Output (MW)
110D	14.0	1.7	12.3
111D	17.4	2.6	10.6
MG-1	6.7	2.9	5.1
MG-19	8.6	5.2	8.3

In cases where decline in output or injection capacity of a well is due to deposition of a mineral blockage in the production zone or reservoir formation, work-over with acidizing is usually conducted. A good example is the case of wells 5R1D and 5R4, which accepts most of the waste brine injection load in Malitbog sector of Tongonan field. In just a short time of utilization, these wells showed drastic declines in the injection capacity. Geochemical assessment attributed this to silica deposition in and around the wellbore which caused a reduction in formation permeability and consequently in the injectivity of the well. As an immediate solution to this problem, periodic work-over and acidizing operations were conducted in these wells in order to recover their injection capacity. Table 4 summarizes the extent of injection capacity recovered after the work-over and acidizing.

Table 4: Injection capacity of wells 5R1D and 5R4.

Well	Previous Measured Capacity (kg/s)	Pre-WO/ Acidizing Capacity (kg/s)	Post-WO/ Acidizing Capacity (kg/s)
5R1D	123	44	137
5R4	160	76	201

There are instances wherein acidizing is conducted to open up production zones damage by mud during drilling. There are also cases wherein the decline in output or capacity is due to casing damage. Work-over and casing relining is usually conducted to address this problem and recover the well's output or injection capacity.

5.7 M&R Well Drilling at Existing Production Sector

In order to maintain the required steam supply for the power plants, M&R drilling within the existing production sectors was considered. The major advantage of this scheme is that the newly drilled wells can be readily connected to the existing FCRS pipelines and separators. This will also be a stopgap option to sustain production, considering the current state of the reservoir, while waiting for the completion of the development of expansion areas. A two-prong approach has been considered in M&R drilling within the exiting production sector. These are the deep well and shallow well drilling.

Deep well drilling aims to tap the liquid zone believed to still exist at deeper section of the Tongonan reservoir. Evaluation of dry steam discharges in TGF wells through the use of gas equilibria method has shown that the original two-phase zone has expanded both laterally and vertically, with the depth of boiling occurring now at a much deeper level. In the periphery of the field, this assessment has been confirmed geochemically through wells still having liquid discharges. Production at the deeper levels of the reservoir remains to be tested and is expected to increase the steam reserve of the field.

Shallow well drilling was also considered, the objective of which is to produce from the shallow untapped two-phase zone of the TGF. This shallow two-phase zone has already existed at the central part of the Tongonan field even before exploitation Two shallow wells were programmed for drilling within the year. Major consideration in the well design of the shallow wells is the limitation of structural intercepts with target azimuths directed to lower production density areas to minimize drilling interference and feed sharing with adjacent wells.

5.8 Expansion Drilling

In the Mahanagdong sector, additional areas remain untapped because of the use of the SLI from Tongonan and Upper Mahiao. However, in the long term, Mahanagdong needs to get its additional supply from its own reserve which are available to the east called MG-F (Fig.10) and the currently utilized injection sector in pad RD1. The injection wells have high temperatures at depth (260-280^{o}C) and is estimated to contribute 40 MW when converted to production wells. If the area to the east proves successful, development drilling for future expansion plants may be considered.

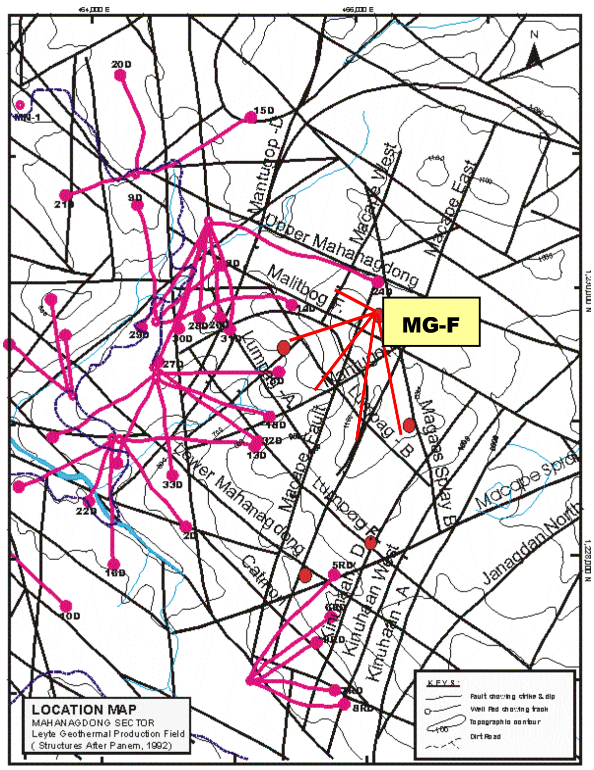

Figure 10: Location map of the Mahanagdong Geothermal Field and the MG-F expansion sector.

In Tongonan, the area to the north of Pad 4RCR is currently being surveyed to locate farther injection pads in case the power plant condensate injection in pad 4RCR proves detrimental to the sustainable production of Pad 405 and in the central production sector of Upper Mahiao. The easternmost pad where well 403 is located is also envisioned to become a step-out drill pad location for further exploring the eastern margins of exploitable resource in Tongonan.

6. SUMMARY

Field management strategies were formulated and implemented in the Greater Tongonan Geothermal Field to optimize the available steam from the entire field and ensure full production of 700 MW geothermal power generation facilities. With the turnover of ownership of the expansion (BOT) power plants to PNOC-EDC in the near future, PNOC-EDC management plans to optimize utilization of these geothermal resources. A good prospect also in the future is the expansion drilling of sectors of the geothermal reservation outside of the currently exploited area.

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