BAY OF PLENTY REGIONAL COUNCIL
TOI MOANA

Annual Report to the Community on Kawerau Geothermal System

This report was prepared by Bay of Plenty Regional Council with technical input from the Kawerau Peer Review Panel.

Based on 2019 annual reports (reported in April 2020)

Background

Bay of Plenty Regional Council (BOPRC) manages the Kawerau Geothermal System under the Resource Management Act (RMA) 1991 through resource consents for the taking of geothermal water and heat, and geothermal discharges. Under the Regional Policy Statement (RPS), the system is classified and managed as a development system. Bay of Plenty Regional Council is assisted in this role by the Kawerau Geothermal Peer Review Panel, consisting of three independent geothermal technical experts.[1]

There are currently four Consent Holders taking geothermal fluid and energy for industrial direct heat uses and for electricity generation, including Mercury (KGL), Ngati Tuwharetoa Geothermal Assets (NTGA), Geothermal Developments Limited (GDL) and Te Ahi O Māui (TAOM). These consent holders report annually to BOPRC on their consented activities and monitoring of the system.

As part of its responsibilities for sustainable management of the Kawerau Geothermal System, and implementation of the Kawerau System Management Plan, an update is provided annually to elected members, iwi, stakeholders and the community on the overall state of the Kawerau Geothermal System.

Detailed information on the Kawerau Geothermal System and its management, as well as previous community reports, can be found on Council's website https://www.boprc.govt.nz.

[1] For the year 2019, the Panel comprised two technical experts due to the retirement of one Panel member. That position is to be filled by BOPRC and the new Panel member will commence duties at the beginning of 2021

Scope

The technical content of this report is based upon the consolidation of data and activities for the four Consent Holders for the period 1 January to 31 December 2019 and presented to Council in the Annual Joint Technical Report in April 2020.[2] It covers activities undertaken by the Consent Holders, changes to the reservoir, environmental effects of taking geothermal fluid and model development.

Key operational highlights

1 The first full year of electricity generation by Te Ahi O Maui (generation commenced September 2018) (Figure 1).

2 The first year in which all four Consent Holders contributed to the Annual Joint Technical Report for the Kawerau geothermal field.

3 The receipt of a draft report on the first full audit of Consent Holder procedures for measuring flowrates of geothermal fluid extracted and disposed of by injection and river discharge.

4 The completion of three new wells, one production and two injection in 2019, and the drilling of another production well was commenced.

Figure 1: Te Ahi O Maui

[2] A separate Compliance report for 2019 was prepared by each Consent Holder

Sustainable management summary

Reservoir cooling/enthalpy decline remains as probably the key issue for the long-term sustainability of the Kawerau resource. The robust monitoring programme in place, will ensure that reservoir trends continue to be monitored closely. Those observed to date are as expected and consistent with forecasts using reservoir simulation.

Monitoring of the potential effects of taking geothermal fluid on the surface environment, particularly significant thermal tolerant vegetation and surface features will continue. Analysis of changes to surface features over time, and a review of the surface feature monitoring programme is needed to ensure effective and efficient monitoring, and to better inform any future remediation or mitigation strategies.

Geothermal takes from the Kawerau Geothermal System

The four Consent Holders, Mercury (KGL), Ngati Tuwharetoa Geothermal Assets (NTGA), Geothermal Developments Limited (GDL) and Te Ahi O Māui (TAOM), together extracted a total of around 47.8 million tonnes[3] of geothermal fluid from the Kawerau reservoir during 2019, which equates to an average daily take of around 131,000 tonnes, slightly higher than that for 2018. The increase was due to fluid abstraction for the TAOM power station, which was commissioned in September 2018. The total daily take was approximately 75% of the total consented take amount of 174,680 tonnes per day.

All Consent Holders have generally complied with their average daily take limits and except for TAOM, the maximum daily take specified in their respective consents. Te Ahi O Māui exceeded their maximum daily take by a small margin on nine occasions during January and once in October.

Summary of reservoir trends

Overview

The following sections of this report summarise trends in key physical parameters (discharge enthalpy and reservoir pressure), and geochemical trends which provide important insights to processes occurring within the reservoir.

Trends in discharge enthalpy

Reservoir cooling/enthalpy[4] decline remains the key issue for the long-term sustainability of the Kawerau resource. The potential sources of cooler recharge that are likely to be contributing to enthalpy decline are inflows of meteoric water[5] at the reservoir margins, particularly at its western edge, and injection of geothermal fluid at reduced temperatures (50 ºC-130ºC) into the reservoir. That said, the rate of enthalpy decline for many of the production wells has decreased in recent years and in some cases, appears to be approaching a stable state suggesting that the reservoir may be reaching a new thermal equilibrium. This is consistent with modelled predictions.

[3] One tonne approximately equals 1000 litres

[4] Enthalpy is the sum of internal energy and work done by applied pressure. In a constant pressure system, it can be viewed as ‘heat content’. Work performed by a turbine, for example, equates to the change in fluid enthalpy

[5] Meteoric water is water derived from precipitation

The discharge enthalpies of the individual production wells in Kawerau are mainly a function of the temperature of the reservoir fluid encountered by the wells.

Data for the Kawerau production wells is analysed to understand the effects of taking geothermal fluid on reservoir temperatures. For example, some areas of the production well field are more strongly affected by cooler marginal recharge, other areas by reinjected fluid. Both marginal recharge and return of reinjected fluid have the potential to negatively impact the enthalpy of produced reservoir fluid. An understanding of how these processes are influencing the reservoir over time is therefore important for reservoir management.

To better understand this aspect of reservoir behaviour, the Consent Holders, in their Joint Annual Technical Report for 2019, grouped the production wells according to the interpreted dominant process(es) operating in different sectors of the reservoir (Figure 2). In this regard, average mass weighted long-term enthalpy decline for the western wells, central and eastern wells (0.8%/year) is higher than for the southern wells (less than 0.1%/year). This may reflect the proximity of the southern production wells to the inferred hot upflow to the Kawerau reservoir.

The long term well enthalpy trends are reported in terms of exponential decline values, which do not account well for the more recent apparent stabilisation and may therefore be conservative. That said, for some wells there is evidence from well measurements of continuing enthalpy decline, which is consistent with modelled predictions.

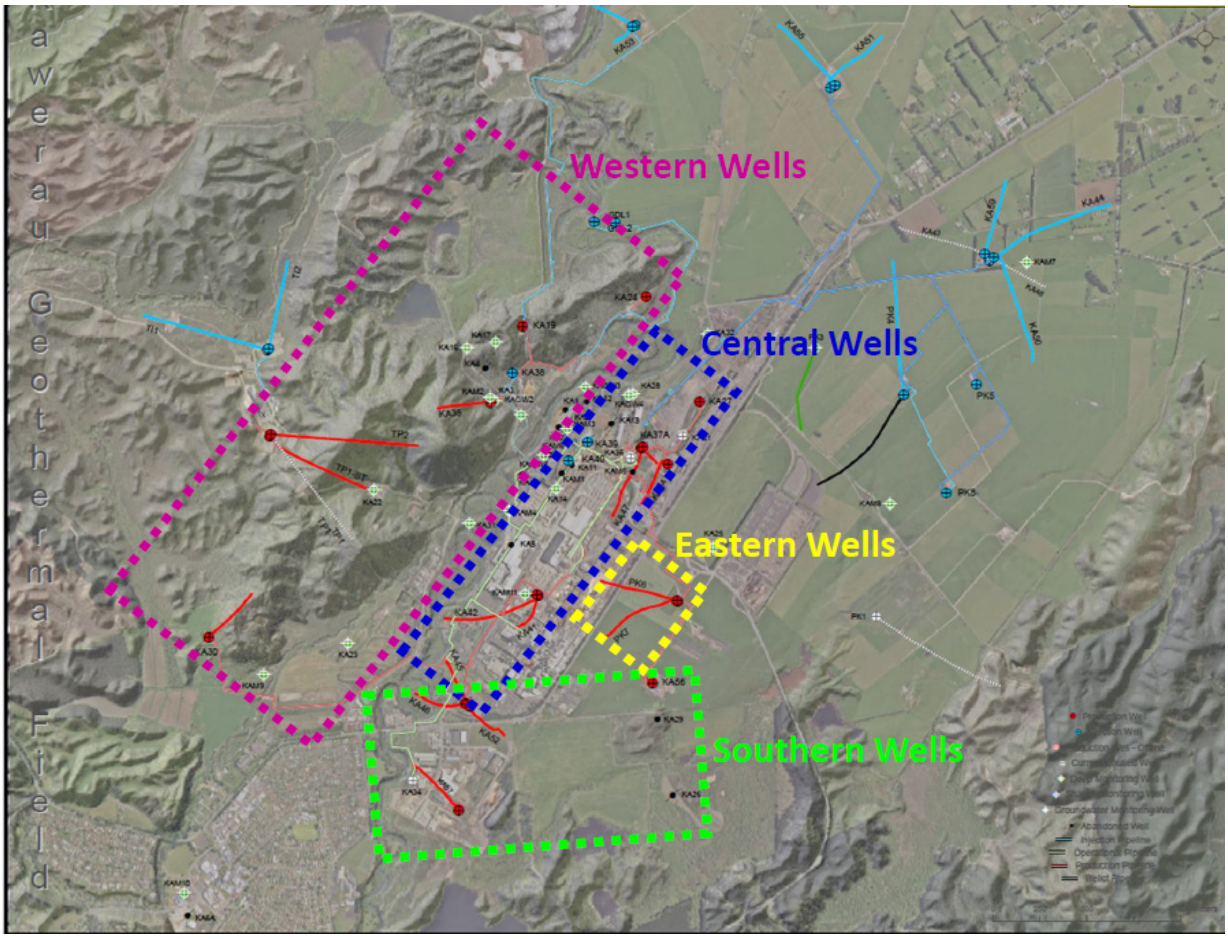

Figure 2: Well grouping

Trends in pressure

When fluid is extracted from a geothermal reservoir, changes including pressure occur. Reservoir pressure at Kawerau is measured continuously using special tubing inserted in six deep and one intermediate depth wells. These pressure monitoring wells are located to be representative of the reservoir.

For 2019, the pressure field wide was generally increasing as seen in the deep pressure monitoring wells which is comparable to the noted trends in recent years and well within modelled limits. This is despite the fact that of the total amount of fluid extracted from the Kawerau reservoir during 2019, only about 65% was returned to the reservoir via reinjection. The other 35% was discharged to atmosphere from power stations and directly to the Tarawera River. It is therefore considered likely that the inflow of cool meteoric water is providing much of this pressure support.

During the year, there were several instances when coincident, or nearly so, minor pressure changes were reported for the pressure monitoring network. Some appear to have been related to significant events such as a power station shut down for maintenance and are consistent with a reservoir that is highly permeable[6] and interconnected both horizontally and vertically. The explanation for other such changes is less clear since they do not appear to be linked to a 'major event'. The Panel, in its final report on the Consent Holders' Annual Report for 2019, recommended that these changes be investigated more fully, to better understand the reservoir response to geothermal takes.

Trends in chemistry

When groundwater's seep deep into the ground they become heated, as in the Kawerau area the thermal gradients are very high (perhaps 100°C per kilometre of depth). Over time the hot water dissolves minerals in the rocks to produce the reservoir fluids which at Kawerau are low salinity hot waters with temperatures as high as 300°C.

Production well sampling for fluid analyses is carried out once every quarter, alongside the Tracer Flow Test enthalpy measurements. The chemistry of injected fluid is analysed every six months. This enables close monitoring of the physical processes occurring within the reservoir in response to geothermal takes, as well as the potential for fluids to deposit scale in the rock formation adjacent to the well bore, the production and injection bores and in surface pipework.

Lateral marginal recharge is essentially meteoric water and as such has a very low concentration of dissolved salts, in contrast to both the source reservoir fluid, and the reinjected water which is enriched in dissolved salts. The dissolved salts include chloride which, because it does not react with the reservoir rock, is one of several tools used to assess the influence of marginal recharge and/or reinjection.

Long term geochemical data show that production wells located near the western edge of the reservoir are being progressively diluted which is interpreted to result from mixing of reservoir fluid with cooler (200°C-220°C) lateral marginal recharge from the west, in response to the prevailing pressure gradient induced by taking of fluid. Cool (approximately 100°C) down flowing water is also likely to be a contributing source of recharge to some of the western production wells. This interpretation is supported by a gradual increase in sulphate concentration in fluid produced by this group of wells. Sulphate is found in cool marginal recharge at higher concentrations than the reservoir fluid.

Cool deep lateral marginal recharge is heated as it mixes with the hot reservoir leading to only modest enthalpy decline despite progressive dilution. Shallow injection may also help provide pressure support and limit cool lateral recharge.

[6] Permeability is a measure of the ability of the reservoir rock to transmit fluids

The geochemical data suggest that most of the central production wells are also affected by marginal recharge. However, the geochemical trends for these wells could also be explained by a reduction in the amount of injected fluid that is returning to these wells or a combination of these processes. Sulphate is present at elevated concentrations in both cool marginal recharge and injected fluid. This is because both KGL and NTGA use sulphuric acid dosing to manage silica scaling issues which results in increased sulphate concentrations in the injected fluids. As such, it is not possible to distinguish between these processes using available geochemical tools.

The chemistry of fluid tapped by the eastern production wells was relatively stable in 2019. This followed significant change in 2018 which was attributed to the same processes or combination of processes that have affected the western wells.

Prior to 2018, it was thought that the southern wells were largely unaffected by injection returns or marginal fluids due to their relatively stable chemical and enthalpy trends. Chloride concentrations in fluid produced by these wells have since declined whilst sulphate concentrations increased, suggesting that reservoir fluid tapped by wells in this sector of the field is now also influenced by marginal fluids.

As noted elsewhere in this report, discharge enthalpy measured for most of the production wells has been declining at a low rate for the past few years and appears to be stabilising, suggesting that the reservoir might be approaching a new thermal equilibrium. That said, because reservoir cooling/enthalpy decline remains as probably the key issue for the long-term sustainability of the Kawerau resource, monitoring of enthalpy changes will continue to be high priority.

Flow measurement audit

Early in 2019 concerns were expressed by NTGA, that taking of geothermal fluid by TAOM appeared to be causing an increase in the enthalpy decline rate of NTGA well, KA35. Monitoring of the effects of TAOM production was immediately expanded and NTGA later reported the enthalpy decline rate was due to a faulty instrument.

The KA35 enthalpy issue, together with the accuracy of well production measurements and other matters relating to management of the Kawerau reservoir were discussed at a meeting of the Peer Review Panel, the Consent Holders and BOPRC in February 2019. On recommendation of the Peer Review Panel, BOPRC commissioned Thermarock to carry out an audit of well measurements conducted by all Consent Holders (completed August 2020).

Groundwater monitoring

What is monitored and why?

The shallow groundwater system at Kawerau overlies and interacts with the geothermal system. As such, groundwater present in the shallow aquifers is mixed with small amounts of geothermal reservoir fluid, some of which discharges into the Tarawera River as seeps.

In addition to natural mixing, it is possible that reinjected fluid, particularly at shallow depths, will leak into the groundwater over time changing its chemistry. Leakage of injected fluid into the groundwater aquifers is indicated by increased concentrations of the chloride ion that is present in the injectate.

The monitoring program comprises continuous temperature and water level measurements in a large network of shallow bores and six monthly or yearly sampling for chemical analysis to determine whether the geothermal component of the groundwater is changing. The Te Ahi O Māui groundwater monitoring well (TM1) is currently sampled monthly.

Recent trends

Rainfall fluctuations were the main reason for the minor variations in groundwater level reported during 2019. Temperatures measured in most wells were stable. Three showed a minor decrease while KAM11, which is the deepest groundwater monitoring well and is located in the central part of the field, showed no change in temperature or water level.

No geochemical changes of significance were reported for 2019.

Monitoring of surface thermal features and thermal vegetation

What is monitored and why?

The surface thermal features of the Kawerau geothermal field reportedly occupy an area of some 13 km^2. They include several groups of warm springs and seeps at different locations, mud pools sinter sheets, steaming and heated ground.

Historical reports on the surface thermal features indicate that there is evidence for an overall slow natural waning of surface thermal activity that commenced prior to development of the geothermal field.

Also, changes in surface thermal activity can be expected to occur over time in response to the taking of geothermal fluid which inevitably results in slow cooling of the reservoir.

The Consent Holders monitor selected surface thermal features of the Kawerau field to measure changes over time, recognising that it can be difficult to distinguish between change that is occurring naturally and that due to abstraction induced cooling. The monitored areas are within the Parimahāna Reserve, Te Taukahiwi o Tirotirowhetu Scenic Reserve, the A8D block and the Eastland Generation lease area.

Monitoring, which is carried out at frequencies set out in Consent Holder monitoring plans, includes temperature measurements and water samples (for chemistry) for two hot springs, photographic surveys of 28 surface thermal features, ground temperature measurements at 1 m depth within areas of heated ground, surveys of thermotolerant vegetation and thermal infrared imagery of the field. Thermotolerant vegetation comprises plant species which tolerate or even thrive in elevated ground temperatures. This habitat type is rare and contains threatened species generally considered significant under Section 6 of the RMA. For these reasons, it is important to monitor thermotolerant vegetation for possible changes in response to those occurring within the geothermal reservoir.

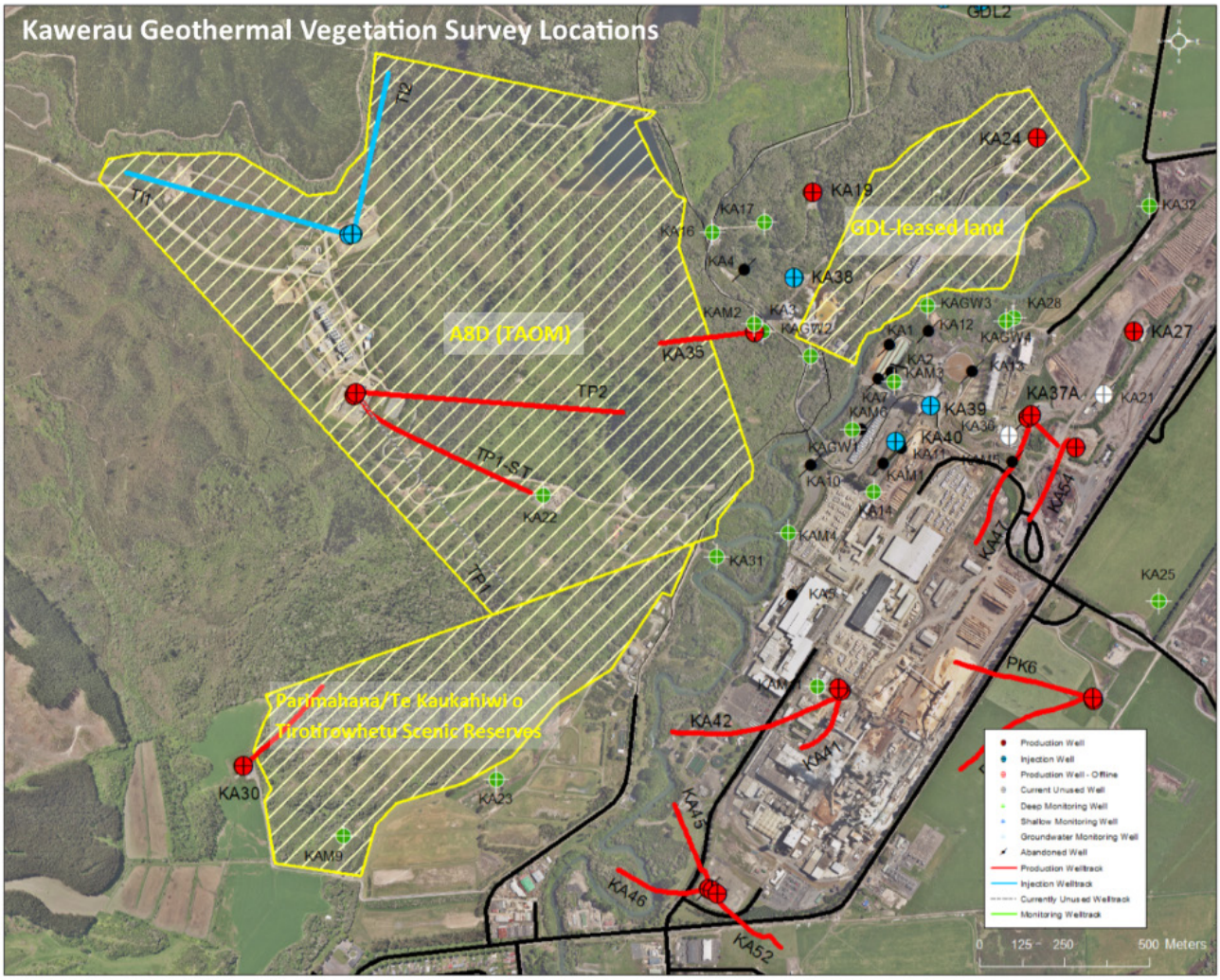

Figure 3: Vegetation survey areas

Recent trends

The two monitored springs, known as KAF8 and KAF18, ceased flowing in 2018 and 2016 respectively and so are not currently sampled. Analyses of water samples from the Te Wai U o Tuwharetoa (TWT) Spring show a dilute chemistry with minor, if any geothermal influence.

Ground temperature measurements obtained at the two permanent monitoring plots (known as 'A' and 'B') in 2019 were consistent with recent trends. Temperatures at Plot 'B' at a depth of 1 m during 2019 ranged from ca. 10°C to ca. 26°C, a significant decline since 2014 when temperatures ranged from ca. 80°C to ca.100°C. Temperatures measured at Plot 'A' have also decreased in recent years but to a much lesser extent. They remained relatively stable in 2019, ranging from 78°C-97°C. Baseline ground temperatures for heated ground within A8D block in 2019 reportedly ranged from 28°C-100°C. Ground temperature changes reported at a depth of 1 m are generally reflected in changes reported recently (2018) for shallower (10 cm and 40 cm) depths.

Despite the changes in ground temperature, changes to thermotolerant vegetation were reportedly relatively modest, at least in terms of the most recent (2016 and 2018) surveys. In Plot 'A', the occurrence and cover of most taxa[7] and ground cover variables remained largely unchanged between 2016 and 2018, except for a large increase in the occurrence of geothermal kānuka in higher height tiers, which may correlate with the cooler soil temperatures observed in 2018.

It is clear from results reported for recent monitoring that significant changes to at least some Kawerau surface thermal features have occurred. The principal change has been cooling of heated ground and the 'drying up' of some warm/hot springs. The Peer Review Panel, in their review of the 2019 Annual Joint Technical Report, recommended to BOPRC that historical data be reviewed to better understand medium term changes that have occurred, factors responsible and if appropriate, to recommend changes to the monitoring programme. The implications of any changes to significant surface features and mitigation and remediation also needs consideration.

Subsidence

What is it and how is it measured?

Taking of fluid from New Zealand geothermal systems usually results in downward movement of the ground surface above the reservoir (subsidence). This is in addition to naturally occurring regional subsidence. At Kawerau historic subsidence rates have been relatively modest. That said, land above the reservoir hosts industrial machinery some of which is particularly sensitive to non-uniform subsidence (known as tilt).

Subsidence at Kawerau is monitored by means of repeat precise levelling surveys of several hundred benchmarks installed across the field. This benchmark network is linked to a 'stable' benchmark which is located outside the field and therefore not susceptible to geothermal influence. Subsidence within the geothermal field is determined in relation to this benchmark.

Past surveys at Kawerau have shown a relatively large bowl of slowly subsiding ground above the reservoir. Within this bowl are localised areas within which the ground is subsiding at higher yet still relatively modest rates. Shallow processes that are unrelated to the taking of geothermal fluid are thought to be largely responsible for these localised areas, also known as bowls.

Until 2018 it had been the practice to conduct full precise levelling surveys every four years. By 'full' is meant that all benchmarks accessible at the time of survey are included. Partial surveys (utilising only part of the benchmark network covering locations with level sensitive infrastructure) have been carried out in the intervening years. In 2019, a decision was taken by the Consent Holders to conduct full surveys every year. The survey carried out in 2019 was the second consecutive full survey carried out at Kawerau.

[7] A taxon is a group of one or more populations, in this case, plant populations, considered to form a unit

Recent trends

The 2019 survey comprised precise levelling of 784 benchmarks covering an area of approximately 50 km^2. This survey included also levelling of 40 well casing head flanges for the first time in the subsidence survey, on as many wells as were accessible.

Comparison of processed levelling data for the current and previous surveys, showed an overall decrease in subsidence rates across the field. The area bounded by the 10 mm/year subsidence, 10.6 km^2, was smaller than that for the previous comparison of full surveys (2014 and 2018) - 14.1 km^2.

Also, subsidence rates for four of five localised areas identified from previous surveys, were less than rates reported for previous surveys, with one exception which has shown continually increasing subsidence rates since it was first recognized in 2016. Maximum subsidence rates for these five bowls, for the latest period, ranged from 26 mm-99 mm/year.

The subsidence pattern across the mill areas has been fairly regular with low tilt gradients, except for the area north of Asaleo Care and the western part of the CHH Wood Products in the timber storage areas, Tilt gradients at the NST paper machines were lower in the latest period.

While most ground level change concerns subsidence, it is not unusual for there to be areas where the ground level has risen relative to the reference benchmark. This is known as inflation. An area of inflation at the western edge of the field was reported for the 2018-2019 reporting period. The maximum rate, +11 mm/year was reported at the junction of Old Coach Road junction and SH 34.

In summary, subsidence rates to date, including tilt, are relatively modest and are not of concern.

Field development

There are several reasons why new production and injection wells need to be drilled from time to time. It may be due to increased demand for fluid, or due to declining performance on some wells. Production wells are sometimes ‘worked over’ to remove mineral scale that has deposited in the well bore reducing flow at the wellhead significantly.

The capacity of injection wells to accept geothermal fluid may also decline due to mineral deposition. Injection wells may be ‘worked over’ to restore some or all the lost capacity while new wells are drilled as needed to maintain the required injection capacity.

Injection wells may also be drilled to reduce the risk of potential cooling issues related to ‘short circuiting’ of injected fluid with the production sector of the reservoir.

Prior to commencing drilling, Consent Holders are required to submit to BOPRC for approval, a well plan which details the drilling location, the proposed well track and a prognosis of the anticipated sub-surface geology. Following completion of the well, they provide BOPRC with an end of well report which details the design as completed and early test results.

New wells

Several new wells were drilled at Kawerau during 2019:

- Geothermal Developments Limited (GDL) completed a new vertical shallow injection well (GDL3) due to the decline in injection capacity of existing wells (brought online in August 2020).
- In November 2019, Mercury (KGL) drilled a new deviated[8] deep injection well (KA59). Early testing of the well was in progress at year end (brought online early 2020). KGL also commenced drilling a deviated production well (KA58) during December 2019.
- Ngati Tuwharetoa Geothermal Assets, drilled a new deviated deep production well (KA57) during 2019. At the close of 2019 the well had yet to be brought online (Figure 4).

Figure 4: Well testing for KA57

[8] A deviated well is one for which the well track at depth is directed at some angle from vertical. The bottom of a deviated well may be several hundred metres or greater horizontal distance from the location of the wellhead.

Numerical reservoir modelling

Computer modelling is the most advanced tool currently available for management of the reservoir. Numerical reservoir models, calibrated using key reservoir data, are used to gain an understanding as to how the reservoir has responded to historical takes/injection and to evaluate potential reservoir responses to various future take/injection strategies, including investigating and evaluating options for adaptive management in the event of a reservoir issue.

Mercury maintains a numerical reservoir model of the Kawerau geothermal field on behalf of the Consent Holders. The Kawerau Peer Review Panel submitted to BOPRC in June 2019 its final report on their review of the updated reservoir model known as KRMv4.

The Panel, whilst concluding that the KRMv4 update was as good as or better than the KRMv3 version of the model in terms of matching historical production and reservoir pressure data, noted that KRMv4 may be less reliable in terms of forecasting reservoir responses to production from the A8D block from which TAOM produces, than other parts of the Kawerau reservoir. That said, the Panel concluded that the model continued to be an acceptable working hypothesis of the TAOM sector of the Kawerau reservoir.

Mercury, assisted by geothermal specialists from NTGA and TAOM/GDL, commenced a process to ‘update’ KRMv4, to improve model matches to ‘natural’ state temperatures and address inconsistencies in the permeability distribution in the TAOM sector (the A8D block) of the reservoir model.

The Peer Review Panel concluded that matches to the reservoir natural state and production history achieved using KRMv5 were of better or comparable quality to those obtained using KRMv4. Importantly, changes made to the numerical model appeared to address concerns raised by TAOM in relation to the modelling of reservoir conditions beneath and adjacent to the A8D block.

On the Peer Review Panel’s recommendation BOPRC adopted KRMv5 as the official numerical reservoir model for Kawerau in November 2019.

Future work

Review of discharge strategy

The discharge strategy for Kawerau Geothermal System (i.e. reinjection and discharges of geothermal fluid to land or water) is a key consideration for sustainable management and is addressed in resource consents and the Kawerau System Management Plan. The current strategy and potential future changes are being considered by resource consent holders and BOPRC with support from the Peer Review Panel. The Panel has recommended the exploration of injection options for Kawerau, conceptually and through reservoir simulations, with a view to optimising the discharge strategy, particularly with respect to the potential for ongoing marginal recharge and associated cooling effects.

Review of surface monitoring

The Panel in their review of the 2019 Annual Report recommended a review of monitoring data to determine what, if any, changes in near surface ground temperatures and surface thermal features have occurred over the monitored period and whether any such changes might be related to the taking and injection of geothermal fluid. It would include also, a review of the monitoring programme, including overall objectives and those of individual surveys and any recommendations for change. Bay of Plenty Regional Council is working with consent holders to progress this review.

Review of Kawerau System Management Plan

The Kawerau System Management Plan has approved by Council in 2018. However, it now needs to be reviewed to reflect changes in best practice management on the system, including adaptive management processes and modelling. Any changes to the discharge strategy and monitoring programmes also need to be reflected in the System Management Plan. Bay of Plenty Regional Council will work with Consent Holders to review the plan in 2021.