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Evaluation of the Downflow Effect on The Well "X" to Reservoir Temperature Decrease in the Field "Y" Using PetraSim Geothermal Reservoir Simulation

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ABSTRACT

The Field "Y"is one of the geothermal fields which produces two-phase fluid in the form of steam and water which is dominated by water. However, one of the wells in the field produced a single-phase fluid in the form of dry steam, namely the "X" Well. This is because the "X" well has four feed zones, where the shallower feed zone becomes a source of production (inflow) in the form of a steam cap, whereas the deeper feed zones do not produce geothermal fluid. After all, it has died due to downflow or cold-water flow from shallow feed zone that goes down. This causes the flow of fluid in the deep feed zones can't come out due to the pressure which is less than the pressure of the downflow. The inflow is from the feed zone located at a depth of 2,500 - 3,000 ft, while the downflow at the feed zone is located at a depth of 2,630 - 4,734 ft MD (from the negative PTS survey results). Besides turning off the deeper feed zones, this downflow can also cause a decrease in temperature in the reservoir field. If the temperature drop in the reservoir lasts for a long time it is possible to cause the reservoir to become dead due to cooling. Therefore, the effect of downflow to changes in temperature in the reservoir must be analyzed. With PTS "X" well survey data, a simulation will be conducted using PETRASIM software to see the effect of the downflow. From the simulation, the result of temperature decrease for 60th, 100th, 200th and 300th year of simulation time setting is 0.25%, 0.58%, 1.42%, and 2.21%. For temperature decrease per year is 0.0042%. so, the results show a very small decrease in reservoir temperature, so that the reservoir is still in good condition even for the next 300 years.

1. INTRODUCTION

The Field "Y" geothermal system is associated with several volcanic eruption centers around Mount "X". Geothermal manifestations consisting of fumaroles and sulfate hot springs that are directly related to the geothermal system are spread at elevations > 1050 masl, while bicarbonate hot springs and bicarbonate-chloride mixed springs can be found in areas with lower elevation. The chloride hot spring is located in the north of the area about 12 km from the geothermal site.

In the Field "Y" there are several wells experiencing downflows. Downflow is a flow that falls to the bottom of a well with a low temperature and can cause a decrease in reservoir temperature. This downflow causes a scale in the isolated liner area and can close the feed zone, thus making the production of a well go down. Downflow in the Field "Y" is thought to be caused by the entry of water flow from outside the reservoir (return outflow fluid) with low temperatures into the well. If this process takes place for a long time it is likely to affect the temperature in the reservoir.

2. TEMPERATURE LOGGING WELL SECTIONS THAT FOLLOW

Four typical temperature profiles in wells after drilling are shown in Figure 1 to 4 (include reference). It is assumed in the schematics that three feed zones are active in the well. In Figure 1 (profile A), water is injected into the well and is lost into the three feed zones, a, b, and c. The temperature increases gradually with depth due to conductive heating of the down flowing water from the hot formations around the well. As we pass the first two feed zones the slope of the temperature curve changes slightly as some of water is lost into the feed zone and the continued flow down the well is slower than above the feed zone but the heat conduction rate unchanged. The down flow ends at the deepest feed zone. Often this is the most pronounced feed zone seen in the temperature log showing rapid heating below it. This does, however, not necessarily mean that it is the most permeable zone accepting more water than feed zones above. Profile A is the most common profile for the production part of geothermal wells during injection.

Profile B (Figure 2) is also measured with injection. It is typical for high permeable wells with multiple feed zones. The temperature log shows temperature steps at the shallow feed zones (a, b) due to inflow of warmer water mixing with the injection. The fluid mixture flows down the well and into the deepest feed zone. All the three feed zones are clearly seen in the log but it should be pointed out that possible outflow zones in the interval between feed b and c can't be excluded due to high flow in the well. Such out flow should show up in the log as a change in slope as in profile A. The reason for the inflow from the uppermost feed zones is the high permeability of the well so the injection into the well is not sufficient to lift the pressure above the reservoir pressure at feed a and feed b. Increased injection will increase the pressure in the well and change the inflow into out flow, first for the deeper feed zone (b) and eventually also feed a at very high injection rates. The temperature profile will then be like profile A. Profile B is therefore more common at low injection rates than high injection rates and for most wells a down flow from shallow to deep feed zones is observed in temperature logs after injection is stopped at the end of drilling and the well starts to heat-up.

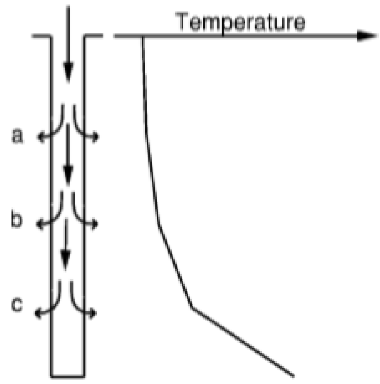

Figure 1 : Water injection

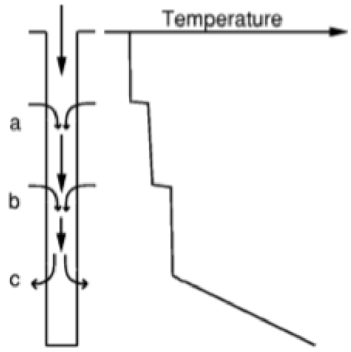

Figure 2 : Water injection

3. BASIC THEORY OF PETRASIM

3.1 Numerical Model

For numerical simulations time variables and continuous spaces must be discretized. In modeling the geothermal system using a simulator Petrasim, the system to be modeled is divided into several interconnected blocks or elements so that diversity in fluid and rock properties can be calculated. The results of the discretization of non-linear algebraic equations are set out in groups of equations that are solved using Newton's iteration Raphson.

3.2 Modeling

The Petrasim Simulator (PetraSim User Manual. June 2007), using TOUGH2 as the simulation software, can solve the equilibrium equations of mass and energy that describe the flow of fluid and heat in multiphase and multicomponent systems. Fluid flow follows Darcy's law for flow in porous media, where the volume flux is proportional to the pressure gradient. The flow of heat occurs because the process is conductive and convective. The depiction of the thermodynamic conditions is based on the assumption of local equilibrium of all phases (liquid, gas, solid). Relative permeability is used to model as two-phase flow. The boundary conditions can be written in constant pressure and temperature or constant mass and heat flux. The code can be solved well with transient problems and equations using the integration of the finite difference method for pressure and temperature (fluid saturation) in each block, with mass and heat flow occurring on the connection between blocks.

3.3 Basic Equation

In the Numeric Model, the flow from one block to another block is calculated by the Darcy flow equation, which is mathematically stated with equation:

$$Qm = -\frac{k}{v}\left(\frac{P_2-P_1}{\ell}\right) \quad (1)$$

That flow in three dimensions stated with:

$$Qm = -\frac{k}{v_1}(\nabla P - \rho_1 g) \quad (2)$$

If the flow consists of two phase, there are steam and water then the mass flow rate of fluid is

$$Qm = Q_{ml} + Q_{mv} \quad (3)$$

Each phase considered to flow according to Darcy, so that

$$Qm= -\frac{kk_{rv}}{v_1}(\nabla P - \rho_v g) \quad (4)$$

$$Qml= -\frac{kk_{rl}}{v_1}(\nabla P - \rho_1 g) \quad (5)$$

where

Q = Flow rate

v = Viscosity of the fluid flowing

k = Permeability

p = Pressure

g = gravitation term

rho = Density

dp/dl = Pressure gradient

The rate of heat flow from one block to another is determined using the following equation

Qe = Qe(convection) + Qe(conduction)

The rate of heat flow by convection is

Qe(convection) = h1 Qml + hv Qmv

While the rate of heat flow by conduction is

Qe(conduction) = -K

So, the total heat flow is

Qe = h1 Qml + hv Qmv – K

where h1 and hv is enthalpy of water and steam

4. DOWNFLOW IN WELL

For downflows to occur, it is necessary for the intermediate feed zones to develop a higher "potential" than the deep feed zones to both reverse the normal wellbore flow and overcome the pressure in the deep reservoir. This means that the pressure at the intermediate feed zone (plus the hydrostatic head in the wellbore) must be higher than the deep feed zone reservoir pressure so that the downflowing fluid can enter the deep reservoir. The hydrostatic head is a function of fluid density and is therefore a function of the inflow temperature, a lower temperature (higher density) downflowing fluid will result to a greater hydrostatic head. Hence, if the shallow recharge fluids are causing both pressure support and cooling in the shallow reservoir, these will increase the potential for downflows to occur.

Analysis of historical downhole pressure survey data indicates that the deep reservoir pressure drawdown over the past 35 years has been ≈150 psi (10.3 bar) greater than in the shallow reservoir (Figure 4). Based on this data and an assumed inflow temperature of 450°F (232°C), the potential difference between the shallow and deep reservoirs has been calculated and the basic condition for down flows to occur (shallow potential > deep potential) has been satisfied since the early 2000s. However, individual well conditions, such as feed zone temperatures, pressures and permeabilities, are also important factors in determining whether downflow will occur or not. It is therefore very difficult to determine the "trigger" condition that allows downflow to start in any particular well. If the well is producing from the deep zones, then the shallow inflow fluid also needs to overcome the momentum of the rising column and reverse the flow. In some cases, the onset of the downflow was preceded by an upset or abnormal condition, such as a plant or separator station shutdown, that caused a perturbation in the wellhead pressures and was sufficient to change the dynamics in the wellbore. However, in most cases, there was no upset condition and the possible "trigger" was not apparent.

From the information of well "X" in the field "Y", namely as follows:

- Silica Scaling Index: <1 (no potential scale)
- Flow pattern: Annular (no potential scale)

From this information, wells "X" is not going to run into scaling problems in a time that is sufficiently long. However, the well is experiencing scaling and it formed in a period of a few months only. Because othis the authors are looking for information and go back and look for some references to find out the causes of actual formation of scaling in wells "X" (Sunio E. U., 2015)

5. DOWNFLOW IN WELL "X"

After doing the collection of information the authors concluded that the scaling in the wells "X" is caused due to the water cooler with a mass that is a great entry into the well so that makes the flow of downflow in the wellbore terms of this can be seen from the graph results of PTS, which is as follows:

1. From the results of the closed and flowing PTS in 2013 (Figure 5) before scaling occurs, these results show that there is a change in temperature or the temperature drops suddenly at a depth of 2630 ft. MD (slightly below the 13-3 / 8 "shoe case) Also at this depth the spinner shows a sudden drop, indicating that cold fluid from outside enters the well so the temperature is lower at that depth.

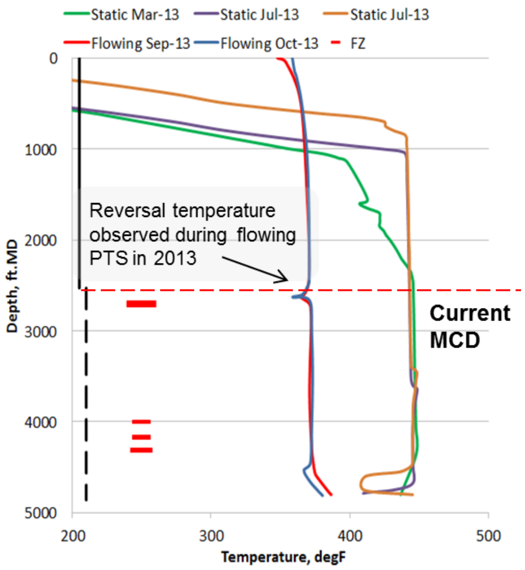

Figure 5 : PTS results in the "X" well before the scale occurs

2. The results of the Maximum Casing Depth (MCD) evaluation on the "X" well (Figure 6) show that it has changed more superficially since 2015 and are currently at the same depth as the reversal temperature location, which is at the top of the liner. It is suggesting that there is a scale that makes the depths of clean maximum more shallow.

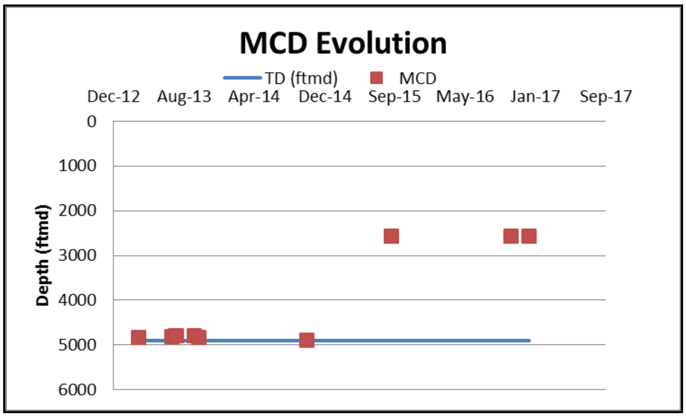

Figure 6 : Development of MCD

3. The results from the PTS after the scale occurred (Figure 7) and cleaned in 2018, showed a negative spinner reading, at a depth of 2900 - 4734 ft.MD, indicating a downward flow.

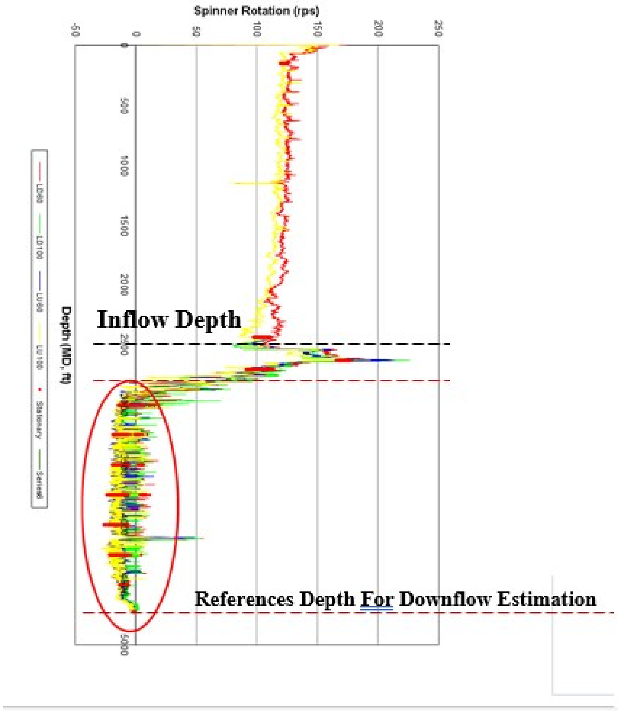

Figure 7 : Downflow and Inflow in the feed zone in the "X" well

5. CAUSE OF DOWNFLOW

The cause of the flow of downflow is as follows:

- There are two reservoirs, namely a shallow reservoir and a reservoir in the middle which is limited by a formation that has lower permeability than the reservoir. There has been no research to determine what formations have low permeability in the "X" field, however, from references in the Mak-ban field there is an Andesite Lava Marker (ALM) which limits the two reservoirs.
- Cooling the water in a shallow reservoir. The shallow reservoir will initially become an inflow flow, but after long production, the water in the shallow reservoir will cool down because it is not connected to the deep reservoir. Coldwater can also come from cold fluids originating from outside the reservoir zone flowing towards the "X" well (Figure 8).
- Water cooler from the reservoir shallow will go into the wellbore and will tend to fall (Figure 9) because the water has a lower temperature and higher density and can therefore cause a pressure that is large (plus pressure surface) compared with the pressure in the deep feedzones.

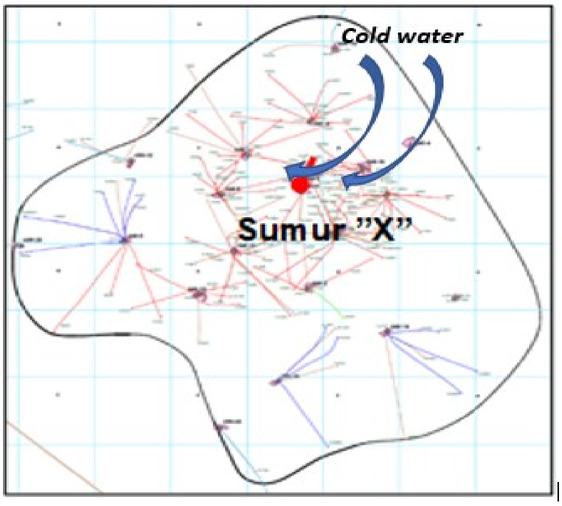

Figure 8 : Estimated cold water flow from outside the reservoir

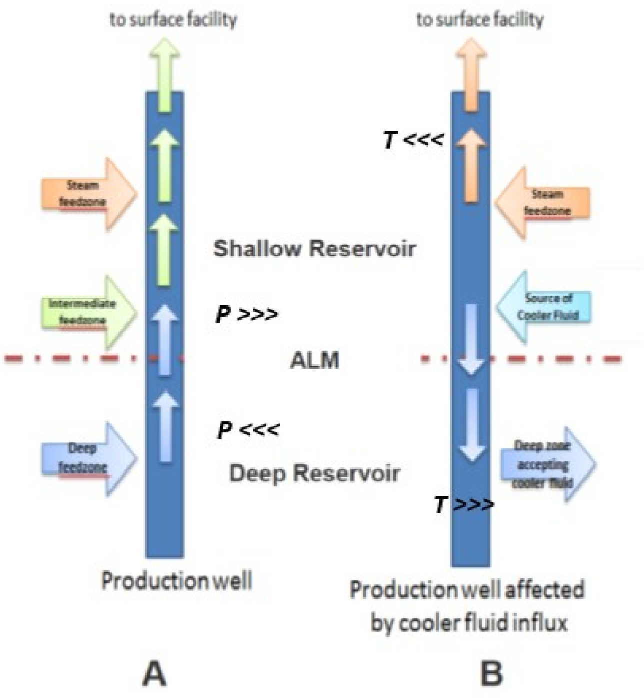

Figure 9 : Normal Well Production Condition (A) Compared to the Conditions After a Downflow Starts (B) (Sunio E. U., 2015)

Base on (Sunio E. U., 2015), when production wells are affected by shallow liquid flow and downflows, this can manifest various impacts depending on the extent of the disruption fluid. Impact of the ordinary happens is as follows:

- Increased production brine: In the beginning when the liquid that is a little more cold flow into the wellbore, the fluid it tends to be carried by the momentum of the flow of feed zone in and the level of production brine will increase without showing the changes are significant in the performance of wells.
- Fluctuations inflow (no downflow): With the increase in the flow of the fluid that is filled back in, it tends to be forming a column of water in the wellbore. It is to be detained by the pressure of the territory that is more in. Fluctuations will be seen in the flow pressure of the head of the well.
- Wells become producers vapor one phase (occur downflow): If the stacking column hydraulic in opening the well to overcome the pressure in the zone is in, in the end, the flow down to be achieved and the well may turn into all the steam and this generally will result in a loss of productivity are significant. The production wells then produce ≤ 20 kph (2.5 kg/s) of steam because they only produce from shallow vapor zones. In some cases, the production of steam is less than that expected, based on a calculation of the balance of the mass of pre -downflow, which indicates that the amount of water cooler that entry also can affect the productivity of the zone of steam.
- Well of sudden death: this is the case when the fluid that fills back really close zones vapor where productivity entirely is disconnected**.**

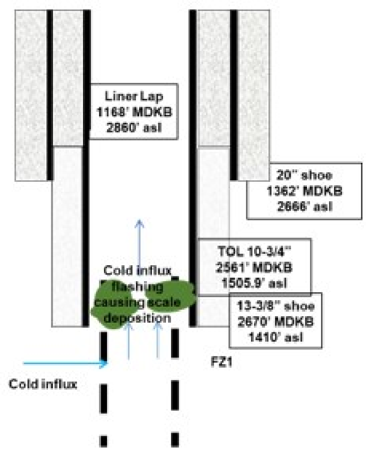

Figure 10 : Scale formation due to the inclusion of cold water at the top of the linear

A Downhole Video (DHV) was taken in Well "X" in 2016 to check on the possibility of scale formation around the top of the liner (Figure 10). The image (Figure 11) shows the scale at a depth of 2576 ft and after obtaining grab samples, the scale analysis showed that it had a composition of 40% amorphous silica. It is proved that the influx of cooler fluid is what causes scaling on the well "X".

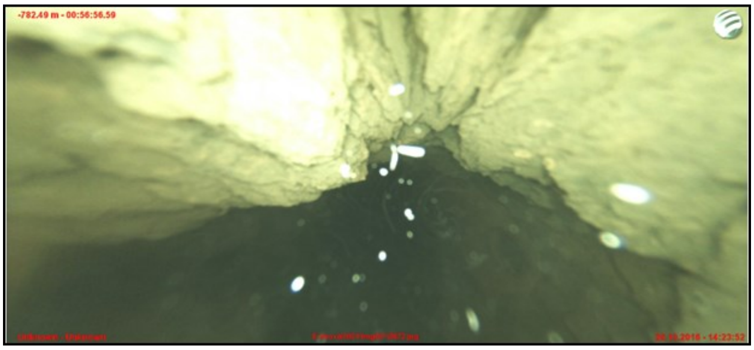

Figure 11 : DHV 2016 at the obstruction point, 2576ft.md

The "X" well is still able to produce because the produced feed zone is a steam cap in a shallow reservoir, so that this well can still produce but because only a small portion is produced so the steam is not too large. Also, the produced fluid is a one-phase fluid, which is only steam. This can be seen in the PTS results graph (Figure 12) which shows the inflow zone in the feed zone (positive value).

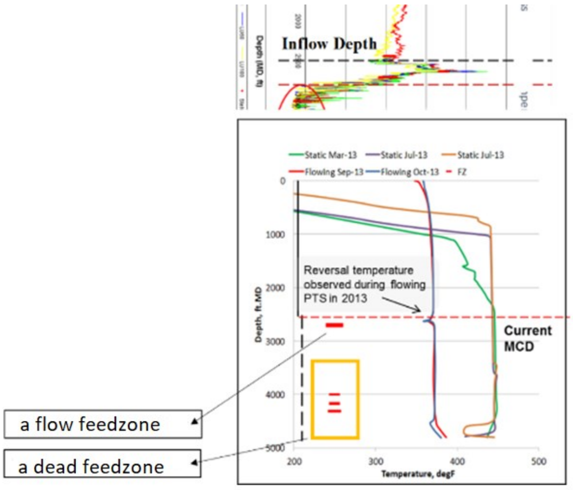

Figure 12: Feedzone inflow and feed zone that have died

With the flow of downflow is the water cooler of the reservoir zone shallower will fall to the lower temperature that is lower so that the liquid that will be more concentrated. The liquid is not able to rise upwards due to the pressure of its more substantial than the liquid with temperatures higher (reservoir in). This liquid will get stuck and eventually will form a scale. The scale is formed because the brine content of silica or scale forming substances is very high, plus because of the heat loss due to flashing in the zone, the scale will be faster to form.

If this is allowed to continue it can cause the level of cold water to be higher and will close the inflow zone in the feed zone and eventually will cause the wells to no longer produce or flow out. Also, quite a lot of cold water can cool the reservoir so that the reservoir temperature will go down and can cause even worse impacts.

6. DOWNFLOW RATE CALCULATION

The following is the calculation of the flow rate that causes the downflow to well "X" based on the (Sunio E. U., 2015) but use data well “X”:

Determine the equation to estimate the parameters to be used.

Table 1: Data line speed and spinner rotation well "X"

Line Speed		Spinner Response
Fpm	**m/min**	**Rps**
140	42	1.5
-140	-42	-4.5
200	61	2.3
-200	-61	-5.5

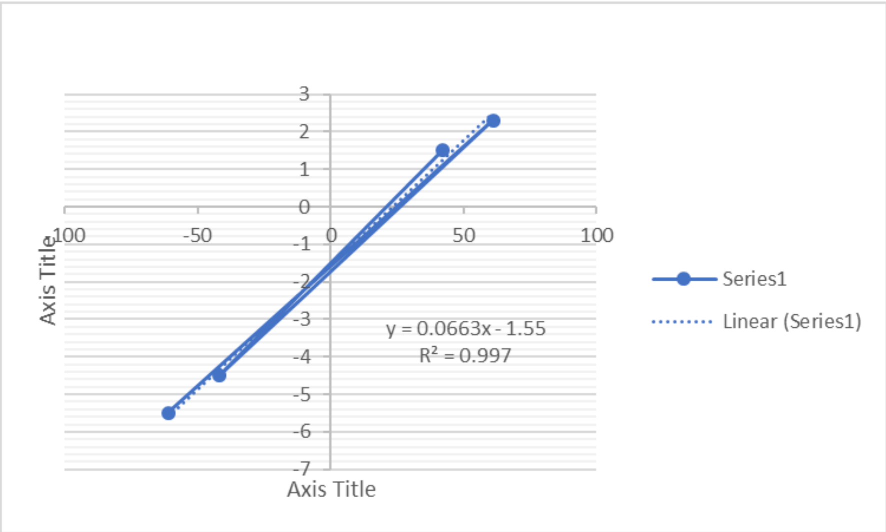

Figure 13 : Graph of tool speed va.spinner

Equations are obtained

Spinner, rps = 0.00663. velocity -1.55

So,

When velocity = 0, then rps = -1.55 (negative)

When rps = 0, then the velocity = 1.55 / 0.00663 = 24 m / min (77 fpm)

From the data above shows that rps worth of negative indicates that the spinner rotation is inverted (negative), thus showing that the downflow. In addition to the speed that is worth positively confirm that the downflow going on with the speed of the.

Furthermore, the determination of the flow rate of downflow by means as follows.

Liner diameter = 9625 inch (0.244 m)

Effective x-sectional area $= \pi \left(\frac{D^2}{4}\right)$

$= 3.14 \left(\frac{0.244^2}{4}\right)$

= 0.0469179 sq.m (0.50502 sq.ft)

Fluid velocity (x-intercept) = 24 m / min (77 fpm)

Volumetric flow = Effective x-sectional area x Fluid velocity (x-intercept)

= 0.0469179 x 24

= 1.096874 cubic m / min (38.735743 cubic ft / min)

Density (240 ° C) = 813.6697 kg / cubic m / min

Flow rate = (Volumetric flow x Density) / 60

= (1.096874 x 813.6697) / 60

= 14.87488 kg / s (118.05648 kph)

So, flowrate which causes the downflow is at 118.05 kph.

Downflow is highly not desirable to happen, by because of it, there are several ways to cope with the flow of downflow such, are as follows :

- Isolation downflow feed zone, an alternative that the first is the zone that must be isolated or closed in order not enter into the wellbore with a way to cut isolated liner and replace it with the casing and cement a regular.
- Injection resins or fluids similar, so feed zone that can be covered way others do is to inject resin or fluid more who were able to close the feed zone.

At the moment is in the field “Y” yet there did handlers such as that presented above, will be but the handling while due to the formation of scale due to downflow it is by way of cleaning the scale it by using the method of broaching (impingement) or roto jet within the period specified to maintain production remain good. The expected future found the technology or the method that is more effective to tackle the problem is because it is very influential for the continuity of the production of a well even for many wells and can affect the supply of steam to generate electricity.

7. THERMAL EFFECT OF THE RESERVOIR

A simple process model (Figure 14) was constructed using the PETRASIM reservoir simulator to investigate the potential impact of the downflows on the deep reservoir and check if there is likely to be a significant thermal effect on the production feed zones in well “X”.

The initial deep reservoir conditions in the model are EOS1 (single phase water) at 297.39 °C with the time is infinite, which is consistent with the average conditions in the deep reservoir at the “Y” field.

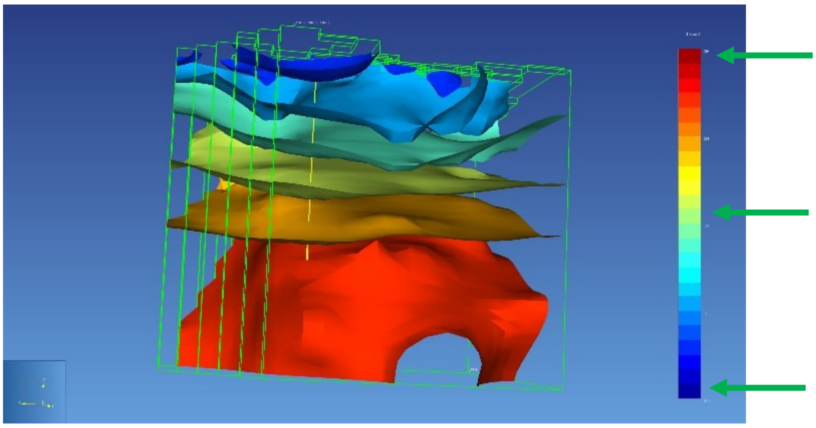

Figure 14 : Natural state

Well “X” is located XY in 2250,2150 with depth is 2010 till -750. Next change the status of the well "X" to the injection well. Because downflow is the flow that enters the well with a flow rate of 14.87488 kg/s and enthalpy of 910.4 kj/kg (temperature is 212.78oC).

After that, do a simulation with different time settings to see the extent of the effect of downflow on the temperature of the reservoir. Sting time used is 60th year, 100th year, 200th year and 300th year.

Figures 15, 16, and 17 are the results of the simulation with adjusted time settings:

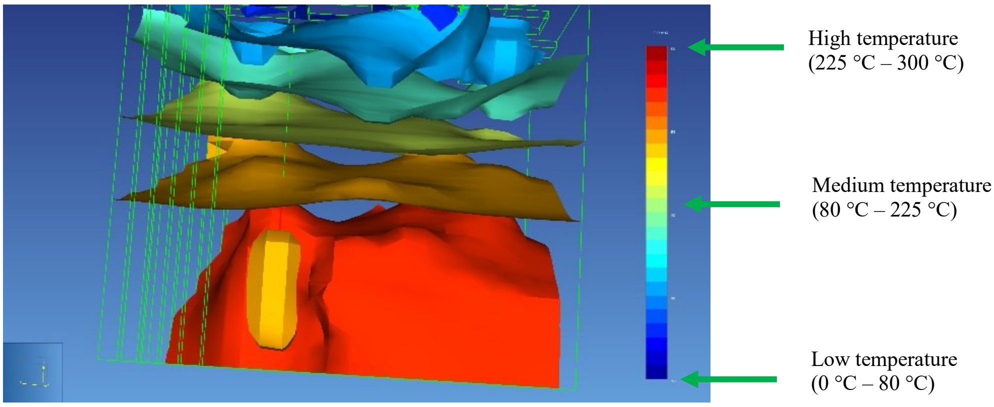

Figure 15 : 60th year time setting

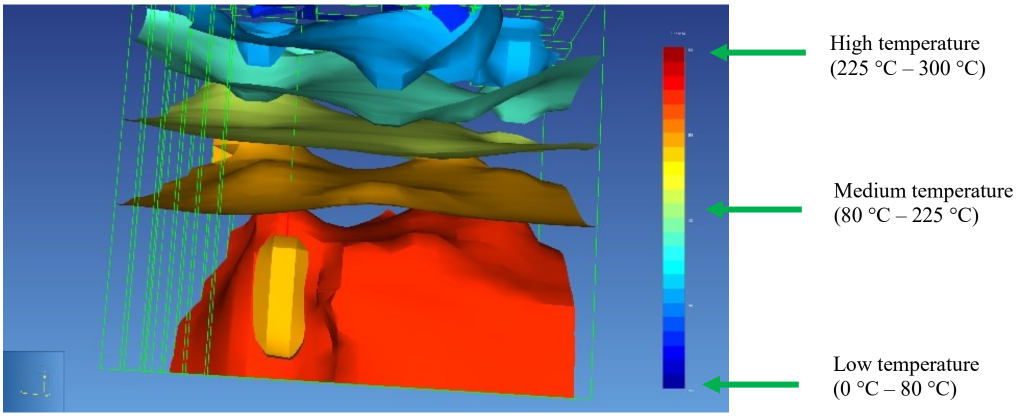

Figure 16 : 200th year time setting

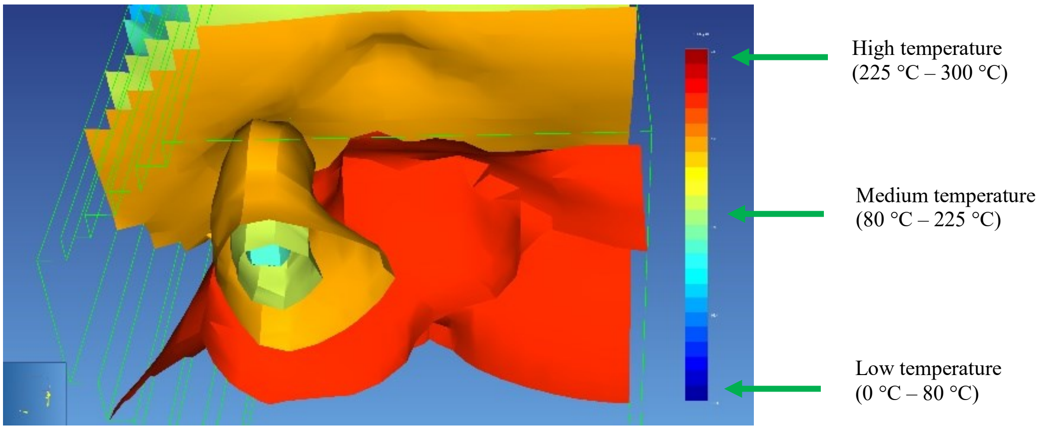

Figure 17 : 300th time setting

In the picture above, it is clear that the downflow will reduce the reservoir temperature. From the resulting simulation, the temperature per depth data is obtained in Excel. Then the data is compared with the temperature data in the initial conditions without injection. From this comparison, the difference in temperature for each depth can be obtained. In the time setting of the 60th year, there is a change in temperature of 0.25%, and the extent of the temperature change is not too wide. Furthermore, in the 100th year there is a temperature change regulation of 0.58%, which means that the area where the temperature drops is wider. Furthermore, for the 200th year the temperature decreased by 1.42%. the area that was falling was getting wider and even near the well the temperature had dropped drastically with a yellow mark. In the 300th year there is a temperature change of 2.21%, this causes the area of temperature drop to become wider and the area near the well has decreased significantly, marked by a change in color to blue. For more details, the effect of downflow on temperature reduction can be seen in Table 2 and Figure 18.

Table 2: Percentage temperature decrease

Year Simulation	Temperatur Drop, %
60- year	0.250948709
100 year	0.587119705
200 year	1.416407732
300 year	2.218691221

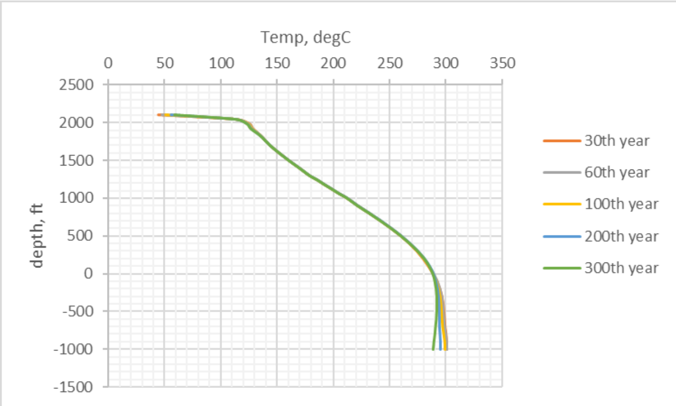

Figure 18 : Difference in temperature reduction with differnt simulation time settings

From the calculation results obtained changes in reservoir temperature by the flow of well "X" are 0.0042 per year. This means that the effect of downflow from well "X" is so small that it does not significantly reduce reservoir temperatures even for the next 300 years. However, it must also be analyzed by several other wells that experience downflow, because if there are many downflow wells, the reservoir temperature will drop faster. Meanwhile, this paper is limited to only processing one well data due to the limited data of other wells that the authors obtain in the field.

8. CONCLUSION

- The downflows are significantly impacting the productivity of the affected wells but there is no clear evidence of negative impacts to neighboring wells to date based on existing limited data. The estimated total downflow rate at present time in the well "X" is about 14.87488 kg/s (118.05648 kph) and the temperature is about 212.78°C.
- Field "Y" with both shallow and deep feed zones is at risk of wells developing a downflow which may result in a significant loss of productivity. Wells need to be evaluated on a case-to-case basis to determine if cool fluid downflow will occur as downflow is dependent on a variety of well properties (i.e., temperatures, pressures, productivity indexes, etc.), although, in most cases, there may be some signs (say, from downhole survey data and geochemistry data) that may indicate its onset.
- The measured temperatures at the shallow inflows have been found to average 212.78 ºC which indicates that there has not been significant cooling of the shallow reservoir.
- The result of PETRASIM simulation to see temperature decrease for 60th, 100th, 200th and 300th year of simulation time setting are 0.25%, 0.58%, 1.42%, and 2.21%. For temperature decrease per year is 0.0042%. so, the results show a very small decrease in reservoir temperature, so that the reservoir is still in good condition even for the next 300 years.
- The effect of downflow from well "X" is so small that it does not significantly because the temperature decrease per year is 0.0042%.

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