MakBan Drilling Campaign Offset Wells Monitoring and Post Drilling Production Evaluation

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ABSTRACT

A recently completed drilling campaign at the Mak-Ban Geothermal Field, Philippines (the 2021-2022 Mak-Ban Steam Production Enhancement Campaign – MB SPEC) targeted production from the deep reservoir to provide steam for the existing powerplants. The campaign included nine production wells and two injection wells, using existing active wellpads. The welltracks of the MB SPEC wells were in close proximity to active wells so there was a need for a proactive approach to monitor the drilling impact and mitigate the potential migration of drilling fluids and cement to the nearby offset wells. The Mak-Ban Resource Management Team developed an offset wells monitoring plan as a guide for recommending whether to shut-in offset wells during the drilling operations and to minimize associated generation losses.

Aerated drilling fluid with bentonite and polymer were used during the drilling operations. As a general rule, when bentonite was used, all offset wells within a radius of 300 ft of the welltrack were proactively shut-in to mitigate the risk of plugging the permeable zones. When polymer was used or when the offset wells were within 300 to 800 ft, a reactive shut-in approach was implemented based on the geochemical parameters that would suggest possible interference. During cementing, all offset wells within 800 ft were proactively shut-in.

The original plan was to have the steam and condensate samples from the offset wells to be analyzed for total %NCG by Wet Test Meter (WTM), Normal Gas Analysis (NGA), Total Suspended Solids (TSS) and pH. For brine samples, pH, Cl and Mg were initially planned to be analyzed. However, the monitoring plan was simplified only for the parameters with the quickest analysis turnaround time which were total %NCG and Cl. Offset wells were shut-in when the parameters increased above threshold values.

The offset well monitoring plan was deemed successful as it was able to help prevent the potential breakthrough of drilling fluids and cement in offset wells. The equivalent of up to 24.5 MWe production from the offset wells was preserved after the end of the campaign and the preventive offset wells shut-in losses were reduced to 16 GWh actual from the planned 34 GWh.

1. INTRODUCTION

1.1 Mak-Ban Steam Production Enhancement Campaign

The Makiling-Banahaw (Mak-Ban, also known as Bulalo) Geothermal Field is located in the Luzon Island of the Philippines. The discovery well, Bul-01, was drilled in 1974 and commercial production began in 1979 (Capuno et al., 2010). To date, 124 wells have been drilled to measured depths ranging from 2,150 ft to 11,889 ft to support the production and injection capacity requirements.

The commercial production of the Mak-Ban Geothermal Field for over 40 years has resulted in an associated reservoir production decline, which is typical across different commercial geothermal fields. Over the years, several drilling campaigns have been executed in Mak-Ban in order to expand the field's operations and to sustain the steam supply requirements of the powerplants.

The Mak-Ban Steam Production Enhancement Campaign (MB SPEC) was the most recent drilling campaign that was executed in 2021-2022. The campaign included nine production wells with the objective of tapping and developing the deep reservoir to augment the steam supply to the powerplant units plus two injection wells to accommodate the additional hot brine. Mak-Ban's production area is relatively small compared to other geothermal fields which presents a challenge in drilling new wells in terms of wellhead and welltrack spacing.

The MB SPEC intended to target the three known upflows and hotspots in the Mak-Ban Geothermal Field (as shown in Figure 1). The Northwest Hotspot is an area with high temperature, but with relatively lower permeability than the other sectors. There are two major wells (1C-4 and 1C-5) in this sector that have stable production, most of which is coming from the deep reservoir. The second target sector is the Central Upflow, which is also identified historically as the "sweet spot" and is considered to be the primary recharge zone for Mak-Ban. The third target sector is the Southeast Upflow, which is known to be connected to the Central Upflow as they have the same magmatic source as confirmed by the isotopes (Mak-Ban SPEC Drilling Program, 2019).

In addition to the permeability associated with the upflows or hotspots, other sources of permeability in the deep reservoir are the silicic units, which were identified in gamma ray (GR) logs from the other Mak-Ban wells. Silicic units, which are interpreted as intrusions, have high GR response as observed in the wells drilled in the central and northwest area of the field.

One of the key challenges in the Mak-Ban Geothermal Field is the downflow associated with shallow recharge that suppresses the production from the deep reservoir. It was determined that the shallow recharge enters through the feedzones at the shallow reservoir and flows down into the deep feedzones. The shallow and deep reservoirs are separated by a tight semi-permeable barrier which is referred to as the Andesite Lava Marker (ALM). The presence of this barrier explains the differential pressure that drives the shallow recharge downflow to occur (Sunio et al., 2015).

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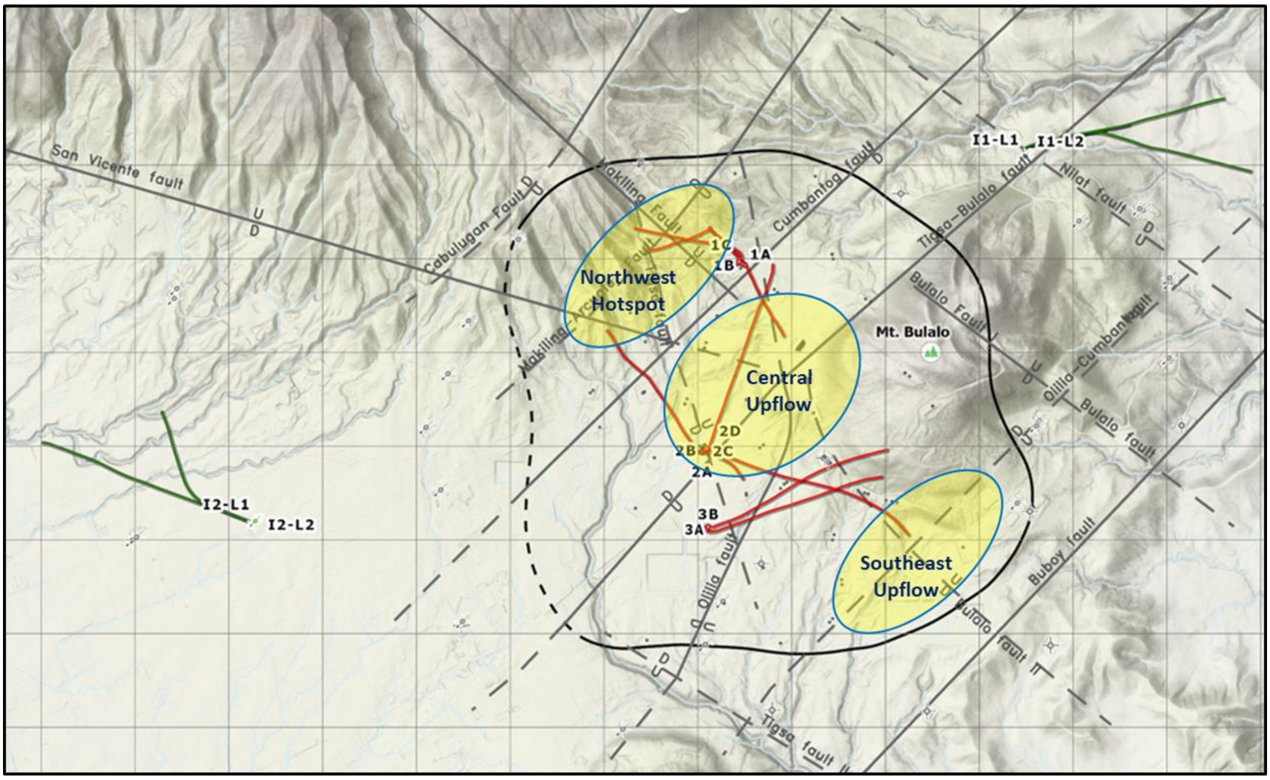
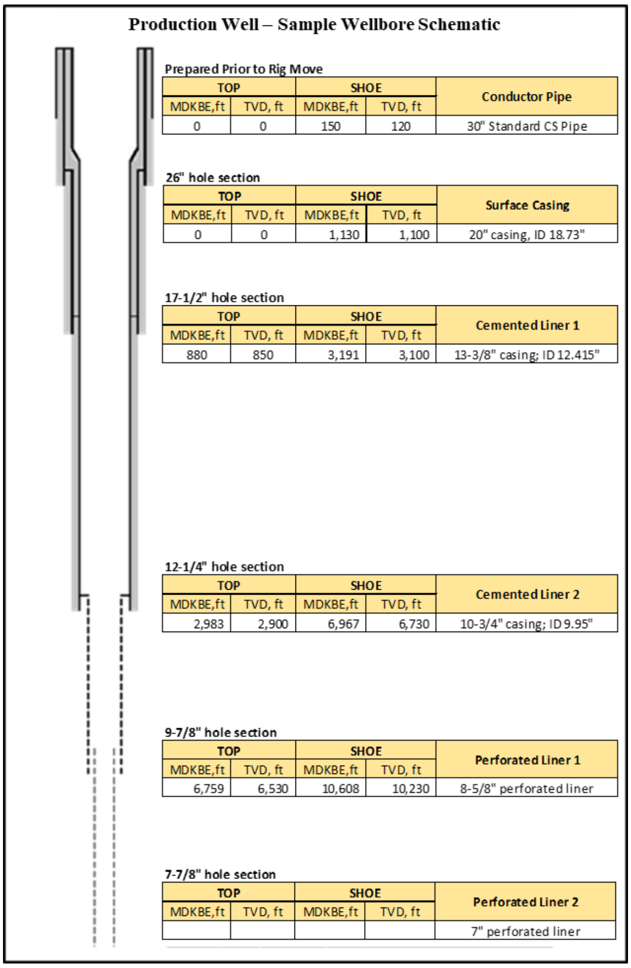


Figure 1: MB SPEC welltracks and target sectors



Prepared Prior to Rig Move

TOP		SHOE		Conductor Pipe
MDKBE,ft	TVD, ft	MDKBE,ft	TVD, ft	
0	0	150	120	30" Standard CS Pipe

26" hole section

TOP		SHOE		Surface Casing
MDKBE,ft	TVD, ft	MDKBE,ft	TVD, ft	
0	0	1,130	1,100	20" casing, ID 18.73"

17-1/2" hole section

TOP		SHOE		Cemented Liner 1
MDKBE,ft	TVD, ft	MDKBE,ft	TVD, ft	
880	850	3,191	3,100	13-3/8" casing; ID 12.415"

12-1/4" hole section

TOP		SHOE		Cemented Liner 2
MDKBE,ft	TVD, ft	MDKBE,ft	TVD, ft	
2,983	2,900	6,967	6,730	10-3/4" casing; ID 9.95"

9-7/8" hole section

TOP		SHOE		Perforated Liner 1
MDKBE,ft	TVD, ft	MDKBE,ft	TVD, ft	
6,759	6,530	10,608	10,230	8-5/8" perforated liner

7-7/8" hole section

TOP		SHOE		Perforated Liner 2
MDKBE,ft	TVD, ft	MDKBE,ft	TVD, ft	
				7" perforated liner

Figure 2: MB SPEC production well diagram

To prevent the downflow from entering the wellbore, the drilling strategy for all the MB SPEC production wells is to case off the shallow reservoir until the ALM and set the perforated liner all the way down to the target depth to produce solely from the deep reservoir. The shallow reservoir is cased off by a 10-3/4” cemented casing with the shoe set within the ALM, and an 8-5/8” perforated liner is set until the target depth. There is also a plan for 7” perforated liner contingency to increase the chance of success that the well will reach the planned target depth. A sample wellbore schematic diagram of the MB SPEC production wells is shown in Figure 2.

1.1.1 First Batch of MB SPEC Wells

The first batch of the MB SPEC wells in Mak-Ban included three production wells (SPEC-1A, SPEC-1B and SPEC-1C) which were drilled at Wellpad-01 as shown in Figure 3. These wells were drilled in sequence, with SPEC-1A targeting the Central Upflow while both SPEC-1B and SPEC-1C are targeting the Northwest Hotspot. They were also aimed to target the silicic units that were observed from other offset wells in the target sectors. The other two existing wells on the pad (1C-1 and 1C-3) are both active wells.

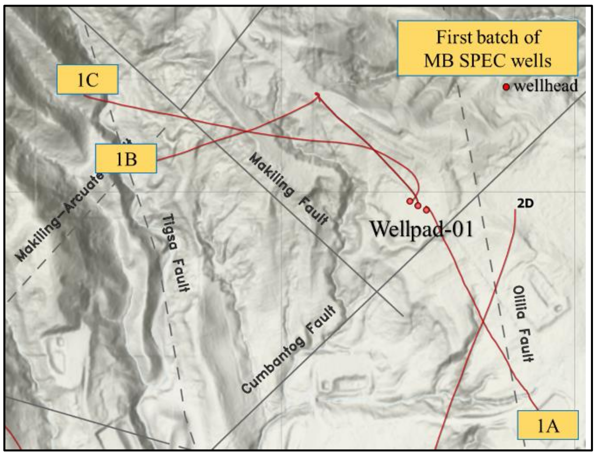


Figure 3: First batch of MB SPEC Wells

1.1.2 Second Batch of MB SPEC Wells

The second batch of MB SPEC wells were drilled at Wellpad-02, which included SPEC-2A, SPEC-2B, SPEC-2C and SPEC-2D (as shown in Figure 4). These wells were drilled in sequence with different intended target sectors. SPEC-2A targeted the Northwest Hotspot and the deep permeability observed from the offset wells. SPEC-2B and SPEC-2D both targeted the Central Upflow, with the latter also aiming to intersect the Olilia North Fault. Meanwhile, SPEC-2C targeted the Southeast Upflow with the objective of intersecting Bulalo II fault as well.

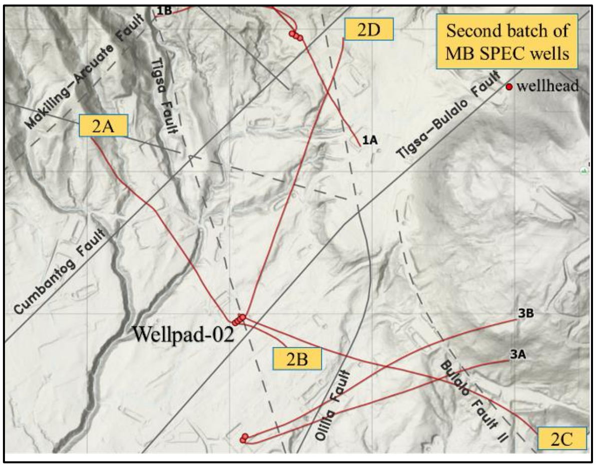


Figure 4: Second batch of MB SPEC Wells

1.1.3 Third Batch of MB SPEC Wells

The third and last batch of MB SPEC production wells included SPEC-3A and SPEC-3B which were drilled at Wellpad-03 as shown in Figure 5. SPEC-3A targeted the Southeast Upflow and aimed to intersect the Bulalo II fault. Due to good indications of permeability from SPEC-3A targets, SPEC-3B welltrack was also directed towards the Southeast Upflow/Central Upflow and with the similar intent of intersecting Bulalo II fault.

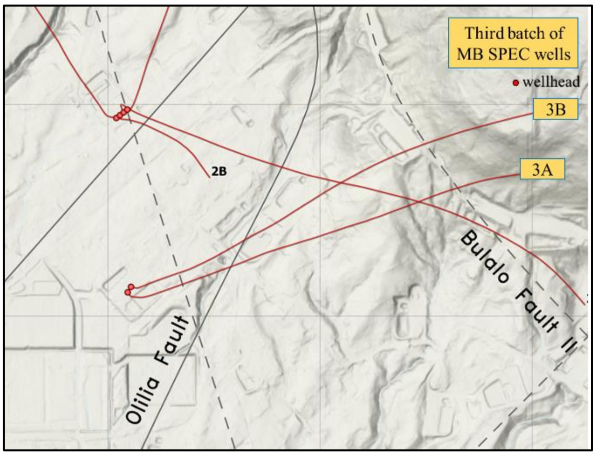


Figure 5: Third batch of MB SPEC Wells

1.1.4 MB SPEC Injection Wells

After the first batch of MB SPEC production wells were completed, the rig moved to Wellpad-I1 for the drilling of the first injection well (SPEC-I1) under the MB SPEC program as shown in Figure 6. This injection well is a multilateral with two legs to increase the hot brine injection capacity in the east sector of the field to accommodate the brine from the first batch of MB SPEC production wells.

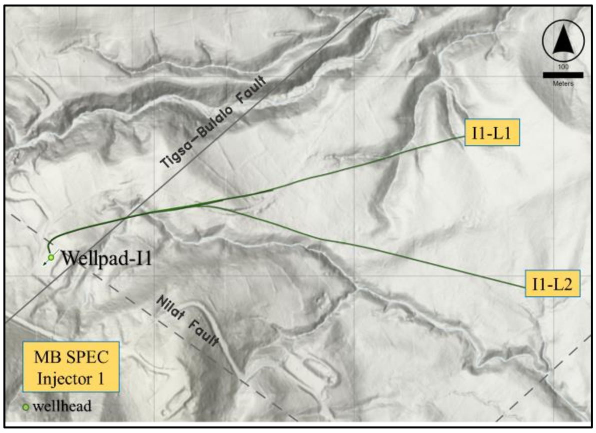


Figure 6: SPEC-I1 Leg 1 and Leg 2 welltracks

The second injection well in the campaign is SPEC-I2 which is located at Wellpad-I2 as shown in Figure 7. SPEC-I2 is also a multilateral well with two legs and was drilled after the completion of the second batch of MB SPEC wells. This injector was drilled to provide additional injection capacity in the west sector of the field to accommodate the additional brine from the remaining MB SPEC production wells.

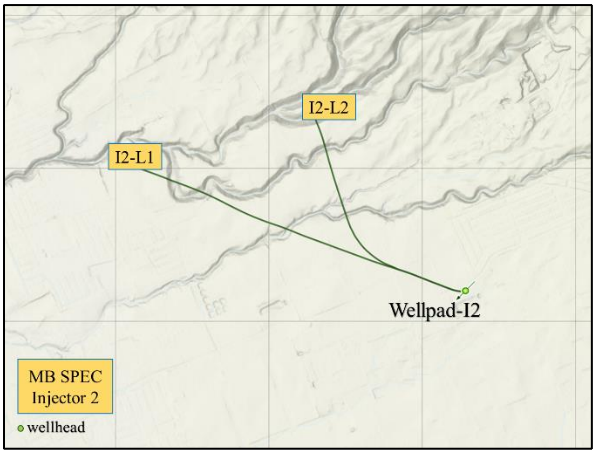


Figure 7: SPEC-I2 Leg 1 and Leg 2 welltracks

1.2 Offset Wells Monitoring Objectives

The nine production wells and two injection wells included in the MB SPEC campaign were drilled from existing wellpads and satellite stations due to space constraints and to optimize the use of existing facilities. This introduced a challenge both on the surface (tight wellpad spaces) and subsurface (well collision and interference). The tight wellpad space was managed by having good coordination among all the work groups involved with the drilling activity, and the well collision was addressed by having an anti-collision analysis for each well in the campaign.

The potential subsurface interference while drilling was addressed by having a monitoring program in place before drilling each of the MB SPEC wells. Since the MB SPEC wells were drilled from existing wellpads, the active offset wells can be within 300 ft radius in terms of proximity.

The offset wells monitoring program had two major objectives. The first is to mitigate the migration of drilling fluids and cement to active production wells that could be detrimental to base production. The second is to minimize the associated generation losses by reducing the downtime of the offset wells. Thus, striking a balance in achieving both objectives seems challenging but still manageable.

The monitoring programs for the MB SPEC injection wells (SPEC-I1 and SPEC-I2) are out of scope of this paper, as these were not as comprehensive as for the production wells in the campaign. The MB SPEC injection wells are located away from the production area (as shown in Figure 1) to mitigate the potential cooling effects of injection fluids to the reservoir, while still providing mass recharge to the geothermal reservoir.

2. MB SPEC OFFSET WELLS

2.1 Offset Wells Selection and Radius of Monitoring

There were uncertainties on the travel time of the drilling fluids and cement to the offset wells, so the monitoring team initially identified arbitrary radii of 300 ft and 300-800 ft for monitoring. These arbitrary distances were tested in the first batch of MB SPEC wells and were then applied in the succeeding wells to simplify the monitoring program.

The team also defined a *"proactive approach"* and *"reactive approach"* for geochemical monitoring and shut-in plans based on the drilling fluid and the proximity of the offset wells to SPEC welltrack. This is summarized in Table 1.

Offset wells distance	Drilling fluid		Cement
	Bentonite	Polymer	
Within 300 ft	Proactive	Reactive	Proactive
>300 ft, <800 ft	Reactive	Reactive	Proactive
>800 ft	No action taken		

Table 1. Reactive and proactive approach for the arbitrary radius of monitoring

The drilling fluid strategy for the MB SPEC wells was to use aerated drilling for all the hole sections of the well. Aerated bentonite of varying mud weights was used for the shallow hole sections while polymer was used in the deep hole sections to maintain the required viscosity. In order to avoid any feedzone damage of the offset wells from fluid migration, a proactive shut-in approach for the offset wells was conducted when the drilling fluid has bentonite *(either pure or aerated)* and if the offset well is within 300 ft. Bentonite does not degrade easily even at high temperatures, and may cause formation damage by plugging the permeable zones of nearby offset wells (Chemwotei, 2011). A reactive shut-in approach based on geochemical data was implemented if the radius is within 300-800 ft and if bentonite was being used as drilling fluid.

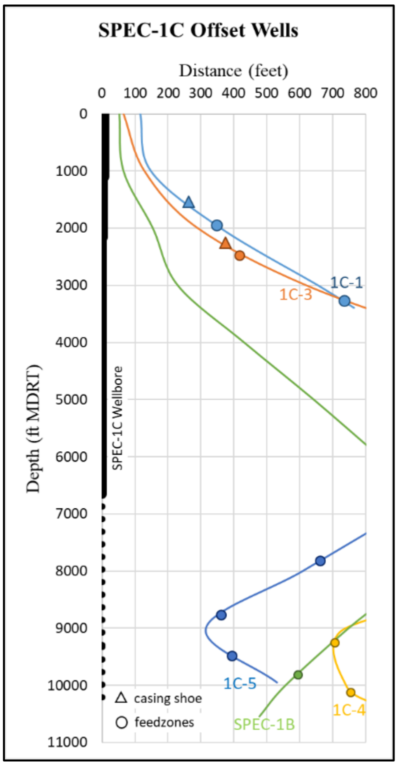


Figure 8: SPEC-1C Offset Wells

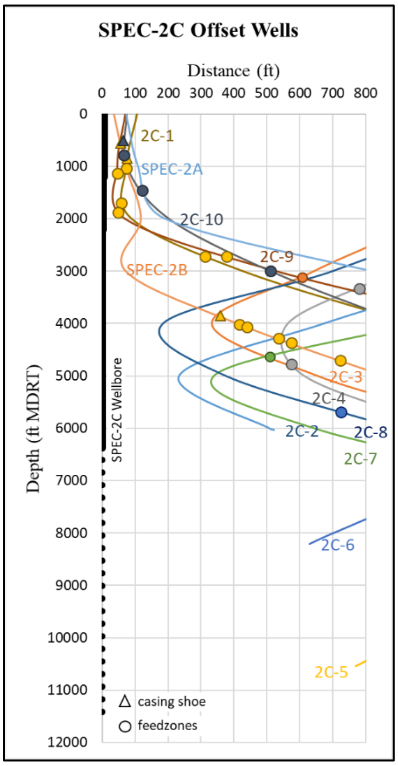


Figure 9: SPEC-2C Offset Wells

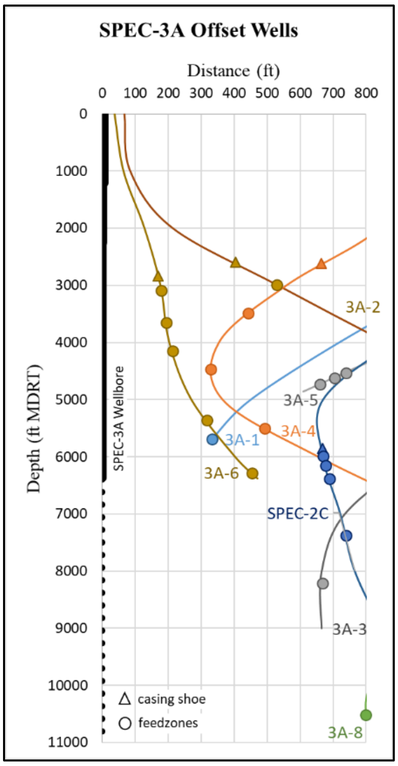


Figure 10: SPEC-3A Offset Wells

On the other hand, if polymer is used, a reactive approach was implemented based on the identified offset wells geochemistry data, regardless of the radius. During cementing, a proactive approach for shut-in of all the offset wells within 800 ft radius was implemented.

In terms of sampling frequency, a reactive approach entailed that samples should be taken onsite every 2-4 days, with analysis available on the same period for the parameters with quick turnaround time. No sampling activities during proactive approach as the offset wells are automatically shut-in.

Another optimization that was implemented by the team later in the campaign is that offset wells with marginal production within the monitoring radius were shut-in for the entire drilling operations to maximize focus of the monitoring activities on the big production wells.

2.2 MB SPEC First Batch Offset Wells (SPEC-1C)

As mentioned in Section 1.1.1, the first batch of MB SPEC wells included SPEC-1A, SPEC-1B, and SPEC-1C. For this paper, SPEC-1C was chosen from the first batch to show the proximity of the offset wells relative to its welltrack which is directed towards the Northwest Hotspot. For visualization purposes, as shown in Figure 8, the simplified wellbore schematic of SPEC-1C is also included in the plot to show the casing section (solid black line) and the perforated liner (dashed line).

The critical radius of monitoring is within 300 ft and the secondary monitoring radius is 300-800 ft. At the shallow section (until ~2200 ft), 1C-1 and 1C-3 are all within 300 ft radius because these wells are located in the same wellpad. The liner section of 1C-1 and 1C-3 started at 1,543 ft and 2,261 ft respectively (relative to SPEC-1C's depth). 1C-1 was monitored by proactive approach in the 17-1/2" hole section, and was changed to reactive approach from 12-1/4" hole section (same with 1C-3). SPEC-1B is also nearby in the shallow sections but was not monitored because it was cased off until ALM.

The offset wells that were monitored by reactive approach in the deep 9-7/8" hole section were 1C-4, 1C-8 and SPEC-1B. There was no strong evidence that the offset wells were affected by the drilling activities based on the geochemical data which is discussed in detail in Section 3.

2.3 MB SPEC Second Batch Offset Wells (SPEC-2C)

The wells included in the second batch of MB SPEC are SPEC-2A, SPEC-2B, SPEC-2C and SPEC-2D (as discussed in Section 1.1.2). These wells were drilled at Wellpad-02, located in the middle of the Mak-Ban Geothermal Field, and so entailed monitoring several active production wells.

SPEC-2C was chosen for discussion in this paper to show the proximity of the offset wells relative to its welltrack, which is directed towards the Southeast Upflow. For visual purposes, the simplified wellbore schematic of SPEC-2C is shown in Figure 9 with the casing section (solid lines) and perforated liner (dashed lines) included.

The offset wells located in the same wellpad for critical monitoring are 2C-9 and 2C-10, as these are within the 300 ft critical radius. The other wells on the wellpad were not monitored. These include 2C-1 which is an idle well and was kept shut-in, and SPEC-2A and SPEC-2B, which are the newly-drilled MB SPEC wells on the pad and have deep casing.

Most of the offset wells were nearest to SPEC-2C's welltrack in the 12-1/4" hole section from 2,205 ft to 6,364 ft. The offset wells within 300 ft, which were proactively monitored are 2C-2 and 2C-8. The other offset wells in the 300-800 ft radius included 2C-3, 2C-4, 2C-7 and 2C-8. For the last hole section (9-7/8"), only two wells were monitored reactively and these are 2C-5 and 2C-6. The results of the geochemical monitoring from SPEC-2C offset wells are presented in Section 3.

2.4 MB SPEC Third Batch Offset Wells (SPEC-3A)

The third batch of MB SPEC wells was drilled from Wellpad-03, and includes SPEC-3A and SPEC-3B (as shown in Figure 10). For the discussion in this paper, SPEC-3A was chosen to illustrate the offset wells relative to its welltrack which is directed towards the Southeast Upflow and Bulalo II fault.

The other wells in the wellpad which are within the 300 ft critical radius were not monitored. 3A-6 is an idle well which ceased to flow several years ago. On the other hand, 3A-2 is a marginal producer and was recommended to be shut-in instead as the losses would be very minimal. This decision simplified the monitoring process during the drilling of the 26" and 17-1/2" hole sections until 2,250 ft.

At the 12-1/4" and 9-7/8" hole sections, there are no wells within the 300 ft radius for proactive monitoring. There are several wells in the secondary monitoring radius of 300-800 ft for reactive monitoring. These wells are 3A-1, 3A-3, 3A-4, 3A-5, 3A-7, 3A-8 and SPEC-2C. The results of the geochemical monitoring from SPEC-3A are presented in Section 3.

3. GEOCHEMICAL PARAMETERS

During MB SPEC, aerated drilling was utilized wherein compressed air was used together with the drilling mud (either bentonite or polymer), fresh water and cold brine to cool the drill bit and lift cuttings out of the wellbore. Cold brine was used to augment the limited fresh water supply needed for drilling. When total loss circulation was encountered, there was a possibility that the drilling fluids can affect the nearby production wells. In order to determine if there was any communication between wells, unique chemical parameters from the drilling fluids are checked in the nearby wells.

For single phase steam production wells, the presence of oxygen and nitrogen by gas chromatography is a good indicator for interference from aerated drilling fluids. It was recognized that it took time for the results to be available, so an increase in the field measurement of %NCG (by wet test meter) was a viable monitoring parameter.

For two phase production wells, in addition to the gas samples, an increase in chloride and/or magnesium should show the effect of polymerized water contamination. However, this analysis required 1–2 days turnaround time, which was observed in the first batch of MB SPEC wells.

The polymerized water can alter the pH as well as manifest visually in the TSS sample. The nitrogen, oxygen, magnesium and chloride trends were used to verify the results of the onsite analysis particularly for the first batch of SPEC wells. However, due to long turnaround time, the monitoring plan was simplified to %NCG and Cl for the rest of the SPEC wells. The geochemistry parameters and trends for %NCG and Cl are summarized in Table 2.

Geochemistry Parameter	Threshold / Trend
NCG *(by wet test meter)*	**1% at the power plant** The %NCG of offset wells was determined and the resulting %NCG mix at the interface is calculated.
Chloride	$[Cl]_{freshwater} < [Cl]_{geothermal\ fluids}$ Change in concentration may suggest dilution coming from the drilling fluids.

Table 2. Geochemistry parameters and trends

3.1 First batch: SPEC-1C offset wells geochemistry

The %NCG (by Wet Test Meter) data from the offset wells while drilling SPEC-1C is presented in Figure 11. The offset wells data from SPEC-1C is also representative of what was observed from the first batch of MB SPEC wells, particularly at the shallow hole sections. 1C-1 and 1C-3 were the critical offset wells for monitoring as these were within the 300 ft radius in the 26" and 17-1/2" hole sections. The other offset wells were outside the 800 ft radius in the shallow hole sections.

As shown in Figure 11, 1C-1 and 1C-3 had an increase in their %NCG during the drilling of the 12-1/4" hole section of SPEC-1C. This can be explained by the proximity of these wells to the welltrack of SPEC-1C (within 300-800 ft). As compressed air was continually injected to SPEC-1C, an interference to 1C-1 and 1C-3 manifested. This was confirmed by the subsequent analysis of the samples, where there was a consistent increase in oxygen (O_2) and nitrogen (N_2). These wells were proactively monitored at the 12-1/4" hole section, and were not recommended for shut-in, as the increase in %NCG was still within the threshold 1% NCG as simulated at the powerplant.

This met the objective of the offset well monitoring plan to minimize the associated generation losses. 1C-3's %NCG went back to normal at the last hole section but remained relatively higher for 1C-1 as compared to its previous %NCG data due to residual interference.

3.2 Second batch: SPEC-2C offset wells geochemistry

SPEC-2C is chosen as the representative well from the second batch of MB SPEC wells for this paper. The critical wells for monitoring during the second batch of SPEC wells were 2C-9 and 2C-10, as these were located in the same wellpad and were within the 300 ft radius at the shallow hole sections. 2C-9 and 2C-10 were shut-in until the completion of the 17-1/2" hole section because their feedzones were exposed at this interval. At the 12-1/4" hole section, a reactive monitoring approach was implemented.

The %NCG of 2C-9 remained low, and there was only a slight increase in %NCG of 2C-10, as shown in Figure 12. These wells were kept flowing from this section until the completion of SPEC-2C drilling. Another well that was part of the monitoring plan was 2C-5, but the high %NCG in the plot is typical for this well. The other wells have relatively stable %NCG values.

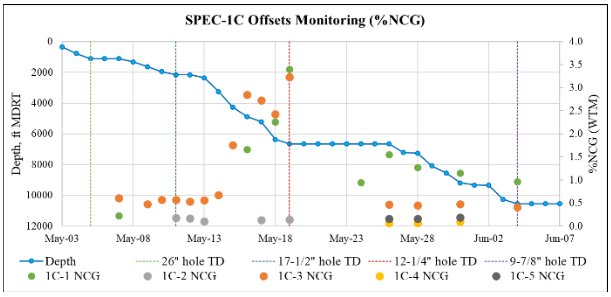


Figure 11: SPEC-1C Offset Wells %NCG data

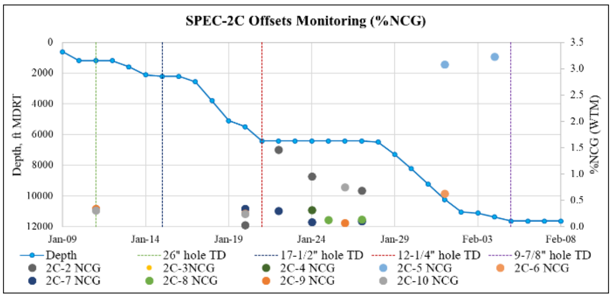


Figure 12: SPEC-2C Offset Wells %NCG data

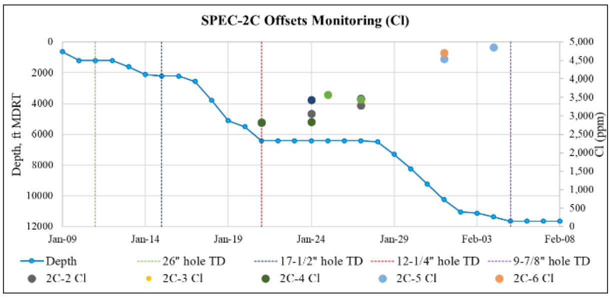


Figure 13: SPEC-2C Offset Wells Cl data

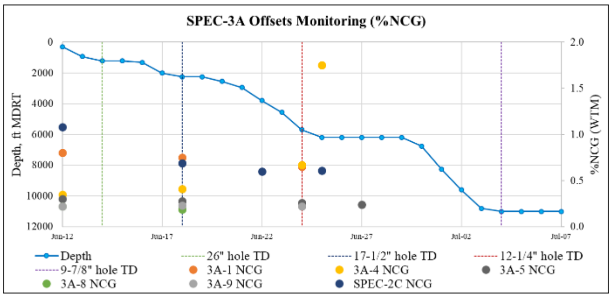


Figure 14: SPEC-3A Offset Wells %NCG data

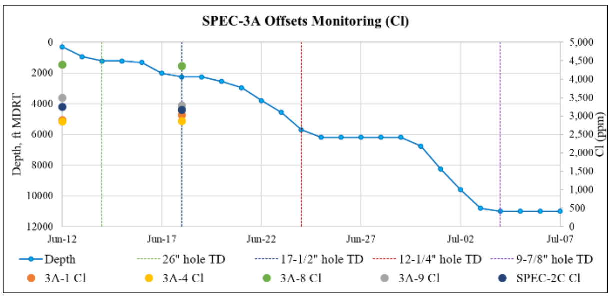


Figure 15: SPEC-3A Offset Wells Cl data

There were no chloride data for 2C-9 and 2C-10 as these are both all-steam production wells. It was observed for another well, 2C-2, that there was a decreasing trend in %NCG in the 17-1/2" hole section coupled with an increasing chloride as shown in Figure 13. 2C-2 was not shut-in because the %NCG mix at the powerplant was still within acceptable limit. The delayed response in Cl could be due to the difference in the rate of diffusion of gas and water in the formation.

3.3 Third batch: SPEC-3A offset wells geochemistry

The third batch of MB SPEC wells (SPEC-3A and SPEC-3B) have relatively few offset wells for monitoring as the other wells that are located in the pad were shut-in. 3A-2 is a marginal producer and 3A-6 is an idle well. It is shown in Figure 14 that the %NCG trends of the offset wells were all relatively flat, except that of 3A-4. The %NCG of 3A-4 had more than doubled at the end of the 12-1/4" hole section. This can be explained by the close approach of 3A-4 to SPEC-3A welltrack at this depth, which is at the edge of the 300 ft radius. However, it was not recommended to shut-in the well because the simulated %NCG at the powerplant was still within the 1% threshold.

As shown in Figure 15, there was no Cl data monitoring after the completion of the 17-1/2" hole section as it was believed that the offset well interference was very minimal to none.

4. OFFSET WELLS MONITORING PLAN RESULTS

4.1 Post-MB SPEC Production Assessment

One of the main objectives of the offset wells monitoring plan during the MB SPEC drilling is to prevent the migration of the drilling fluids or cement to the active production wells in order to preserve their production after the campaign.

Analyses of the production of the wells within the critical 300 ft radius were conducted. The offset wells in the same wellpad were in close proximity to the MB SPEC wells in the shallow hole section (26" and 17-1/2" hole section), while there are also offset wells that came into close approach with the MB SPEC wells at the deep hole section (12-1/4" and 9-7/8" hole section.).

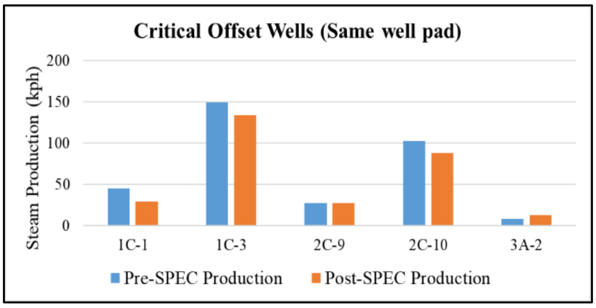


Figure 16: Production Data (offset wells within 300 ft at shallow hole sections)

The active offset wells in the same wellpad are: 1C-1 and 1C-3 (first batch); 2C-9 and 2C-10 (second batch) and 3A-2 (third batch). The comparison of the production of these wells pre- and post-SPEC are presented in Figure 16. The wells with relatively the same production are 2C-9 and 3A-2. The slight increase in steam production of 3A-2 is within known production fluctuations. The production decline in 1C-3 and 2C-10 of approximately 15 kph steam each can be explained by their relatively high decline rates even before the drilling activities. On the other hand, there was a 16 kph production decline in 1C-1 (step drop) that was observed six months after the online of the first SPEC well. Further evaluation, such as through flowing PTS surveys, needs to be done in order to characterize the subsurface cause of the production drop.

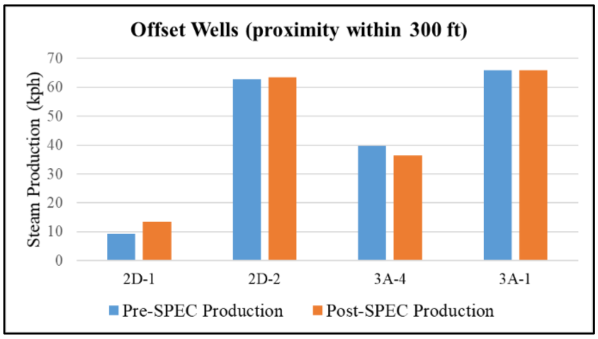


Figure 17: Production Data (offset wells within 300 ft at deep hole sections)

The pre- and post-MB SPEC production of the offset wells that came into close approach (within 300 ft radius) to the MB SPEC wells in the deep hole sections (12-1/4" and 9-7/8" hole sections) are relatively the same as shown in Figure 17. The drilling fluid at the deep hole sections of MB SPEC wells is aerated polymer, which degrades at high temperatures and does not pose risk of plugging the permeable zones. This is consistent with what is observed in the deep offset wells in which the production data was preserved.

Based on the pre- and post-SPEC production assessment, the equivalent of up to 24.5MWe production from the offset wells was preserved after the end of the campaign.

4.2 Avoided Offset Wells Generation Losses

The second objective of the offset wells monitoring plan is to minimize the associated generation losses by employing a reactive shut-in approach based on the geochemical parameters observed from the offset wells. The comparison of the planned generation losses (shut-in all wells within the threshold radius) and actual losses (reactive shut-in approach) is shown in Figure 18.

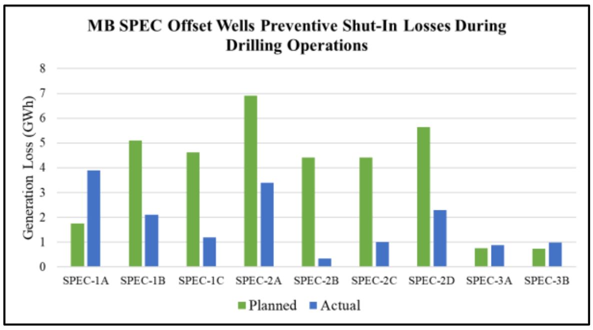


Figure 18: MB SPEC Offset Wells Generation Losses

Specifically for the first well, SPEC-1A, the team still leaned on the conservative side by proactive shut-in of offset wells within the 300 ft critical radius, which resulted to higher actual losses versus planned. As the campaign progressed, the monitoring plan was improved which resulted to the total actual generation losses reduced to 16 GWh from the 34 GWh total planned losses.

5. CONCLUSION

The Mak-Ban Steam Production Enhancement Campaign (MB SPEC) introduced a challenge in terms of ensuring that the drilling operations would not cause any detrimental impact to the subsurface that could possibly affect the production of the active base production wells. To mitigate the potential migration of the drilling fluids or cement to the active production wells, the offset wells monitoring and shut-in plan was developed by the Mak-Ban Resource Management Team and implemented by the workgroups onsite.

The monitoring plan is important to production wells which are of close proximity to the SPEC wells, particularly those with production from the shallow steam and two-phase reservoir. The parameters for monitoring were reduced as the team gained experience in understanding the changes introduced by the drilling fluids. Eventually, the monitoring plan heavily relied on the geochemical parameters with the quickest turnaround time (%NCG by wet test meter) and Cl to make the decisions for the reactive shut-in.

The monitoring plan was able to mitigate the potential breakthrough of drilling fluids or cement in offset wells and it also minimized the generation losses from shut-in of the offset wells during the actual drilling operations. The equivalent of up to 24.5 MWe production from the offset wells was preserved after the end of the campaign and the preventive offset wells shut-in losses were reduced to approximately 16 GWh from the planned 34 GWh losses.

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