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Improved Formation Cleaning in Production Wells: Case Studies from New Zealand

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ABSTRACT

Formation scaling in geothermal production wells can significantly reduce the productivity of the well through permeability damage. This is often manifested as a reduction in produced fluid or in the most severe cases, a complete loss of production from the well. As the scale cannot be removed by mechanical means, the most common solution is the application of chemicals into the formation to try and dissolve the formed scale and recover the well to its original capacity. In the past couple of years, we have undertaken a research project to understand the optimal chemicals to use, both in terms of application method and volume. Following extensive literature searches, a detailed laboratory study and the assessment of dozens of historic formation cleans, we have deployed our learnings in the field. This paper provides detailed case studies on the production well formation cleans undertaken following this research, highlighting how we have applied what we have learnt, the efficiencies we have been able to realise and the improved results we have been able to achieve. The success of each clean has been studied using a combination of pressure, temperature, spinner (PTS) data, pressure transient analysis (PTA) and production data. From these analyses, comparisons have been made with previous cleans to fully understand the impact of the changes we have made and to highlight areas for improvement in future cleans.

1 INTRODUCTION

Scaling in geothermal production wells can occur in the wellbore or formation, depending on the operating conditions of the well. Wellbore scaling can be managed relatively easily through regular mechanical workovers (Wilson 2015 and Wilson 2020) or through the deployment of a calcite inhibition system (Siega 2020, Ferguson 2024). Formation scaling is more difficult to control and typically requires chemical intervention to dissolve the scale and recover the productivity of the well (Fernanda 2014, Muller 2021). Over the last 3 years we have undertaken a research project to better understand the formation cleaning process and optimise the cleaning programme deployed. This involved literature research, laboratory studies and assessment of historic formation cleans to build up a database of knowledge. A large part of this project has also been to improve how we select wells suitable for formation cleaning (McLean 2024). This data driven approach to both well assessment and chemical programme design has led to development of cleaning methodologies for both production and reinjection wells, by identifying the most effective chemicals for each situation and how to apply them in tandem with additives or inhibitors that maximise the chances of a successful job (Ferguson 2024, Ferguson 2025). A key component of this project has been the iterative improvements achieved by collecting additional data pre- and post-clean to fully understand the impact of the treatment and where things could have gone better. Pressure, temperature, spinner (PTS) data and pressure transient analysis (PTA) have been important tools in assessing the success of our formation cleans and have been vital in guiding the design of future jobs.

2 CASE STUDY 1 – BR52

Case study 1 details the formation cleaning of BR52, a production well on the Ohaaki geothermal field in the West Bank production area (Figure 1a). The well has been cleaned twice, once using an external contractor in 2021 and using a methodology developed in-house in 2024. The reservoir around the well is liquid when undisturbed, and flashes in the formation at all eight feed zones when producing, over an extensive open-hole interval (1125-1870 mCHF) (Figure 1b). Based on geochemistry analysis the predominant scale causing production decline was anticipated to be calcite.

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2.1 Job Design and Execution

Previous well workovers have highlighted that the calcite scale formed in our production wells is typically almost 100% calcite. Our laboratory studies highlighted that the best way to treat calcite scaling in the formation was with a dilute acid solution. Hydrochloric acid (HCl) dissolves more scale than a comparative concentration of formic acid, but formic acid has the benefit that it interacts less with the dominant formation minerals, reducing the risk of secondary precipitation or formation damage as a result of a formation clean. During the previous formation clean in 2021, which was conducted by an external contractor using an acid/caustic chemical program, well testing revealed that, as expected, the acid treatments were more effective than the caustic treatments at removing calcite scale and improving the permeability. Based on this data and our previously reported laboratory studies, we designed a chemical program where our 2024 chemical treatment was dominated by the use of dilute formic acid. From literature studies, this appears to be the first publicly reported use of formic acid to remove calcite scale from a geothermal well (Siratovich 2025). It has been used previously, in combination with hydrofluoric acid, to remove silica scale in a reinjection well (Goh 2022). By simplifying the chemical programme we were able to reduce the chemical costs, reduce the number of days the well was on quench, conduct fewer PTS runs and return the well to service quicker.

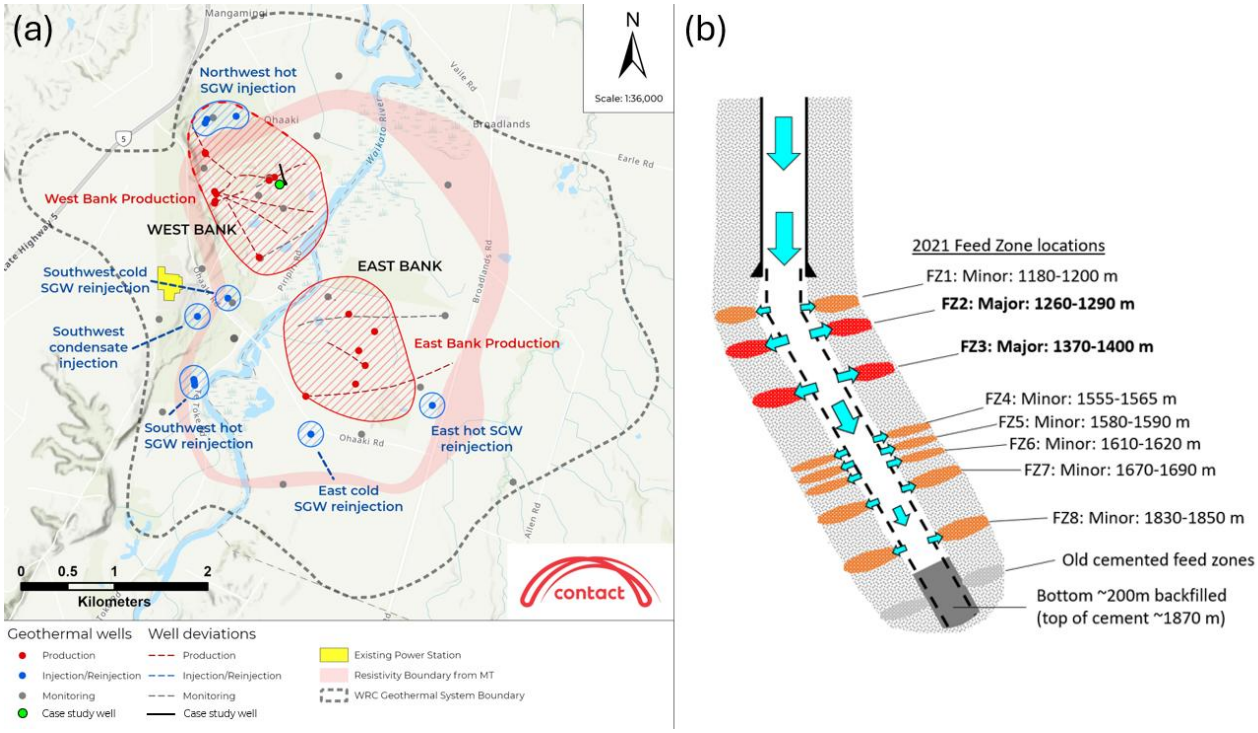


Figure 1: (a) Field map of the Ohaaki field, showing key locations; (b) Feed zone distribution in BR52 production well.

2.2 Results

2.2.1 Reservoir engineering data

Injecting PTS runs were carried out before and after each clean to fully assess the changes in the well characteristics as a result of the clean. Key items assessed from each PTS were the injectivity (t/h/bar), the locations and balance of feed zones, and permeability and skin factor (from pressure transient analysis). The injectivity before and after each clean is given in Table 1. These show that the % increase in injectivity was similar for each clean (within error of this kind of data). This is consistent with the similar job outcome observed in the production data (section 2.2.2).

The feed zone locations did not change as a result of either clean and were virtually the same in 2021 and 2024 (Table 2). There was no observable change in the balance of feed zones. This implies that the capacity gain is the result of clearing scale from existing feed zones rather than creating new ones, and that this cleaning is probably occurring at all zones rather than just some.

Table 1: Case study 1: summary of before and after injectivity values.

	Injectivity (t/h/bar)		
	Before	After	% difference
2021 job	9.3	15.0	+61%
2024 job	14.8	22.2	+50%

Table 2: Case study 1: summary of feed zones interpreted from 2021 and 2024 injecting PTS testing.

Feed Zone	2021 testing Depth range (mCHF)	2024 testing Depth range (mCHF)	Major/ minor	Interpretation comments
1	1180-1200	-	Very minor	NOT PRESENT IN 2024. Very small anomaly in heatup temperature profiles in 2021.
2	1260-1290	1260-1290	Major	PRESENT IN 2024 and 2021. Large spike in heatup, drop in fluid velocity, increased temperature gradient at all flow rates.
3	1370-1400	1370-1400	Major	PRESENT IN 2024 and 2021. Rapid heatup - but partially masked by FZ above, drop in fluid velocity.
4	1555-1565	1555-1565	Very minor	PRESENT IN 2024 and 2021. Very small anomaly in heatup temperature profiles.
5	1580-1590	1580-1590	Very minor	PRESENT IN 2024 and 2021. Very small anomaly in heatup temperature profiles, increased temperature gradient at two flow rates (subtle).
6	1610-1620	1600-1620	Very minor	PRESENT IN 2024 and 2021. Very small anomaly in heatup temperature profiles, slightly higher in 2024.
7	1670-1690	1670-1700	Very minor	PRESENT IN 2024 and 2021. Very small anomaly in heatup temperature profiles.
8	1830-1850	1830-1850	Minor	PRESENT IN 2024 and 2021. Rapid heatup, fluid velocity drops to zero.

Table 3: Case study 1: summary of before and after permeability values from PTA.

	Reservoir permeability k (e-15 m^2)		
	Before	**After**	**% difference**
2021 job	100	200	+100%
2024 job	68	120	+76%
	Skin factors (dimensionless)		
	Before	**After**	
2021 job	+3	-2	
2024 job	-3	-3	

PTA before and after each clean shows a similar increase in reservoir permeability as a result of each clean (Table 3). The most consistent results came from pressure buildups measured at an increase in flow rate. The increases in reservoir permeability are effectively the same within the error associated with this kind of analysis.

PTA also yielded results for skin factor which are summarised in Table 3. Skin factor is affected by changes in permeability close to the wellbore (~5m or less). The Table 3 results show that for the 2021 job the skin factor dropped from s=+3 (indicating damage/blockage of permeability close to the wellbore) to s=-2 (indicating significant removal of blockages close to the wellbore). For the 2024 job the value was s=-3 before the job,

indicating that the halo of scale is likely to have built up further from the wellbore, thus not affecting the skin factor. Also, the value did not change as a result of the job, indicating that the effect of the chemicals was removal of scale at a greater distance from the wellbore than the 2021 job, thus affecting the wider reservoir permeability numbers but not the skin factor. In conclusion, the reservoir engineering results show that the effect of the 2021 job and 2024 job were similar. This is seen in the similar increases in injectivity and permeability, and the similar unchanging locations of feed zones.

2.2.2 Production data

While details on the impact and effectiveness of the chemical treatment in terms of permeability improvement were highlighted by the PTA and PTS analysis, the overall improvement in generation was tracked by production data and tracer flow testing (TFT). As expected, the well initially returned to service with a massive increase in overall mass flow, probably driven by improved permeability but also the lower observed enthalpy and as a result higher water content and total mass flow (Figure 2). As the well gradually heated up to pre-job condition, the total mass flow declined sharply, before gradually reaching a slower long-term decline rate. Prior to the most recent clean, a two-phase orifice plate was installed to allow continuous monitoring of the flow rate from the well. This data is in good agreement with the TFT data, although the TFT mass flow tends to be a little higher than that given by the orifice plate. The clean provided over 1 MW of additional generation for several months before gradually reducing over a period of 21 months. Calculating the exact MW uplift is difficult due to changes in utilisation of other wells on the field around the same time but we estimate the total additional generation over the lifetime of the clean to be around $1.3m NZD.

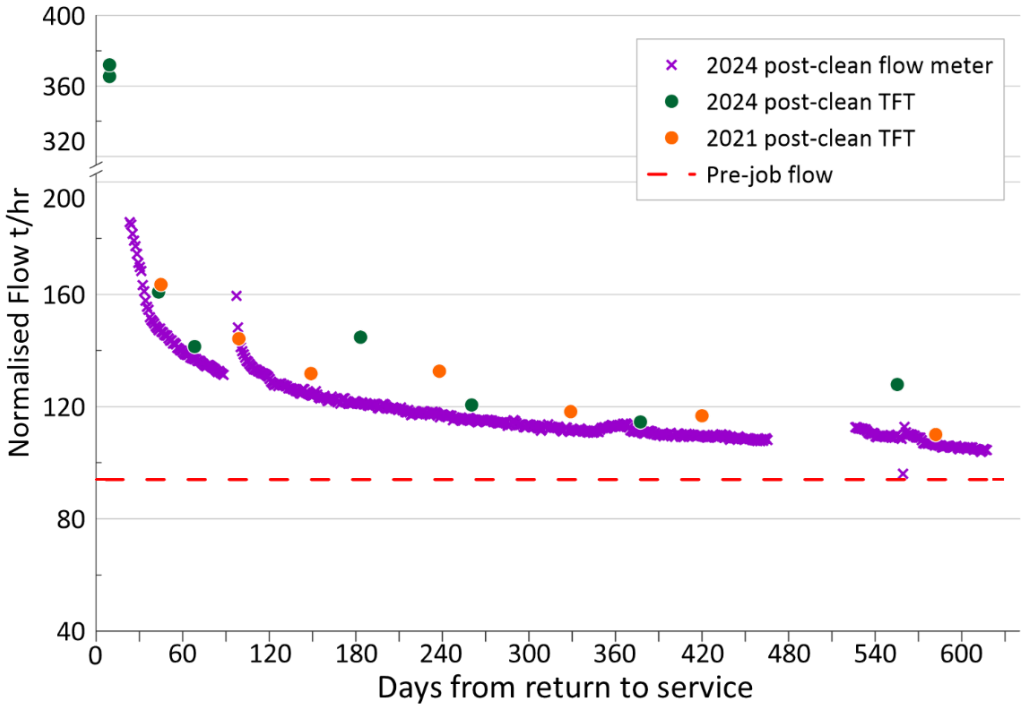


Figure 2: Mass flow decline over time after formation cleaning jobs for BR52 production well.

Comparison of the data reveals that despite two very different methodologies, the 2021 and 2024 formation cleans produced very similar results. Both showed similar decline rates after an initial large uplift in mass flow and maintained a mass flow above pre-job levels for a similar period. Achieving a similar result while adopting a simplified and cheaper treatment programme is a good result and highlights that modification and optimisation of the formation cleaning process has not adversely affected the result. One shared problem between both cleans is the rapid decline, especially in the first 2 to 3 months post-clean. While some of this initial decline is likely due to thermal effects post-quenching, increased calcite scaling is hypothesised to contribute significantly to the reduction in mass flow. Part of our project on developing and optimising our formation cleaning strategy is focused on finding innovations to reduce post-clean decline rates and improve the lifetime of the clean. Given the mass flow is now approaching the pre-job flow, this well is scheduled for another formation clean. We have identified a new technique to geothermal that could significantly reduce the post-clean decline rate and plan to trial this innovative technology in the upcoming clean. Further details and results of this trial will be published in a future publication.

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3 CASE STUDY 2 – WK260

Case study 2 details the formation cleaning of WK260, a production well on the Wairakei geothermal field, located in the Te Mihi production area (Figure 3). This well has been cleaned twice by an external contractor in 2021 (Muller 2021) and 2022, and once using a methodology developed in-house in 2024. For the 2022 clean, the well was not returned to service until 2023. The well flashes in the formation and, based on geochemical data and comparison with nearby wells, is likely to be impacted predominantly by calcite scaling. PTA is not possible on this well due to the presence of strong inflows at all injecting flow rates during quenched conditions. Inflows preclude pressure transient analysis which requires flows in the well to be controlled and stable.

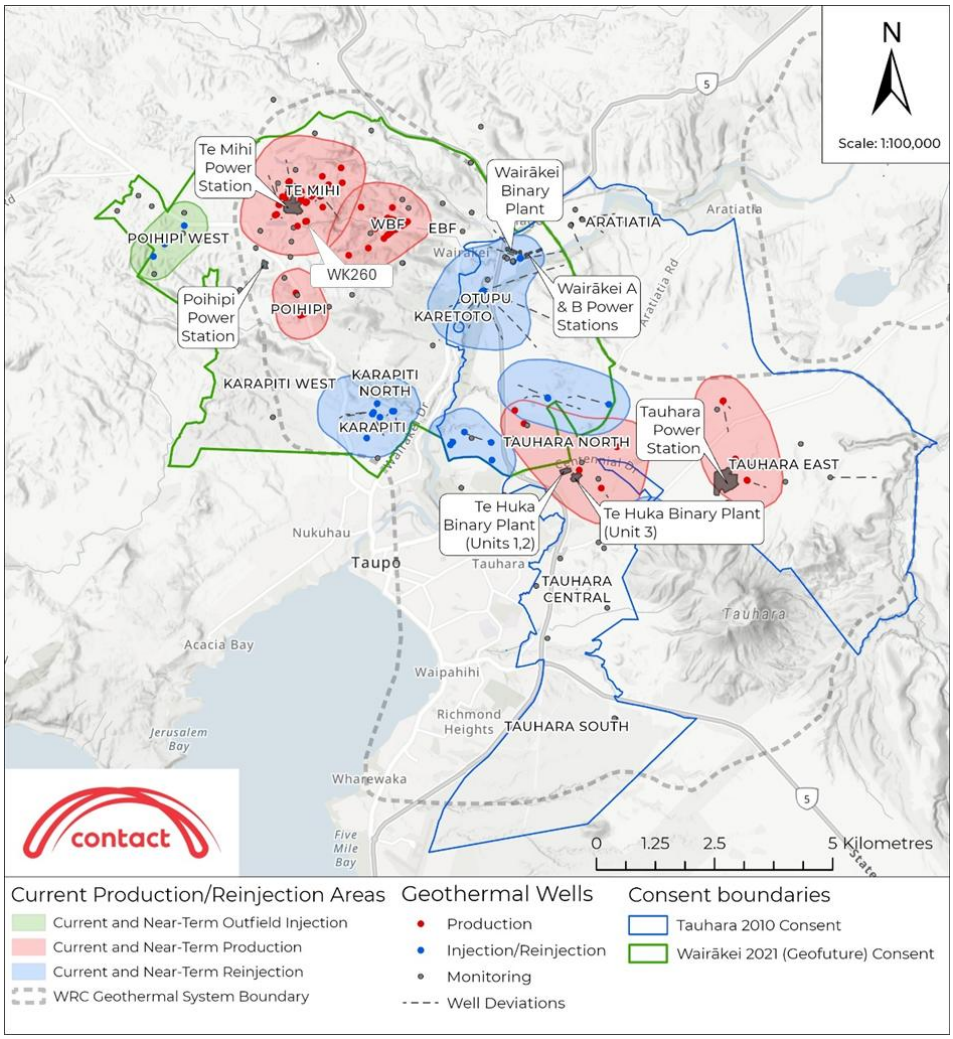


Figure 3: Field map of the Wairākei-Tauhara field, highlighting the location of production well WK260.

3.1 Job Design and Execution

Again, as the predominant source of decline is calcite scaling, the methodology utilised in the 2024 treatment was dominated by the use of a dilute acid, on this occasion the acid chosen was HCl given its excellent performance in laboratory studies and a low risk of permeability damage occurring in this well. As guided by our laboratory studies, the acid was applied differently to the two previous formation cleaning jobs undertaken by an external provider, to reduce the risk of secondary precipitation and maximise the effectiveness of the chemicals used. Given that some feed zones inflow even under quenched conditions, PTS runs were required before each chemical step to ensure the target concentration was achieved at the outflowing feed zones.

WK260 has 9 feed zones (Table 4) while injecting but under flowing conditions, feed zones 3, 4 and 6 are the productive zones. Different flowrates (500, 1000, and 1500 lpm) were used to analyse what chemical dosing flowrate was best to treat many feed zones with the desired concentration. There were some differences in the feed zones from the last formation clean. In 2022, feed zone 3 was an inflow but in 2024, it is an outflow at all 3 flowrates. Feed zones 1 and 5 were inflows, but these were outflows in 2024 at the 1500 lpm flowrate. As a quench rate of 1500 lpm suppressed the 2 inflows at feed zones 1 and 5, this flowrate was also used to deliver the chemicals, to allow treatment of more feed zones.

Table 4: Case study 2: summary of feed zones interpreted from pre-job injecting PTS testing.

Feed Zone	Start depth (mCHF)	End depth (mCHF)	Comments
1	570	595	Inflowing except for 1500 lpm where it's outflowing
2	600	655	Inflow at all rates, as seen from spike in fluid velocity and change in temp gradient. Can be combined to FZ1 for 1000 and 500 lpm flowrates.
3	660	690	In 2022, looks like an inflow. In 2024 it is an outflow
4	705	720	Inflow at all rates, as seen from spike in fluid velocity and strong increase in temperature gradient. Same in 2022.
5	725	735	Inflow for 500 and 1000lpm flowrates (little bit suppressed), outflow for 1500 lpm.
6	745	775	Outflow at all rates, as seen from decreases in fluid velocity, no temperature anomaly. Major feed zone, same as in 2022.
7	790	810	Outflow at all rates, as seen from decreases in fluid velocity, no temperature anomaly.
8	830	860	Outflow at all rates, as seen from decreases in fluid velocity, and temperature anomaly.
9	890	930	Some permeability present at the base of the well, clear from non-convergence of temperature profiles

3.2 Results

3.2.1 Reservoir engineering data

Injecting PTS runs were carried out prior, during, and after the job to fully assess the changes in the well characteristics as a result each step. Key items assessed from each PTS were the injectivity (t/h/bar) and the locations and balance of feed zones. The injectivity before and after each job is given in Table 5. In 2022, the injectivity from the final injecting PTS slightly increased from the pre-job, 155.6 to 184.0 t/h/bar or + 17.0%. There is also an anomalous result from the mid-job testing which showed a decrease in injectivity. In 2024, the injectivity from the final injecting PTS appears to decrease from the pre-job, 220.0 to 180.9 t/h/bar. The mid-job and post-job injectivity indices are similar to the values obtained in 2022. However, there is a high possibility that the indices obtained are incorrect due to the flow control issues during the injecting PTS surveys. For example, in the 2024 surveys (Figure 4), the flows were unstable and had periodic spiking and dropouts which could deem the data almost unusable. It should be noted that very high values of injectivity (>>100 t/h/bar) are difficult to measure accurately due to the very small changes in pressure involved. Extreme care is required, and this type of testing in such a high permeability well is vulnerable to distortion by flow control issues. Overall, the results from the injectivity indices were unclear and as such, the production capacity after the well was returned to service was the best way to determine the effectiveness of the formation cleaning process.

Table 5: Case study 2: summary of before and after injectivity values.

	Injectivity (t/h/bar)		
	Pre-job	Mid-job	Post-job
2022 job	155.6	135.9	184.0
2024 job	220.0	139.7	180.9

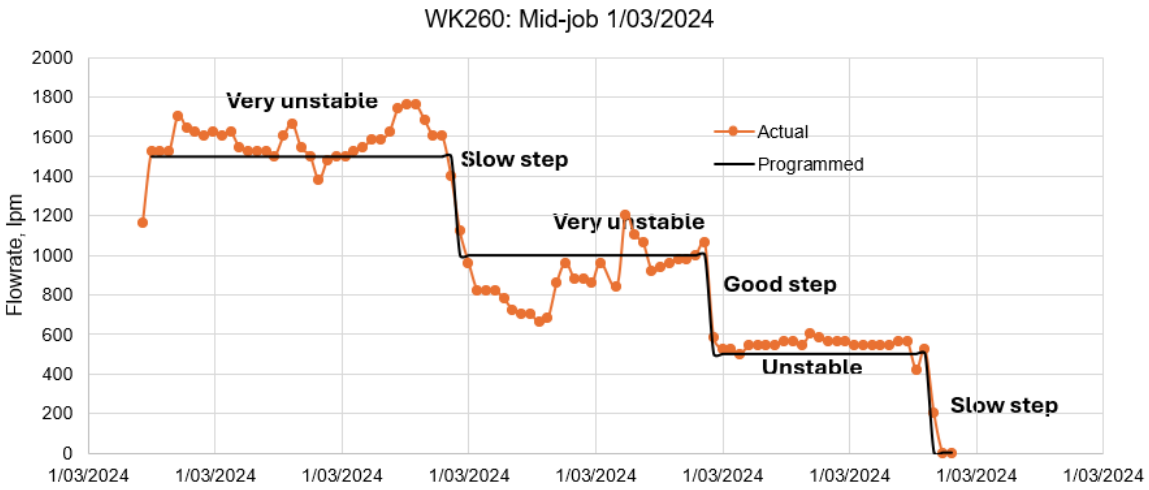


Figure 4: Flow control during the 2024 mid-job injecting PTS survey.

3.2.2 Production data

Given the issues with flow control impacting the usefulness of the PTS data in assessing the true effectiveness of the formation clean, analysis of the production data was vital in understanding the benefits. The flow after the 2024 clean showed the expected slow recovery, reaching its peak maximum flow around 80 days after being returned to service, which is comparable with the recovery seen after previous cleans (Figure 5). The 2024 clean achieved a higher maximum flow than the previous two cleans, exceeding the previous maximum by around 30 t/hr. A planned field-wide outage in late 2024, followed by a period of reduced extraction, allowed the reservoir pressure to increase before slowly returning to the previous long-term trend (Figure 6). This resulted in an inflated mass-flow from the well for an extended period. By August 2025, the reservoir pressure had stabilised and returned to its long-term trend, with the inferred mass flow corrected for outage-induced reservoir pressure changes highlighted by the dashed red line in Figure 5. Previous cleans on this well had lasted on average 300 days before the well became unable to produce. In 2024, the lifetime of the clean was extended by 11 months, with both the higher maximum flow and the lower observed decline rate contributing to this improved performance. The total value of the additional fuel provided by the 2024 clean is $7m NZD, while the benefit compared to the previous best clean on this well equates to $2.7m NZD of additional fuel being available for generation.

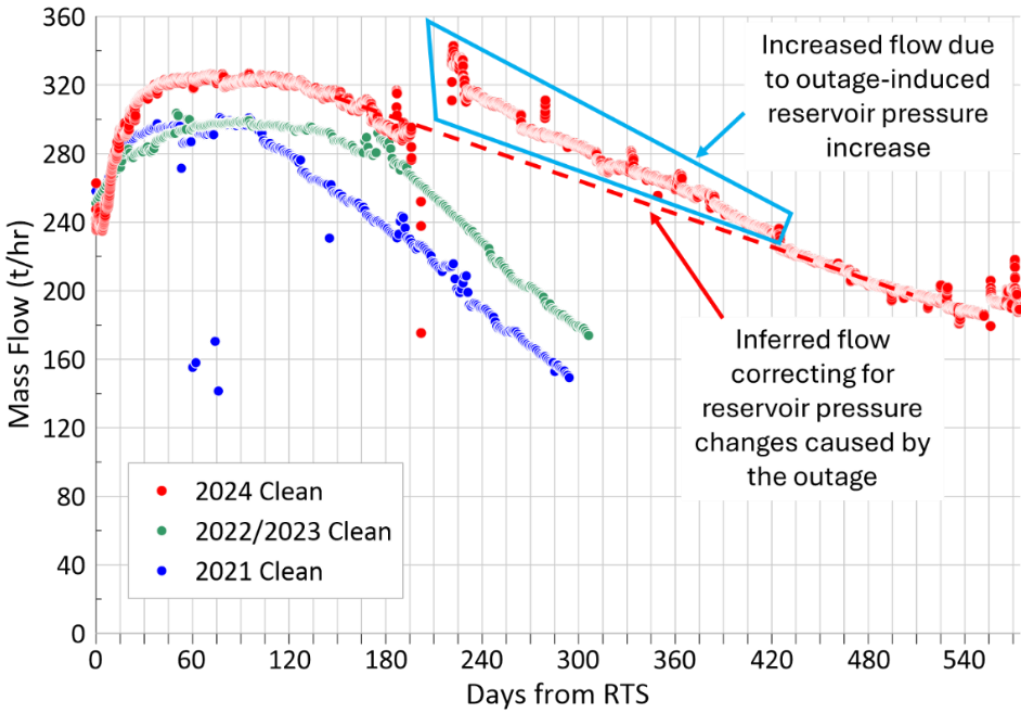


Figure 5: Comparison of well performance from the 3 formation cleans on WK260.

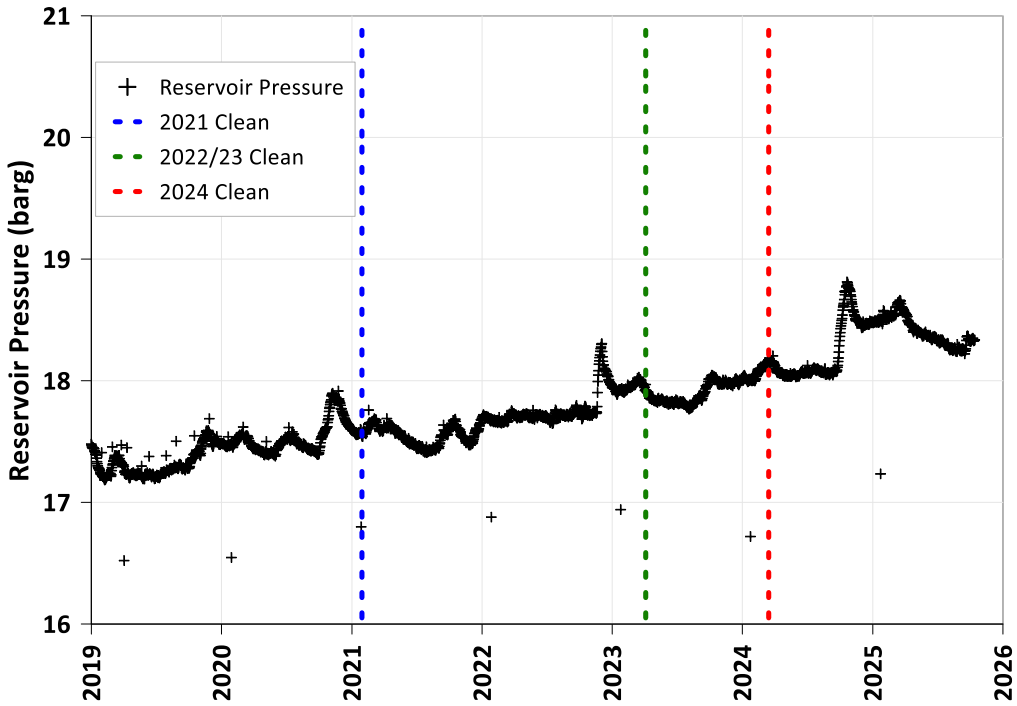


Figure 6: Plot of reservoir pressure over time, showing gradual reservoir pressure change (~0.7 bar increase) across all 3 cleans, with the exception of the period after the field-wide outage and subsequent reduced extraction.

4 CONCLUSIONS

The case studies of two production well formation cleans have been presented above. For BR52, the treatment programme was modified significantly from the previous clean, providing a shorter and cheaper job without compromising on the end-result of an excellent uplift in generation at the Ohaaki field. We believe this is also the first published example of formic acid being used as the primary treatment chemical for the removal of calcite from a geothermal well. As with the previous result, the well experienced a sharp decline in production in the 2-3 months post-clean. We plan to utilise a new technique to geothermal in the upcoming clean of this well to try and influence the post-clean decline rate and improve the benefits and lifetime of future treatments on this well. The formation cleaning programme previously utilised at WK260 was also modified yielding improved mass flow and a longer-lived formation clean. Flow control issues limited the usefulness of the PTS data collected before, during and after the job but production data revealed the excellent result and delayed need for a further clean on the well by 11 months. In total, the cleaning of both of these wells led to availability of $8.3m NZD additional fuel at the Ohaaki and Te Mihi power stations, along with the benefits highlighted from the optimisation and modification of the treatment programmes. Following these promising results we plan to continue to work on improving how we do formation cleaning, trialling innovative solutions and pushing for enhanced results.

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