JOURNAL OF PETROLEUM AND GEOTHERMAL TECHNOLOGY
ISSN: 2723-0988, e-ISSN: 2723-1496
Vol. 5 No. 1 2024

Low Salinity Water Injection Evaluation and Mature Field Development at Anggoro Shallow Sand, Sangasanga Field

Dani Novriyandi[1*)]
[1)] Petroleum Engineering, Universitas Pembangunan Nasional Veteran Yogyakarta
* corresponding email: novriyandidanidin@gmail.com

ABSTRACT

Anggoro's shallow sand was perforated at well ANG-1033 (D4-N1 layer). Oil production in this well increased from an average of 15 BOPD to 170 BOPD. That the perforated layer was affected by low salinity water injection (salinity < 3000 ppm). Evaluation of water injection sweep efficiency was carried out using the Dykstra-Parson method, vertical efficiency of about 0.3, area efficiency of 0.7, and displacement efficiency of 0.3. The Estimated Ultimate Recovery (EUR) of this well provides is 197 MBbls with an additional RF of around 20 %. This increase is due to the low salinity water injection sweep mechanism that occurs. The clay content plays an important role in the mechanism that occurs in this layer, these mechanisms fines migration, increase in pH, multi ion exchange, double layer effect, and salting in which these mechanisms result in increased oil recovery. Seeing the production results from the D4-N1 layer and oil production in this layer can still be maximized, in the future this layer can be developed with several programs such as reactivation, workover, and development drilling.

Keywords: Low salinity water injection, shallow layer, efficiency

I. INTRODUCTION

Anggoro structure is located in the Sangasanga Field, East Kalimantan. This structure is mature, indicating that oil production has declined, high water cut (around 96%), and it uses artificial lifts (ESP, SRP, HPU) to produce oil to the surface.

Water injection (waterflooding) is a secondary recovery method that is carried out in a field that has exceeded its primary recovery limit. In the Anggoro structure, water injection has been going on since 2008 with low salinity water.

The water used for injection can be distinguished based on the level of salinity, the classification can be seen in **Table 1.** below. Injection water with a salinity value below 3000 ppm is categorized as low salinity water injection.

Table 1. Water Salinity Classification (Sianturi, Julfree, 2021)

No	Classification	Salinity Range, ppm
1	Fresh water	< 1000
2	Slightly saline water	1000 – 3000
3	Moderate saline water	3000 – 10000
4	Highly saline water	10000 - 35000

Water injection with low salinity water injection is an IOR/EOR technology that increases the microscopic sweep efficiency of waterfloods by reducing and optimizing the injection water salinity resulting in a change in the wettability of the reservoir rock towards water-wet and increasing oil recovery (Parker et al., 2013).

Several parameters need to be considered in observing the effect of low salinity water injection, namely:

- Sandstone as a porous rock medium must contain a certain amount of clay which functions as a place for cation exchange to occur.
- Crude oil must contain polar acids or bases which mostly adsorb on the rock mineral surface.
- Initial formation water mainly containing divalent cations such as Ca^{2+} and Mg^{2+}.
- Increasing pH value when low salinity water are injected.
- Usually there is an increase in pressure and a decrease in rock permeability, this is related to fines migration.

This paper will discuss the positive impact of the injection of low salinity water on the Anggoro structure. The injection of low-salinity water into this structure has been going on for years.

JOURNAL OF PETROLEUM AND GEOTHERMAL TECHNOLOGY
ISSN: 2723-0988, e-ISSN: 2723-1496
Vol. 5 No. 1 2024

II. METHODS

In this study, the first step was to evaluate the water injection sweep efficiency. The method used to determine the sweeping efficiency in this structure is Dykstra-Parson method.

To see the effect of low salinity water injection, we will look at the parameters described in the introduction section above. To ensure the success of injection of low salinity water in the Anggoro structure, this is confirmed by the recovery factor (RF) from observation wells.

Since water injection in the Anggoro structure gives positive results for increasing oil recovery, it is necessary to consider developing the layer that has a positive effect from low salinity water injection. It is necessary to look at the remaining reserves, drainage areas, the condition of the wells, whether there is still potential for development from a risk and economic point of view.

III. RESULTS AND DISCUSSION

Evaluation of the performance efficiency of water injection in the D4-N1 layer was carried out using the Dykstra-Parson method. Using the method, the calculation results for vertical sweeping efficiency are 0.3, area sweeping efficiency is 0.7, and displacement sweeping efficiency is 0.3. This result concludes that the sweep from water injection in this layer is quite good.

In 2018, shallow layer D4-N1 perforation job was carried out in one of the wells in the Anggoro structure, namely ANG-1033. This perforataion job is based on the results of the RMT, where it is known that the oil saturation is between 15-40%. Oil production in these wells increased from an average of 15 BOPD to 170 BOPD.

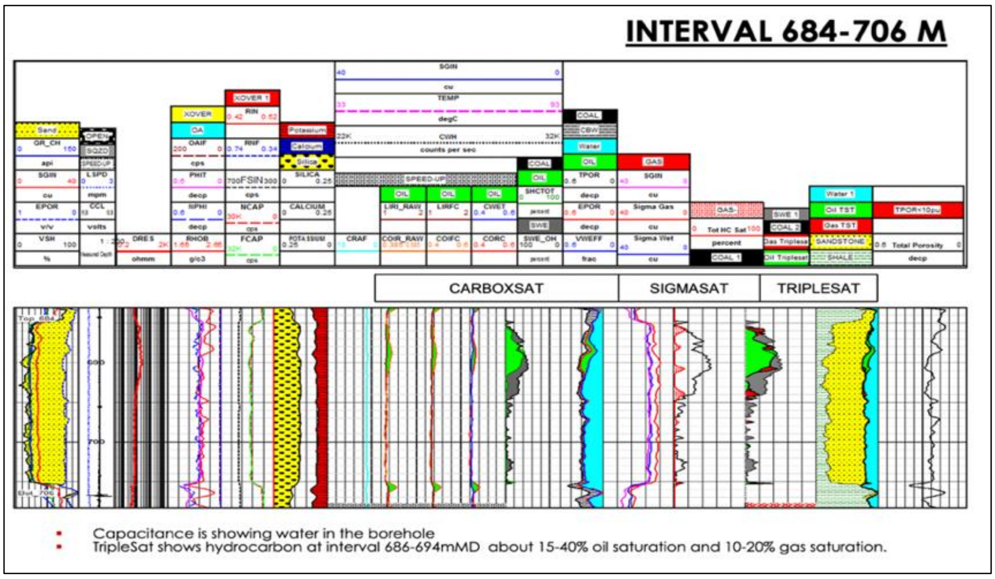


Figure 1. RMT of Layer D4-N1 in the ANG-1033 Well

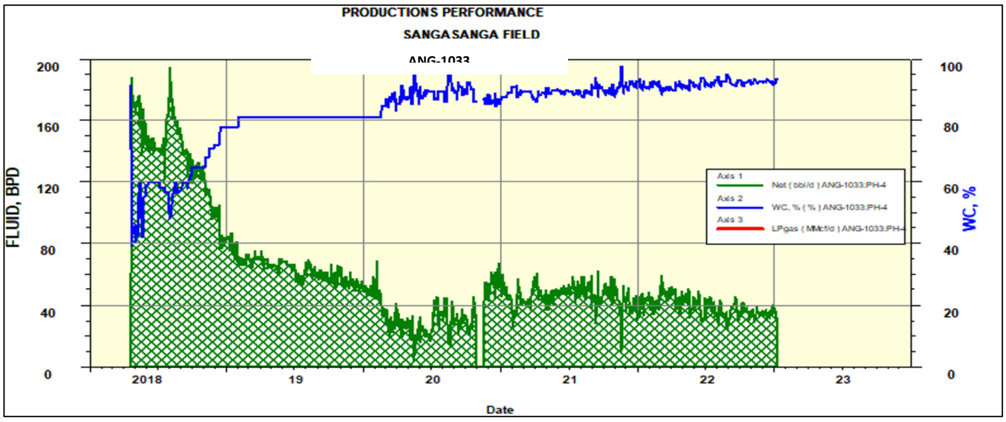
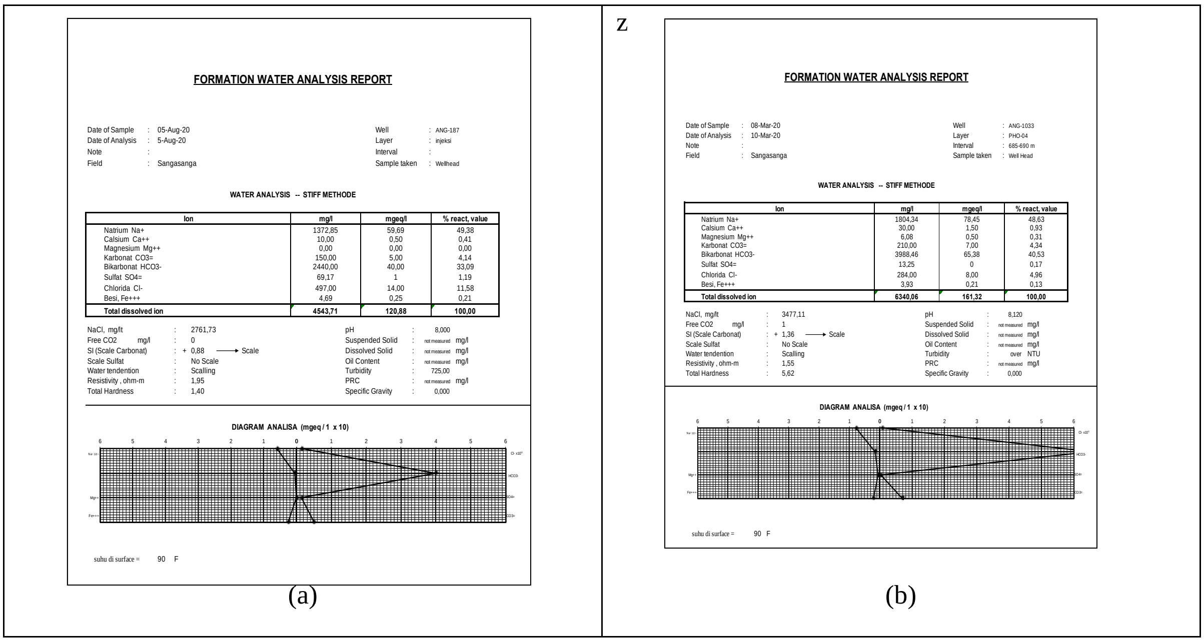


Figure 2. Production Performance of the ANG-1033 well, D4-N1 layer

JOURNAL OF PETROLEUM AND GEOTHERMAL TECHNOLOGY
ISSN: 2723-0988, e-ISSN: 2723-1496
Vol. 5 No. 1 2024

The perforated D4-N1 shallow layer is affected by the injection of low-salinity water. The injected water salinity value is quite low at 497 ppm, and the water salinity value in production wells is 284 ppm.



FORMATION WATER ANALYSIS REPORT (a)

Date of Sample : 05-Aug-20
Date of Analysis : 5-Aug-20
Note :
Field : Sangasanga
Well : ANG-187
Layer : injeksi
Interval :
Sample taken : Wellhead

WATER ANALYSIS -- STIFF METHODE

Ion	mg/l	mgeq/l	% react, value
Natrium Na+	1372,85	59,69	49,38
Calsium Ca++	10,00	0,50	0,41
Magnesium Mg++	0,00	0,00	0,00
Karbonat CO3=	150,00	5,00	4,14
Bikarbonat HCO3-	2440,00	40,00	33,09
Sulfat SO4=	69,17	1	1,19
Chlorida Cl-	497,00	14,00	11,58
Besi, Fe+++	4,69	0,25	0,21
Total dissolved ion	**4543,71**	**120,88**	**100,00**

NaCl, mg/lt : 2761,73
Free CO2 mg/l : 0
SI (Scale Carbonat) : + 0,88 → Scale
Scale Sulfat : No Scale
Water tendention : Scalling
Resistivity , ohm-m : 1,95
Total Hardness : 1,40
pH : 8,000
Suspended Solid : not measured mg/l
Dissolved Solid : not measured mg/l
Oil Content : not measured mg/l
Turbidity : 725,00
PRC : not measured mg/l
Specific Gravity : 0,000

FORMATION WATER ANALYSIS REPORT (b)

Date of Sample : 08-Mar-20
Date of Analysis : 10-Mar-20
Note :
Field : Sangasanga
Well : ANG-1033
Layer : PHO-04
Interval : 685-690 m
Sample taken : Well Head

WATER ANALYSIS -- STIFF METHODE

Ion	mg/l	mgeq/l	% react, value
Natrium Na+	1804,34	78,45	48,63
Calsium Ca++	30,00	1,50	0,93
Magnesium Mg++	6,08	0,50	0,31
Karbonat CO3=	210,00	7,00	4,34
Bikarbonat HCO3-	3988,46	65,38	40,53
Sulfat SO4=	13,25	0	0,17
Chlorida Cl-	284,00	8,00	4,96
Besi, Fe+++	3,93	0,21	0,13
Total dissolved ion	**6340,06**	**161,32**	**100,00**

NaCl, mg/lt : 3477,11
Free CO2 mg/l : 1
SI (Scale Carbonat) : + 1,36 → Scale
Scale Sulfat : No Scale
Water tendention : Scalling
Resistivity , ohm-m : 1,55
Total Hardness : 5,62
pH : 8,120
Suspended Solid : not measured mg/l
Dissolved Solid : not measured mg/l
Oil Content : not measured mg/l
Turbidity : over NTU
PRC : not measured mg/l
Specific Gravity : 0,000

Figure 3. Laboratory Analysis of Injection Water and Production of Anggoro Structure

In addition to good sweeping, the increase in oil recovery in the Anggoro well is also due to mechanisms that occur in the rock due to the low salinity water injection. These mechanisms include:

3.1. Fines Migration
Fine particles will be released from the rock during the injection of low salinity water, and this occurs in unconsolidated sandstone. This unconsolidated sandstone occurs in shallow layers where the rock has lower overburden pressures than deeper layers.

The clay in sandstone is swelling when it reacts with low-salinity injection water, then it will cause plugging in the rock pores and will reduce fluid mobility.

3.2. pH Increase
When the water is injected with low salinity, the salt content in the rock dissolves in the water and the NaOH concentration increases, and there will be an increase in the pH value because the acid material will be absorbed by the clay surface.

An increase in the pH value will form a surfactant in-situ where it will reduce the surface tension of the oil fluid on the rock, in the sense that it will change the wettability of the rock from oil-wet to water-wet.

Formation water in the Anggoro structure during the injection of low salinity water has increased. The trend can be seen in the **Figure 4.**

3.3. Multi-ion exchange
The injection water of the Anggoro structure has Na+ cations which allow the Multi Ion Exchange mechanism to occur in the low salinity water injection system in this structure.

3.4. Double layer effect
The low salinity water injected into the Anggoro structure contains Ca2+ and Mg2+ cations. The two cations make the electrostatic bond between oil and rock very low so that the oil will easily be released from the rock.

3.5. Salting in effect
The salt content in the injection water causes an equilibrium disturbance between oil, water, and reservoir rock, causing the solubility of the oil component in the reservoir water to increase. So the oil is easier to wash off.

In the case of the ANG-1033 well, injection of low-salinity water into the D4-N1 layer can increase the recovery factor by 20%. The estimated ultimate recovery increased from 164 MBbls to 197 MBbls.

JOURNAL OF PETROLEUM AND GEOTHERMAL TECHNOLOGY
ISSN: 2723-0988, e-ISSN: 2723-1496
Vol. 5 No. 1 2024

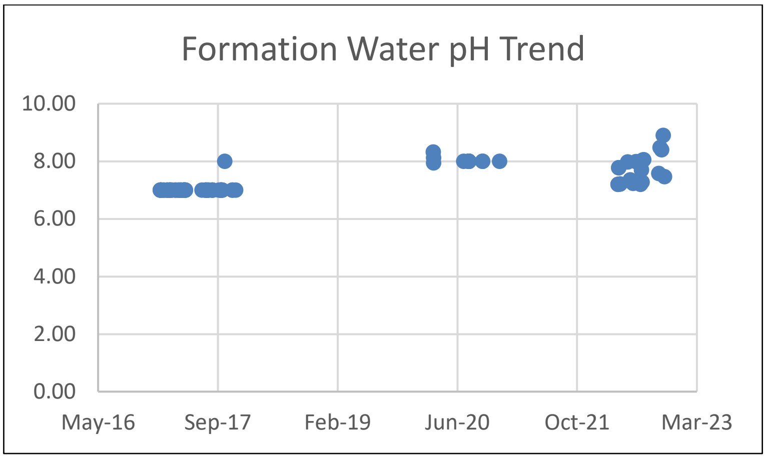


Figure 4. Trend of Formation Water pH of the Anggoro Structure

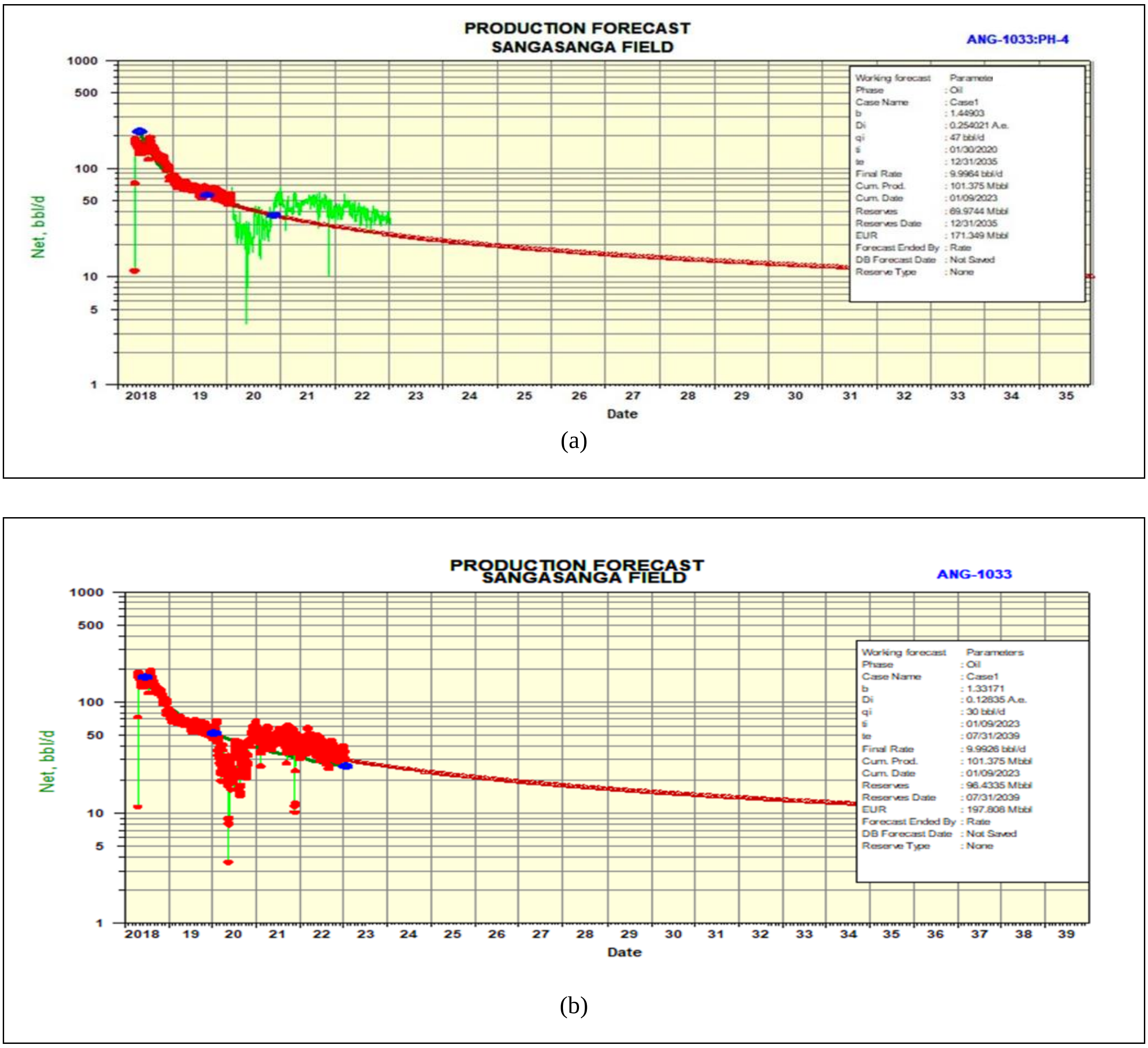


Figure 5. Decline Curve Analysis ANG-1033

Seeing the positive effects resulting from the of low salinity water injection, a study was carried out regarding the continued development plan in this D4-N1 layer. Oil cumulative and drainage radius have been revisited on this layer.

JOURNAL OF PETROLEUM AND GEOTHERMAL TECHNOLOGY
ISSN: 2723-0988, e-ISSN: 2723-1496
Vol. 5 No. 1 2024

The following **Table 2.** describes the production cumulative and radius of the drainage that has occurred in this D4-N1 layer.

Table 2. Production Cumulative, Petrophysical Data and Oil Drainage Radius D4-N1 Layer

Well	Np (Mbbl)	Bo (bbl/STB)	Bw (bbl/STB)	Net Pay (m)	Net Pay (ft)	Porosity	Sw	A (Acre)	Oil Drainage Radius (Ft)	Oil Drainage Radius (m)
Blok Tengah										
ANG-175	467.976	1.08	1.002	20	65.62	0.25	0.4	18.91046	512.059	156.068
ANG-234	124.308	1.08	1.002	22	72.182	0.25	0.4	4.566515	251.6294	76.69291
ANG-236	177.378	1.08	1.002	15	49.215	0.25	0.4	9.556898	364.0219	110.9485
ANG-298	724.78	1.08	1.002	22	72.182	0.25	0.4	9.3188	359.4587	109.5577
ANG-193	843.83	1.08	1.002	20	65.62	0.25	0.4	11.93442	406.7895	123.9834
ANG-1126	4.1	1.08	1.002	14	45.934	0.25	0.4	0.082839	33.89106	10.32949
Blok Selatan										
ANG-233	322.263	1.08	1.002	27	88.587	0.25	0.4154	9.900282	370.5039	112.9241
ANG-184	54.264	1.08	1.002	13	42.653	0.25	0.4154	3.462337	219.1057	66.78016
ANG-293	468.907	1.08	1.002	23	75.463	0.25	0.4	16.47659	477.9722	145.6788
ANG-1033	100.928	1.08	1.002	23	75.463	0.25	0.4	3.546437	221.7508	67.58634
ANG-1037	97.021	1.08	1.002	22	72.182	0.25	0.4	3.564113	222.3027	67.75456
ANG-173	14.4693	1.08	1.002	8	26.248	0.25	0.4	1.461726	142.3646	43.39061
ANG-291	267.316	1.08	1.002	27	88.587	0.25	0.4	8.001467	333.084	101.5191

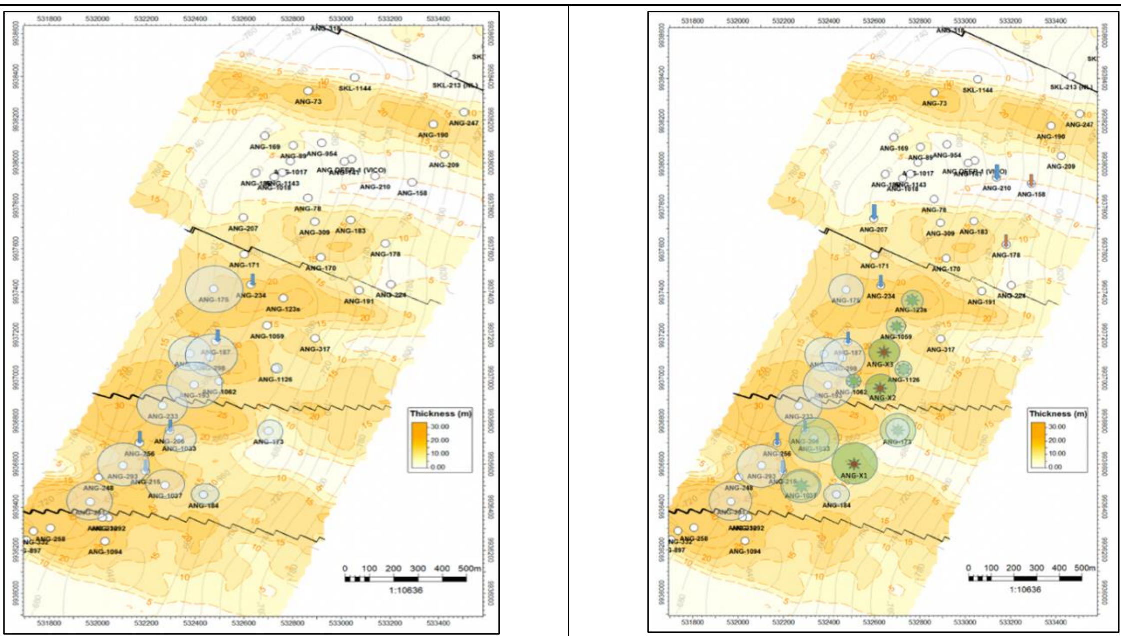
From **Figure 6. (a)** it can be seen that there are still several wells and areas that have not been drained optimally. To maximize the drain on this layer, several programs will be proposed including: drilling, reactivation, and workover.

The drilling program will be proposed in areas where there are absolutely no wells in the vicinity. There are 3 wells to drill in the D4-N1 layer, namely ANG-X1, ANG-X2, and ANG-X3.

The next program is reactivation, the wells that will be reactivated are wells that have previously been produced from the D4-N1 layer but the drainage radius is still small and can be maximized. Candidates for reactivation wells are ANG-123 and ANG-173.

The last program is workover that will be carried out on wells that have penetrated the D4-N1 layer but have never been produced from this layer. The wells for the workover plan are ANG-1037, ANG-1059, and ANG-1062.

Proposed wells for drilling, reactivation and workover can be seen in **Figure 6. (b).**



(a) (b)

Figure 6. Isopach Map and Drainage Radius of layers D4-N1

IV. CONCLUSION

1. The water injection in the Anggoro structure is low salinity water injection with a salinity value of 497 ppm and a production water salinity of 284 ppm.
2. Low salinity water injection in Anggoro structure has a positive impact on oil recovery in the D4-N1 layer (in the case of ANG-1033 well) because of the mechanisms that occur, namely fines migration, increase in pH, multi ion exchange, double layer effect, and salting in effect.
3. Oil drainage in the D4-N1 layer can still be maximized with several well work plans for future field development.
4. The work plan in the D4-N1 layer includes drilling in areas that have not been drained at all, reactivation of idle/suspended wells, and workovers at existing wells.

REFERENCES

Al-Sahiri, Abdullah; Abbas Qeinijahromi; Luis Genolet; Aron Behr; and Patrick Kowolik; Wintershal Holding; Pavel Bedrikovetsky; University of Adelaide, 2018, 'Fine Migration as An EOR Method During Low Salinity Water Flooding', SPE.

Austad, Tor; Rezaeidoust, Alireza; Puntervold, Tina; University of Satavanger, 2010, 'Chemical Mechanism of Low Salinity Waterflooding in this Sandtone Reservoir', SPE Journal.

D, Ivan; T, Pinerez; Austad, To; Strand, Skule; Puntervold, Tina; Wrobel, Stanislaw; University of Stavanger; Hamon Gerald; Total E&P; 2016, 'Linking Low Salinity EOR Effects in Sandstone to pH, Mineral Properties and Water Composition', SPE.

Morrow, Norman R, 2012, 'Low Salinity Waterflooding Fundamentals and Case Studies', IOR/EOR Conference, Wyoming.

Parker, AR, Looijer, MT, Goodyear, SG, Al-Qarshubi, ISM, Sorop, TG, Suijkerbuijk, BMJM, Dindoruk, DM, & Masalmeh, SK 2013, 'Integrated Approach in Deploying Low Salinity Waterflooding'. SPE Enhanced Oil Recovery Conference, 1–9. https://doi.org/10.2118/165277- MS

Qiao, Changhe; John Russell; LiLi; Pennsylvania State University, 2016, 'Understanding chemical mechanism for low salinity waterflooding', SPE.

Sianturi, Julfree; Bayu Setyohandoko; Aditya Suardiputra; Radya Senoputra; Pertamina Hulu Mahakam, 2021, 'Peripheral Low Salinity Water Injection Handil Case Study', IPTC.

Tang, GQ; Morrow, NR, 1999, 'Influence of Brine Composition and Fines Migration on Crude Oil/Brine/Rock Interactions and Oil Recovery', Journal of Petroleum Science Engineering.

Tarek, A, 2016, 'Reservoir Engineering Handbook (Fifth)'. Oxford, UK: Gulf Professional Publishing.

Wilhite, G Paul, 1986, 'Waterflooding', SPE textbook series vol 3.

Tetteh, Joel T; West, Rezai; University of Kansas, 2019, 'Crude-Oil/Brine Interaction as a Recovery Mechanism for Low-Salinity Waterflooding of Carbonate Reservoir', SPE Reservoir Engineering and Evaluation.