Egyptian Journal of Petroleum (2016) 25, 1–14

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Egyptian Petroleum Research Institute

Egyptian Journal of Petroleum

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REVIEW

Assessment and evaluation of degree of multilateral well's performance for determination of their role in oil recovery at a fractured reservoir in Iran

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Received 17 July 2014; revised 21 September 2014; accepted 29 September 2014
Available online 8 January 2016

KEYWORDS

Multilateral wells;
Oil recovery;
Degree;
Role

Abstract Current drilling costs may exceed more than million dollars for each well; therefore designing a well completion, which can increase production, is essential. Multilateral well is a well completed in two or more zones, also has a great potential to optimize oil well production. The first goal of such wells is to improve the primary recovery through increasing the reservoir exposure. The rate of development of multilateral wells in the petroleum industry has been increased in the recent decades. In addition to this, recent advanced technological tools have made enough flexibility for developing complex multilateral wells. Since the challenge is becoming a question not of whether a multilateral system is available, but rather a question of what type of multilateral, if any, is the best suited to the reservoir and production demands. The object of this study is to develop an integrated completion-planning approach, based on the current global and broad experience. In this research the role and performance of 2 kinds of multilateral wells are considered these are identified in this research as planar dual-lateral and dual opposite laterals, then their performance to enhanced oil production in one of the fractured reservoirs of Iran, in ILAM formation, is compared.

1. Introduction

Multilateral wells in their most simple form have been utilized in the oil and gas industries since the 1950's. These early multilateral systems, however, were only suitable in their application to a small segment of wells. The first multilateral well was drilled in 1953 in the late soviet union (USSR) and this well was drilled with 9-lateral in carbonate reef for an increase surface of contact with the reservoir [3]. In 1990s development in drilling technology helped engineers increase the number of laterals and multilateral wells [4]. Multilateral drilling is a new technology developed after directional drilling, sidetrack, and horizontal drilling. The technology can increase oil-drainage area, improve oil well production, and greatly reduce reservoir development cost through drilling several lateral wells in one borehole. Up to December 2006, there were more

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Peer review under responsibility of Egyptian Petroleum Research Institute.

http://dx.doi.org/10.1016/j.ejpe.2015.06.006
1110-0621

than 8000 multilateral wells all over the world, and a remarkable economic profit has been obtained. Multilateral wells are defined as wells with two or more laterals drilled from a common trunk. These laterals may be horizontal, vertical, or deviated. They may be in the same, or in different planes. Economides et al. (1998) presented a detailed description of multilateral wells, Fig. 1.

The cost for drilling multilateral wells is higher than that of normal vertical wells; however, oil production volume and recovery factor of these wells are much higher than the other ones [2]. This production improvement occurs because of the large contact area between the reservoir and the well. In cases where rig size is limited, but drilling a deep well with a large contact area is required, multilateral wells are the best possible option (Fig. 2).

One can drill two diametrically opposite wells or other shapes to achieve a large contact area with the reservoir. Minimizing surface locations results in a smaller environmental footprint on the surface, reduces the number of wells required to develop a reservoir, and reduces surface facilities and flow lines required to gather and process the crude oil and natural gas. This results in an overall improvement in the field economics [1].

2. Application of multilateral wells

The successful implementation of horizontal drilling over the last two decades has led to the development of multilateral well technology. There are various reasons for drilling horizontal wells, that could be extended to multilateral wells as well:

(1) increased reservoir exposure,
(2) connecting high permeability areas (natural fractures),
(3) eliminating or minimizing water and gas coning,
(4) accelerating production from thin beds,
(5) their stabilized production rate is about 2–5 times more than that of vertical wells,
(6) depending upon the location and type of drilling technique used, the cost of a horizontal well is 1.6–2 times the cost of conventional wells,
(7) and the cumulative oil and/or gas produced by a horizontal well is about 2–6 times more than that of a conventional vertical well [11] and [8].

The number of multilateral well completions has increased substantially in the last several years due to advances in directional drilling and completion systems. In coning situations, such as production of oil reservoirs with a bottom aquifer or a gas cap, utilization of multilateral wells will reduce the detrimental coning effect, then leading to reduction in investment and operating costs. In combination with enhanced oil recovery methods or with assisted gravity drainage, these wells can provide means to produce more oil at an economic cost [1]. This is because, to reduce coning, it is essential to have a certain stand-off (vertical distance) between the oil–water and or gas-oil contact and the horizontal well to prevent rapid breakthrough of water and or gas in a horizontal well [4]. In recent decades, as a result of development in drilling tools, engineers had designed multilateral wells in various methods. Some of usual multilateral wells, that have drilled in filled around the world, with their name are shown in Figs. 1–4.

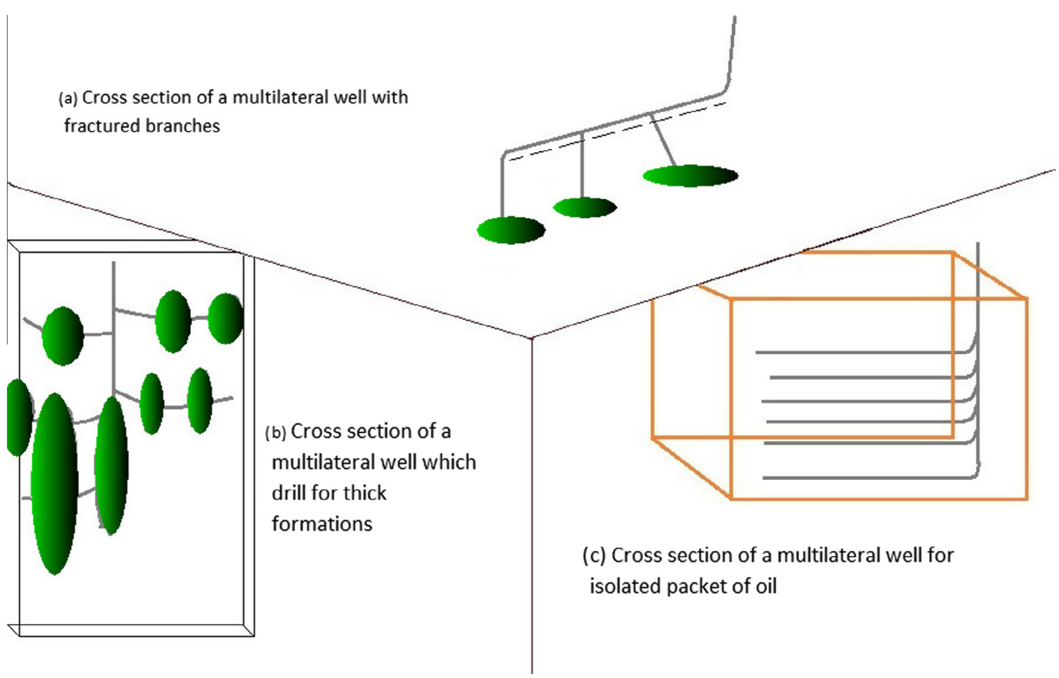

Figure 1 Typical multilateral wells for petroleum productions [7].

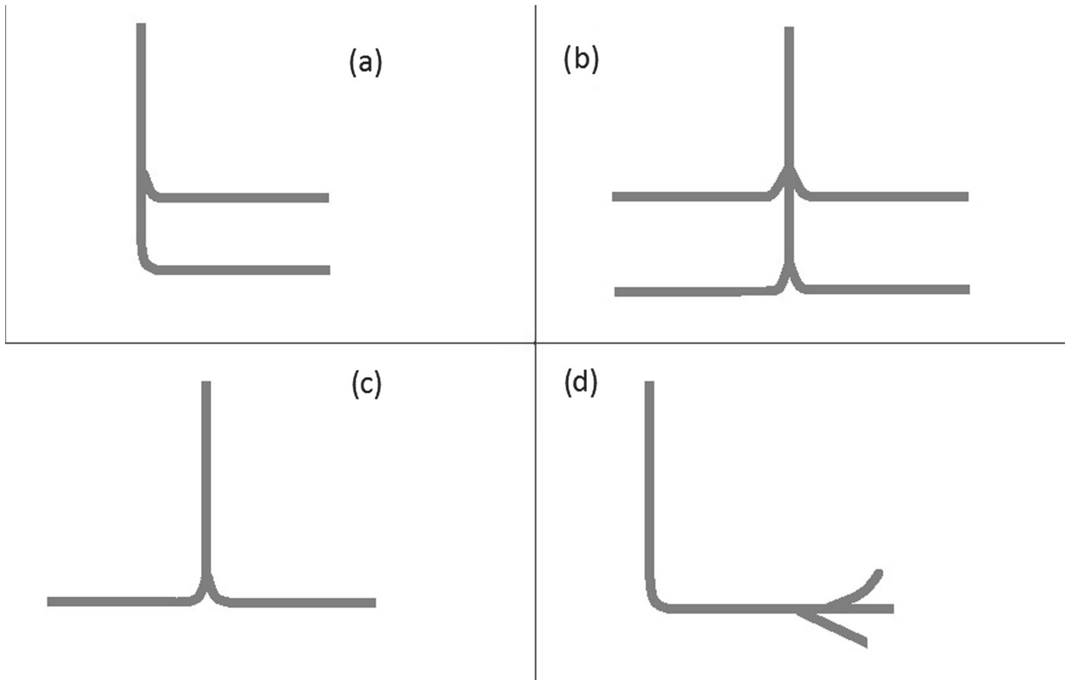

Figure 2 Multilateral well configurations [6].

Table 1 shows the various applications of horizontal wells and examples of the sample reservoirs for each application. The table also includes properties of the reservoirs in which the wells have been drilled [10].

On balance, motivations of operators for performance of this technology will be due to:

1. Drilling footage to primary target area is drilled only once.
2. More production or payzone exposure.
3. Reduction of platform costs.
4. Better utility of existing platform slots and existing wells.
5. Extend life in marginal fields.
6. Environmental concerns lessened.
7. However, this comes at potential costs of risking loss of a parent hole and significant production if the well goes down [5].

3. Case study

The field, that has been studied in this project, belongs to ILAM formation and Bangestan group. The base of geological information of ILAM formation has been created in upper cretaceous, in the stage of senonian-campanian (stratigraphic chart has been shown in Fig. 5). This formation has mostly one type of rock which is lime stone; however some narrow layers of shale have been found in parts of this formation, but the reservoir of this project has only one type of rock. GURPI and LAFAN formations are the upper and the lower formations of ILAM formation respectively.

Relative permeability and the capillary pressure of oil–water and oil–gas of this model are shown in Fig. 6.

3.1. Reservoir fluid properties

The degree of API of oil of this reservoir is about 31 API degrees. The initial state of the reservoir and properties of the reservoir fluid, as well as constraints that should be applied, are presented in Table 2.

Precise and accurate characterization of a reservoir fluid is an imperative factor in reservoir simulation studies. PVT experiments are usually expensive and time consuming, and are performed under restrictive conditions. Therefore, EOS based PVT packages are used widely for the prediction and evaluation of fluid properties in well and surface conditions over a wide range of temperatures, pressures and composition. Here, using a PVTi module of ECLIPSE, three-parameter Peng–Robinson EOS which predict the behavior of Iranian reservoir fluid quite well were tuned to present the fluid sample of the reservoir.

Among different available PVT samples, the one that better described the behavior of the reservoir fluid and better accorded with real data was taken as the reservoir fluid representative. Components defined in PVTi and EOS were tuned without any grouping, since in a non-compositional run, no grouping is needed. The results of the tuning process for gas–oil ratio, liquid viscosity and oil relative volume that will be used in this study are given in Figs. 8 and 7.

Dual porosity model has been used for reservoir simulation and assumed that gravity segregation is effective in production. From a pervious analysis made for this reservoir, it was determined that the best BHP(bottom hole pressure) are from 3000 to 3200 PSI, and the pressure defined for simulation of new wells for this project is 3000 PSI, some economic limitations were determined for shutting wells that are shown in Table 3.

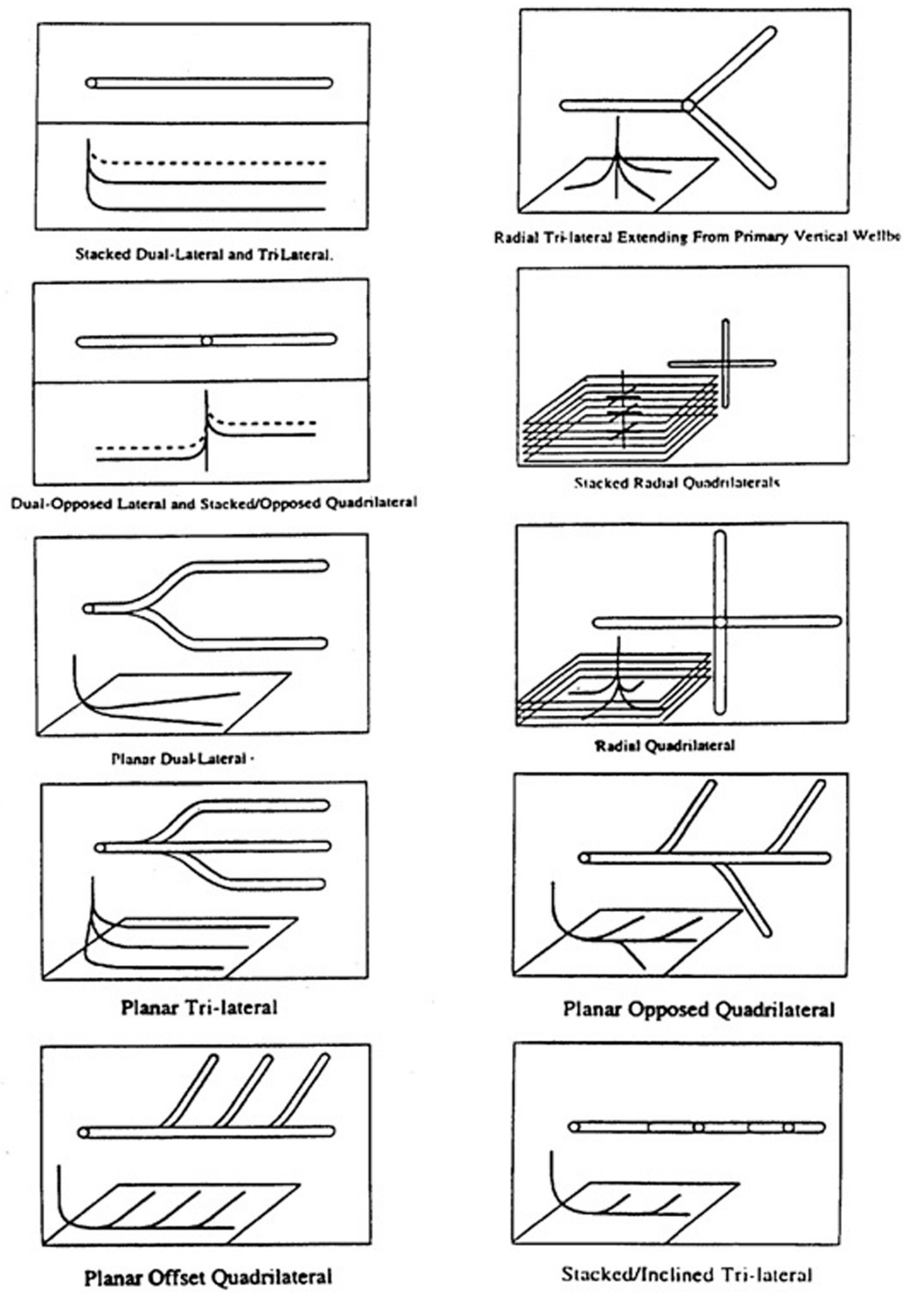

Figure 3 Some type of multilateral wells (5).

The shape of simulated reservoir and the position of new product well are shown in Fig. 9.

3.2. Studying some multilateral wells scenarios

In this project 2-kinds of multilateral wells called dual opposed lateral and planar dual-lateral are studied from different points of views. In other words, two shapes of multilateral wells in this project are defined as scenarios for this reservoir. After that each scenario is studied individually, and finally the better scenario has been chosen based on the most evidence.

3.2.1. Dual opposite lateral

The shape of this well is illustrated in Fig. 10. As can be seen, this well includes two horizontal laterals that are drilled as opposed to each other.

The amount of oil production by this well in next 2-years, calculated by soft ware, is shown in Fig. 11 but for getting a better result, this amount is compared with that of two other kinds of wells, horizontal and vertical.

In other words, for having a better effect, this question was raised that; if instead of this well, a normal horizontal or vertical well is drilled, how much oil will be produced? Therefore, the volume of oil produced by this well was compared with

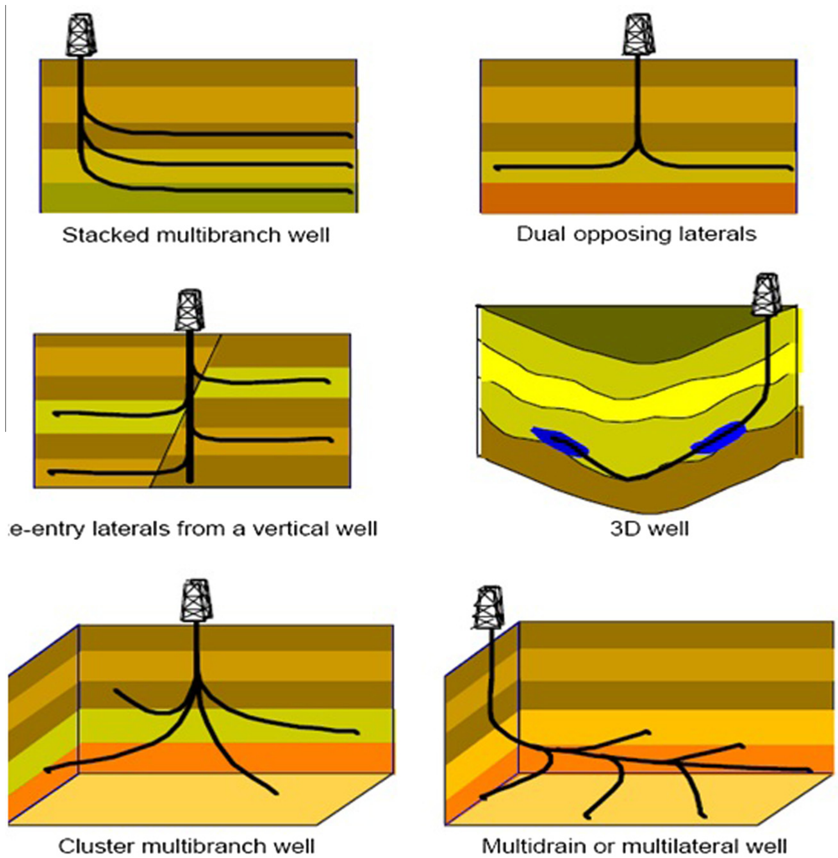

Figure 4 Various types of advanced wells (9).

that of two other kinds of wells whose results have been shown in Fig. 11.

As can be seen, Fig. 11 illustrates that the volume of oil production, oil recovery, of the dual opposed lateral well is more than the others and if this well is drilled, instead of horizontal wells, the oil recovery will increase up to 1.44% more than the horizontal ones and up to 10.15% than the vertical ones. In other word, this well increase the oil production up to nearly 1.44% in comparison with horizontal well and approximately 10.15% in comparison with vertical well.

3.2.2. Planar dual-lateral

A 3-D picture of this well drawn by soft ware is shown in Fig. 12.

The amount of oil production by drilling planar dual-lateral and vertical and horizontal well is compared in Fig. 13.

As can be seen, Fig. 13 illustrates that the volume of oil production, oil recovery, of the planar dual-lateral well is more than the others and if this well is drilled, instead of horizontal wells, the oil recovery will increase up to 3.08% more than the horizontal ones and up to 11.92% than the vertical ones.

4. Discussion (comparing the scenarios and choosing the best)

As mentioned before, using the multilateral wells one could have more access to the reservoir, and this advantage could lead to know the reservoir much better than before. Another advantage that could be gained with drilling multilateral wells is to connect to the areas that have high permeability or are more isolated than another parts of the reservoir.

However; because of a variety in well completion in multilateral wells, engineers should choose the best option for improving oil recovery and keep it for the future. Hence the goal of this study is to find the best option among other ones mentioned.

According to Fig. 14 of oil production for all the above mentioned multilateral wells, as it is seen the volume of the oil recovery from all kinds of multilateral wells, are more than the horizontal and the vertical ones. This point has been shown in Fig. 14 and also it could be seen that the planar dual-lateral shape has the most volume of the oil recovery among the other wells with 3.08% more volume of the oil recovery than the horizontal wells and 11.92% more volume of the oil recovery than the vertical wells and 1.61% more volume of the oil recovery than the dual opposite lateral wells in the next 2-years.

For choosing the best shape of multilateral well, not only the total oil production was considered but also some other factors like total water production, field water cut and field pressure rate were checked (Figs. 15–17).

Water-cut is usually a troublesome problem, and it has been tried to keep it within the lowest possible level. Fortunately in this simulation limitation for this problem has been determined. As can be seen from the water-cut chart, the

Table 1 Horizontal well applications [10].

Reservoir application	Reservoir	Payzone thickness (ft)	Porosity (%)	Horizontal permeability (md)
Thin reservoir	Bakken Shale, ND, USA	10–30 ft	1.5–12.9	< 1
Naturally fractured reservoirs	Austin Chalk, Texas, USA	25–70 ft	3–12	< 1
	Bakken Shale, ND, USA	10–30 ft	1.5–12.9	< 1
	Mancos Shale, NM	60 ft (max)	2	< 0.1
	Niobrara, Wyoming, USA		< 10	< 0.1
Formation with gas and water coning	Prudhoe Bay, Alaska, USA (SS)	100–200	22	200
	Elk Hills, California (SS	1500	23	8–80
	Bima Field, Indonesia (LS)	20–100	31–36	100–1000
	Gunung Kembang, Indonesia (LS)	35	24	230
	Helder Field, North Sea (SS)	80–130		1000–6000
	Rospo Mare Fields, Italy (LS)	130	1.8	2–1500
	Empire Abo Unit, NM, USA (Reef)	90	8.6	25
	Troll Field, North Sea (SS)	75	30	6–10
	S. Pepper Field, Australia (SS)	25–75	20	1000
	Loma de la Lata, Argentina (SS)	115	14	1
	Chihuido de la Sierra Negra, Argentina (SS)	75	19–21	86–164
	Nimr Area, S. Oman (SS)	275		
	Safah Field, Oman (SS)		19–23	5
	Saih Ruwi Field, Oman (SS	82	21–27	1–12
	Hayat & Salam Fields, Egypt (SS)	30–80	14–20	1000–3000
Heavy oil	Countless Upper Manville "RR", Canada		18–24	250–5200
	Cactus Lake North McLaren, Canada	40	30–33	> 5 Darcies
	Winter Field, Canada	100	30	6000
	Edam West, Sparky Sandstone, Canada	65–100	34	1000–10,000
	Midway Sunset Field, U.S. California	400	28	1000–6000
	Lake Maracaibo, Venezuela	20	17	440
	Jobo Field, Venezuela	100	27	1700
	Cerro Negro Sector, Orinoco Belt, Venezuela		34	12,000
Gas reservoirs	Devonian (L. Huron Shale), U.S.	15–50	2	0.13–0.43
	Big Sandy Field	250	2	0.045
	Gulf Coast, U.S. (SS)	40	33	6000
	Zuidwal Field, Netherlands	140–200	10–15	1–10
Waterflood	Weyburn Field, Canada	20	3–26	0.01–500
	Yowlumne Field, California Waterflood (SS)	0–400 ft Avg. net 55–75 ft	15–20	
	Texaco New Hope Shallow Unit, Franklin Co. TX Horizontal Injector Waterflood Project	18	12	2
EOR	Rainbow Keg River G Pool, Canada, Miscible	35–40	10	565
	Pembu Nisku Field, Canada, Miscible	130–330	10–30	1.5–10 Darcies
	Chateaurenard Field, France Polymer	0–23	30	800–3000 md 1600 md (avg)
	Cold Lake, Canada, Thermal	35–40	10	565
	Talnglflags North Field, Canada, Thermal	90	33	4000

planar dual-lateral has the most volume among the others; however this volume is under our limitation.

5. Conclusion

As described before, according to the reservoir simulation results and charts, the wells that are defined as planar dual-lateral in this project have the best oil recovery factors of 3.08% and 11.92% respectively which are more than the recovery of the horizontal and the vertical ones; however this kind has the most volume of water-cut among the others. The planar dual-lateral has the maximum oil production owing to the fact that this well covers more area of the reservoir also has more contact surface with reservoir. After that the Dual opposite lateral had the most oil recovery factor respectively 1.44% and 10.15% more than the horizontal ones and the vertical ones. Therefore these two kinds, planar dual-lateral and Dual opposite lateral, have been recommended to drill.

Planar dual-lateral has the most volume of Water-cut among the others; however this volume is under our limitation also the pressure drop on this well is the least and this could

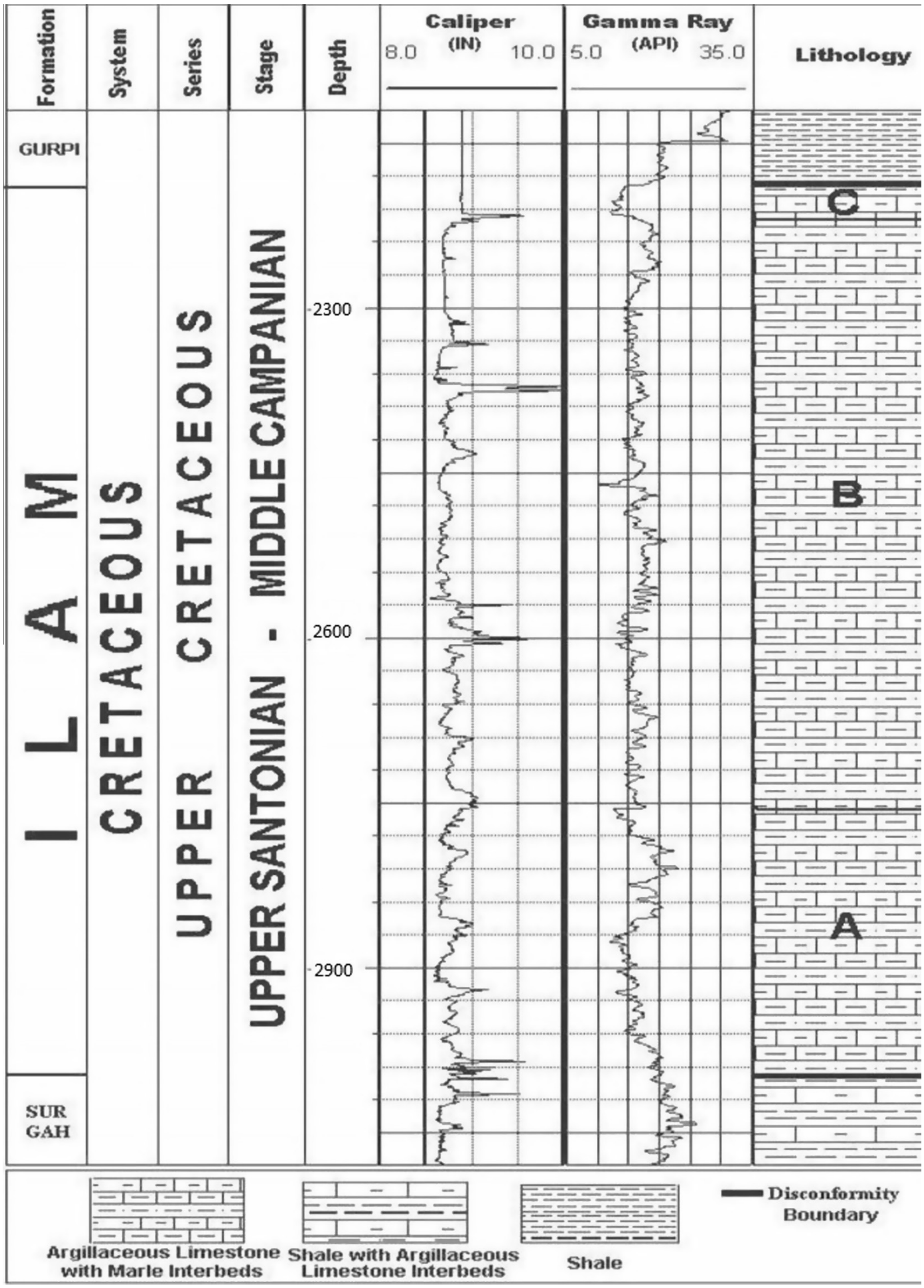

Figure 5 Stratigraphic chart of one of the wells of understudy reservoir (illam formation stratigraphic chart).

possibly be because of the volume of oil and gas that this well product

Planar dual-lateral has not only the most volume of field oil production, but also has the most volume of field gas production that this point can be useful for further development programs.

By adding the number of laterals the oil recovery will increase and deviation laterals have better effect than horizontal lateral in this case.

The result of simulation shows the increase of production period by replacing multilateral wells with the normal vertical wells.

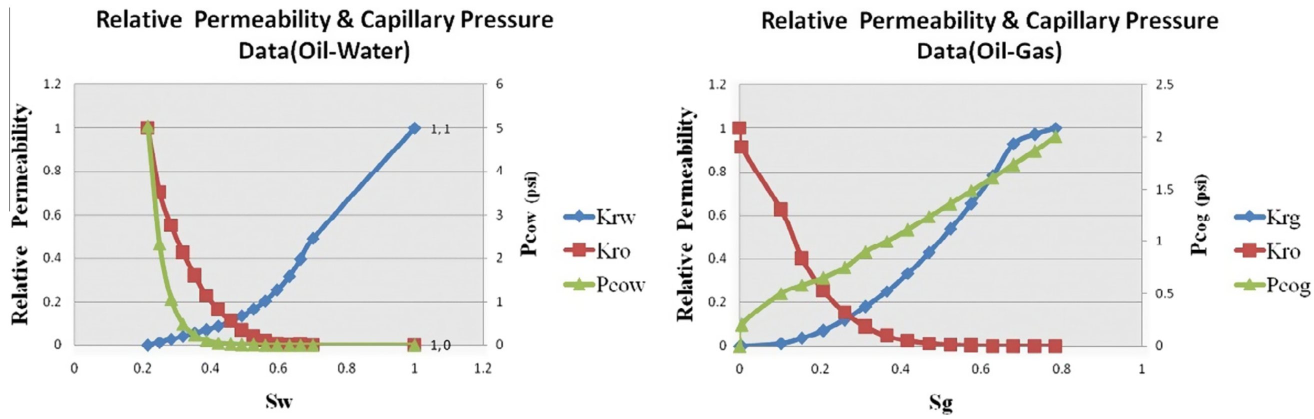

Figure 6 Relative permeability and the capillary pressure of oil–water and oil–gas.

Table 2 Initial condition of reservoir.		
Reservoir pressure	Psia	4120
Reservoir temperature	°F	151
Bubble point pressure	Psia	3052
Density of stock tank @ S.C	API	31
GOR @ S.C	SCF/STB	857.4
BO @ PB	Rb/stb	1.443

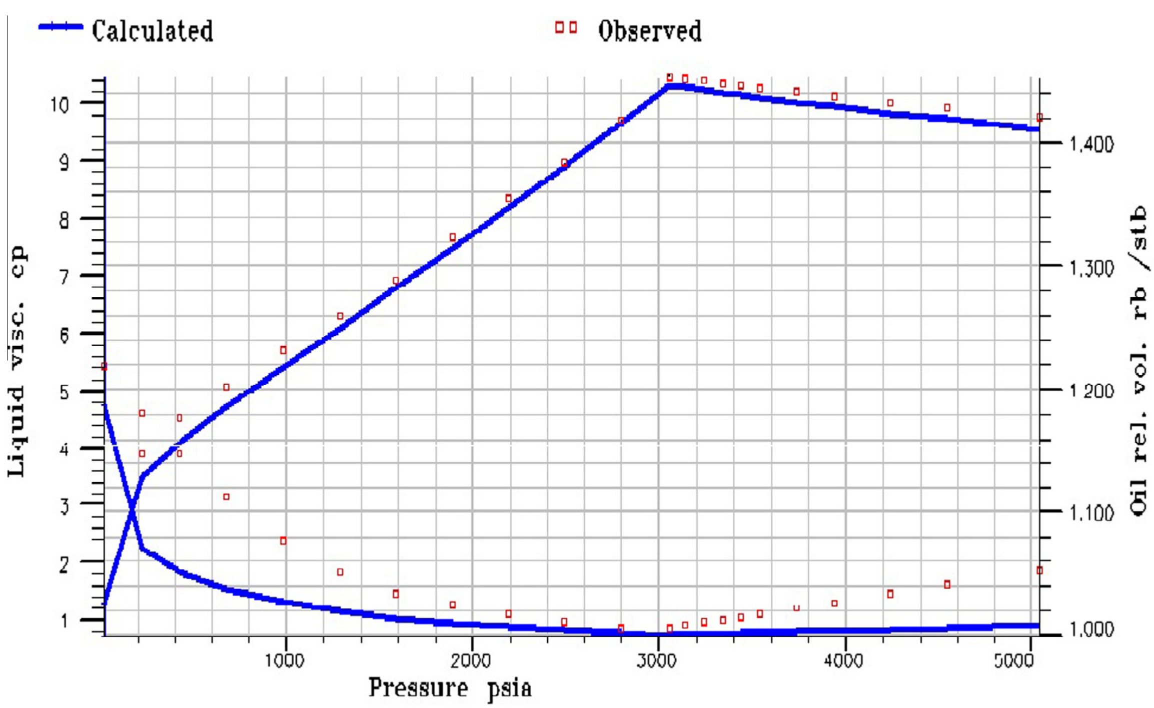

Figure 7 Comparison of calculated and observed liquid viscosity and oil relative volume.

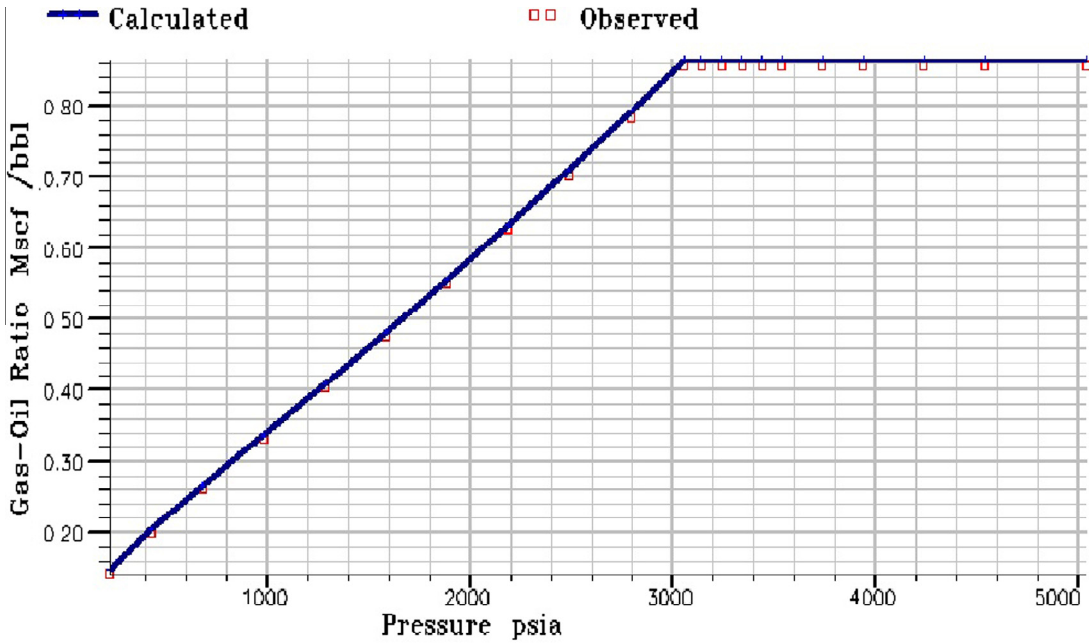

Figure 8 Comparison of calculated and observed gas-oil ratio.

Table 3 Economic limitations for shutting product wells.

Minimum oil production rate (STB/day)	Maximum water cut	Maximum gas oil ratio (MScf/STB)
100	0.05	1.2

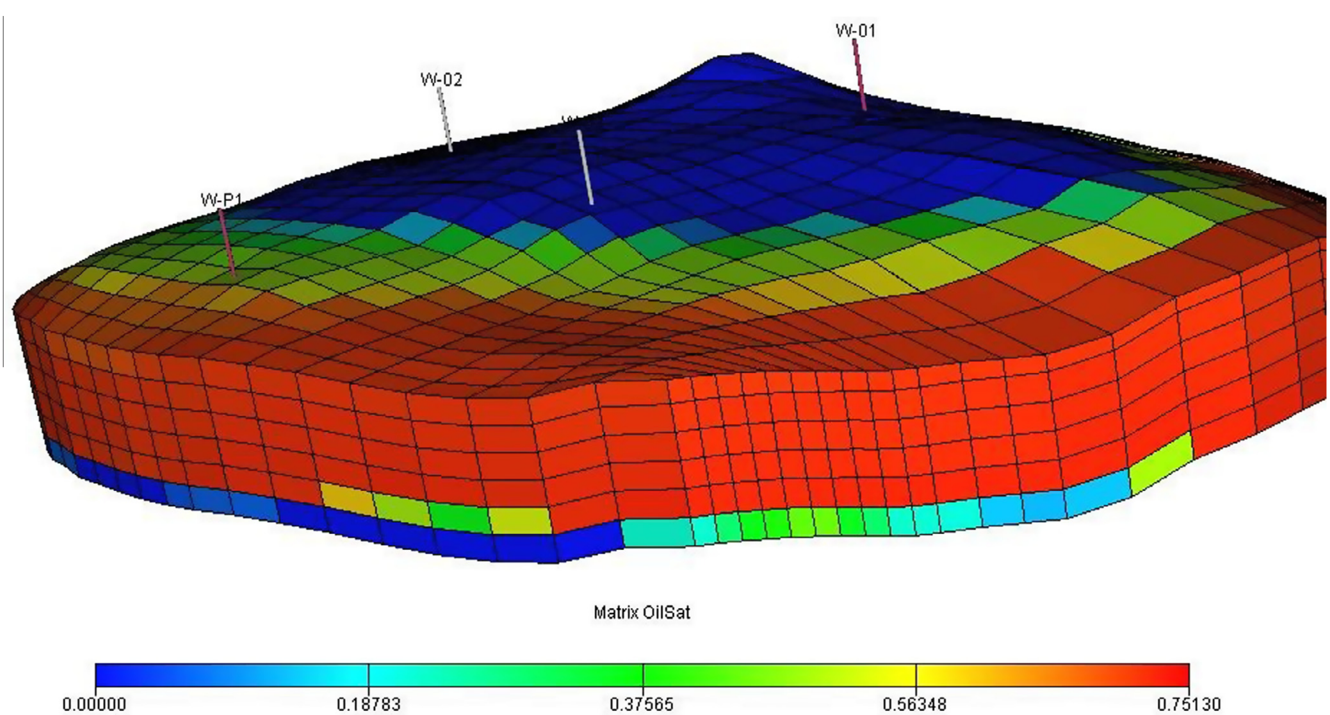

Figure 9 Shape of simulated reservoir and the position of new product well, that called w-p1.

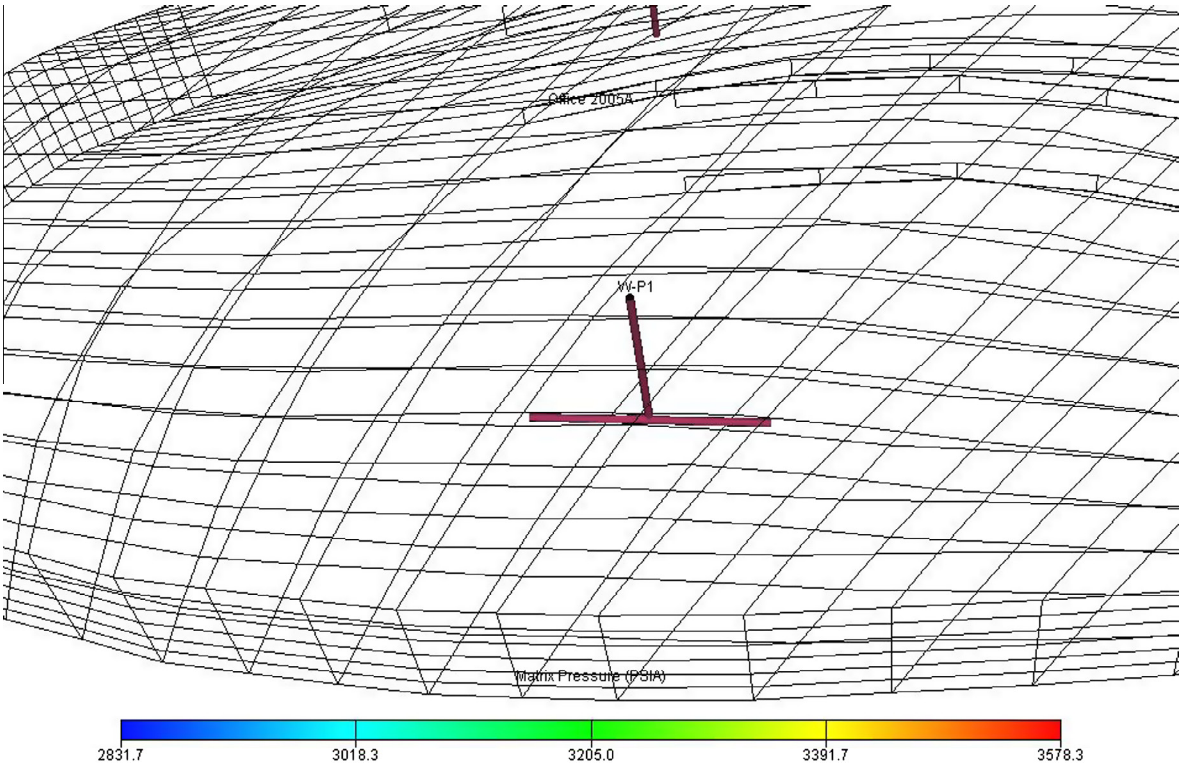

Figure 10 3-D picture of the well drown by soft ware.

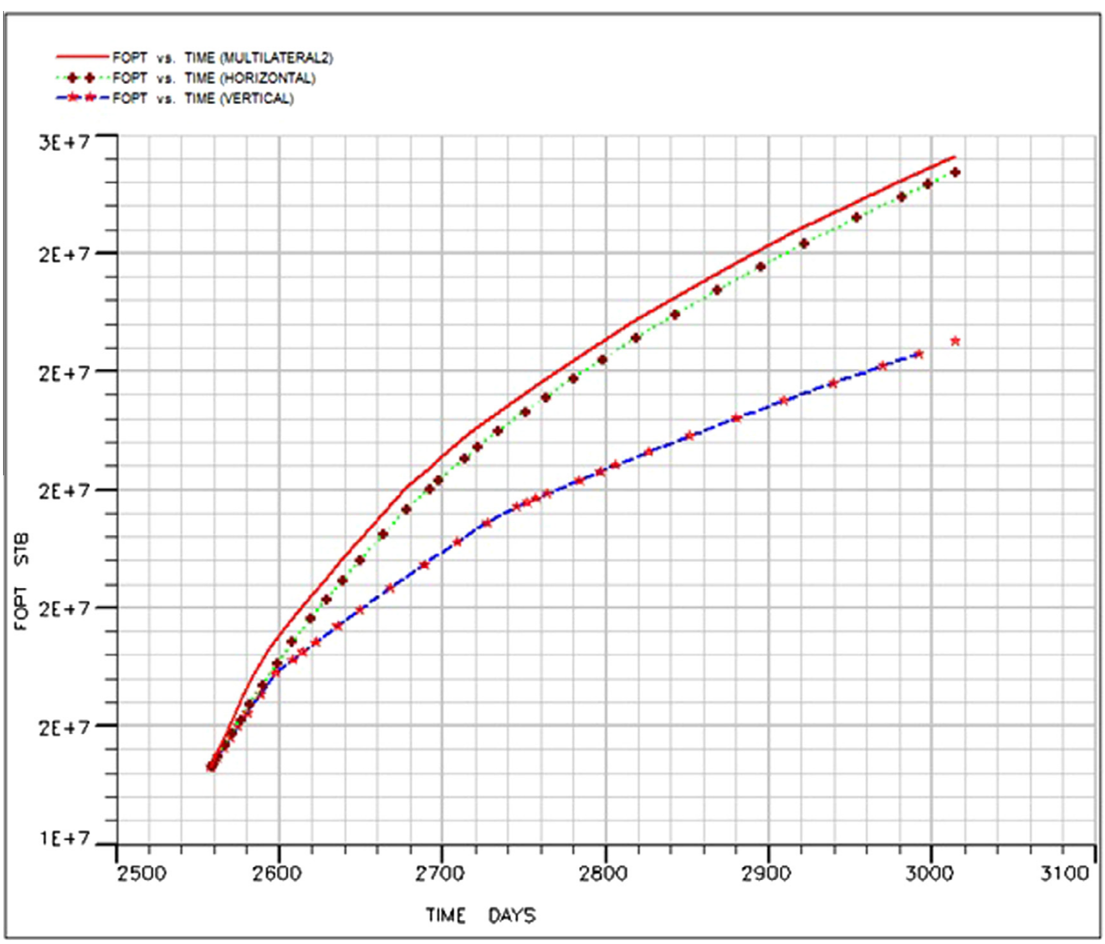

Figure 11 Field oil production total for 3 kinds of well (multi lateral 2 = dual opposed lateral).

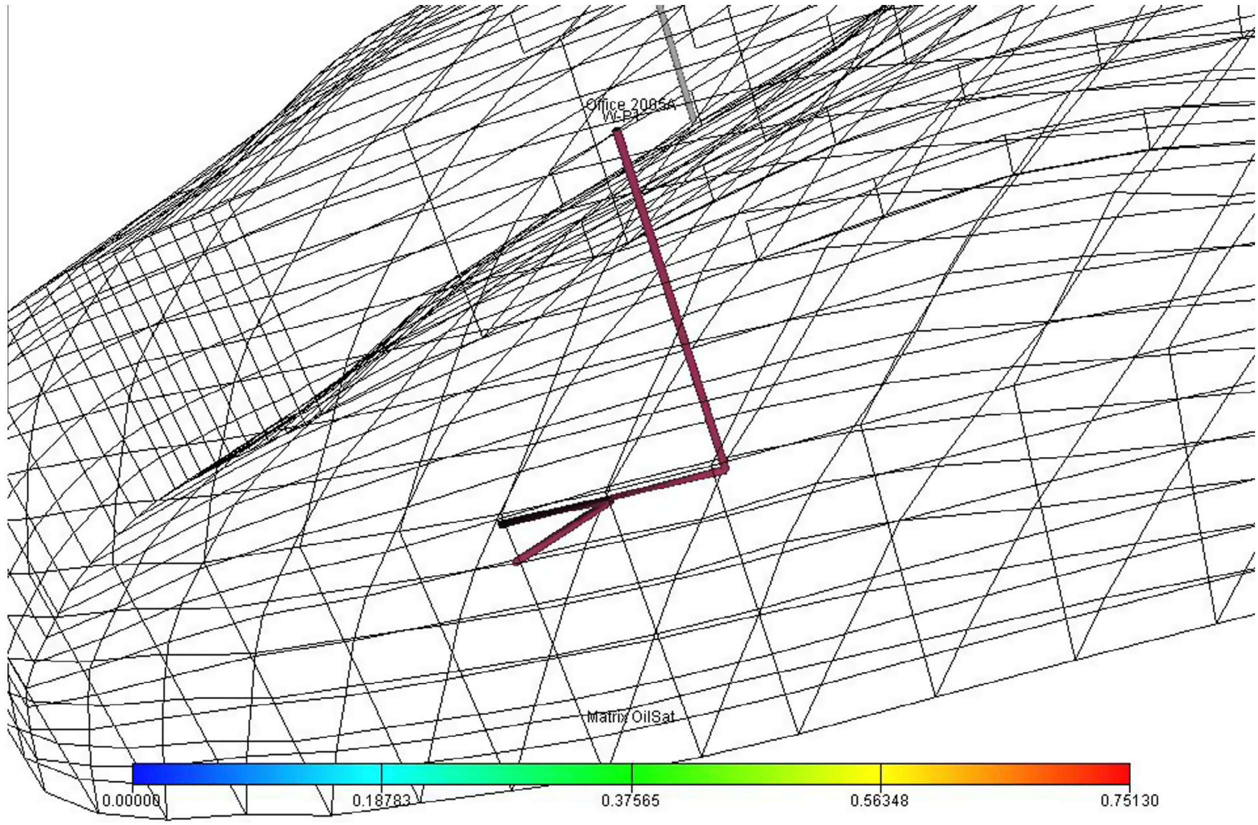

Figure 12 3-D picture of the well drown by soft war.

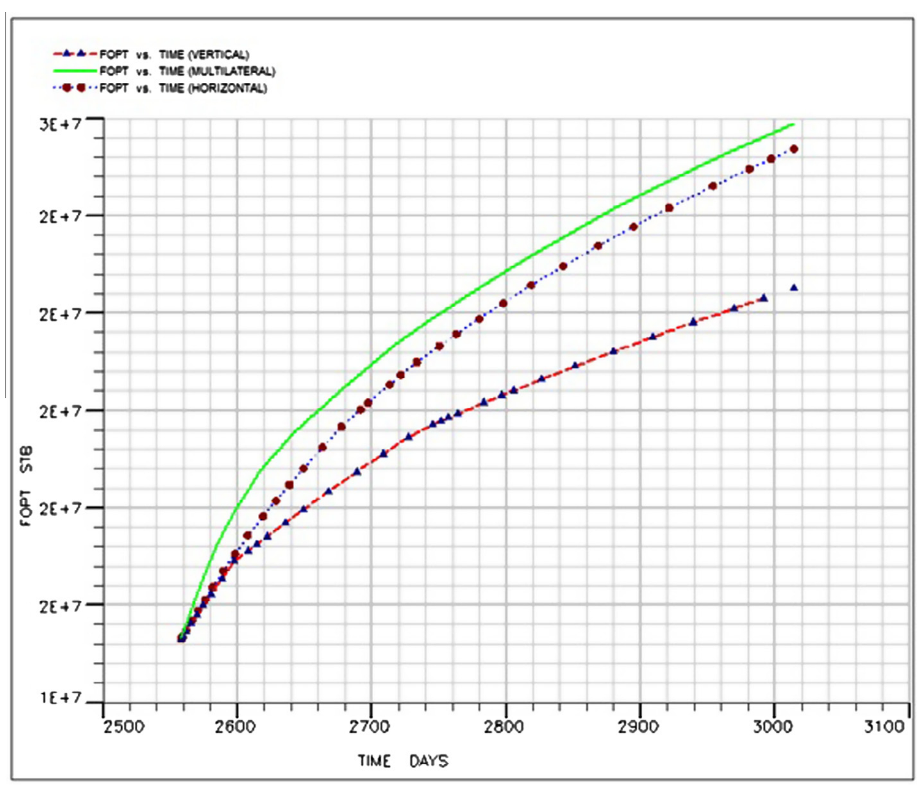

Figure 13 Oil production total for 3 kinds of well (multi lateral = planar dual-lateral).

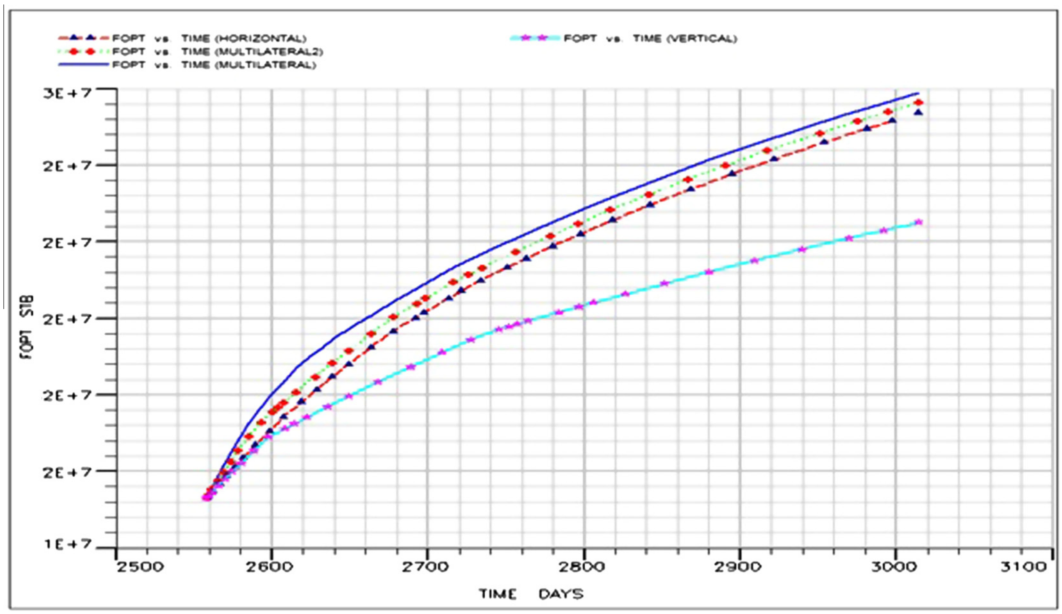

Figure 14 Oil production total for all kinds of well (multi lateral = planar dual-lateral and multi lateral2 = dual opposite lateral).

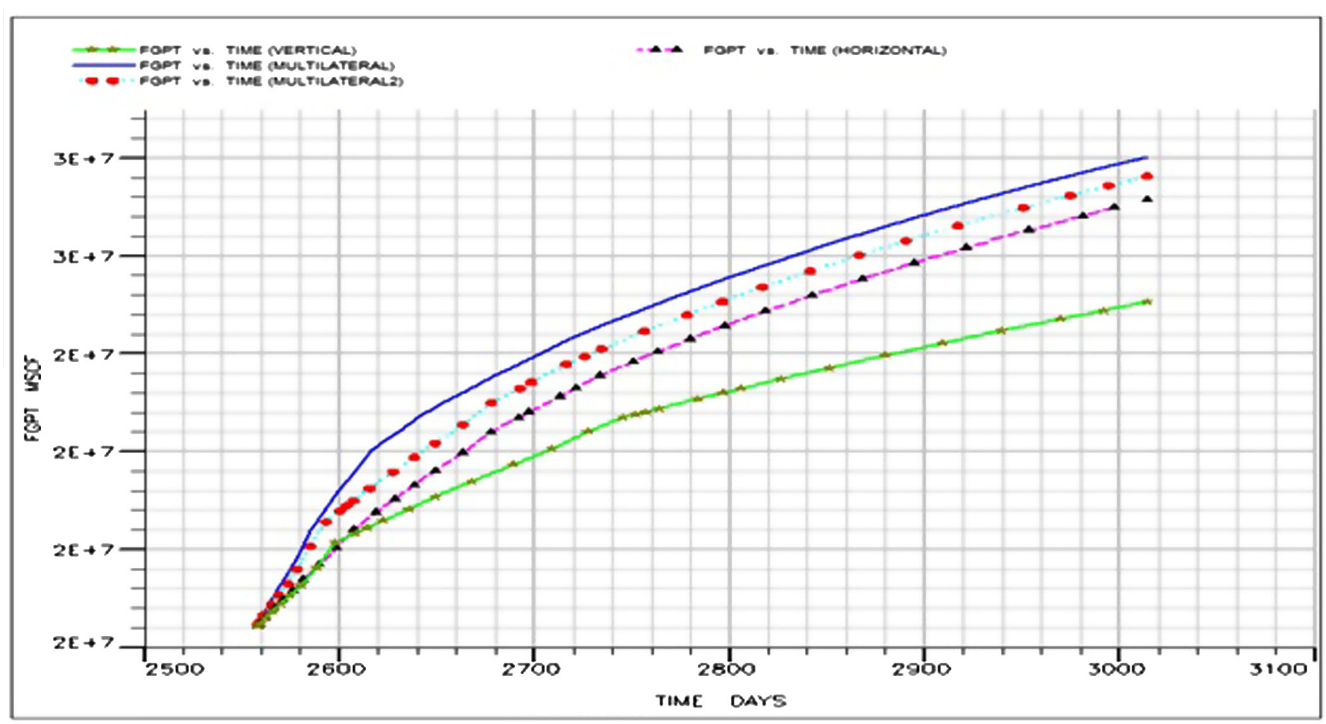

Figure 15 Gas production total for all kinds of well (multi lateral = planar dual-lateral and multi lateral2 = dual opposite lateral).

As shown, multilateral wells not only cover more area of the reservoir but also cover the reservoir better than the vertical wells, therefore they have more production index and oil recovery, thus these wells reduce the need for drilling new development wells in the reservoir.

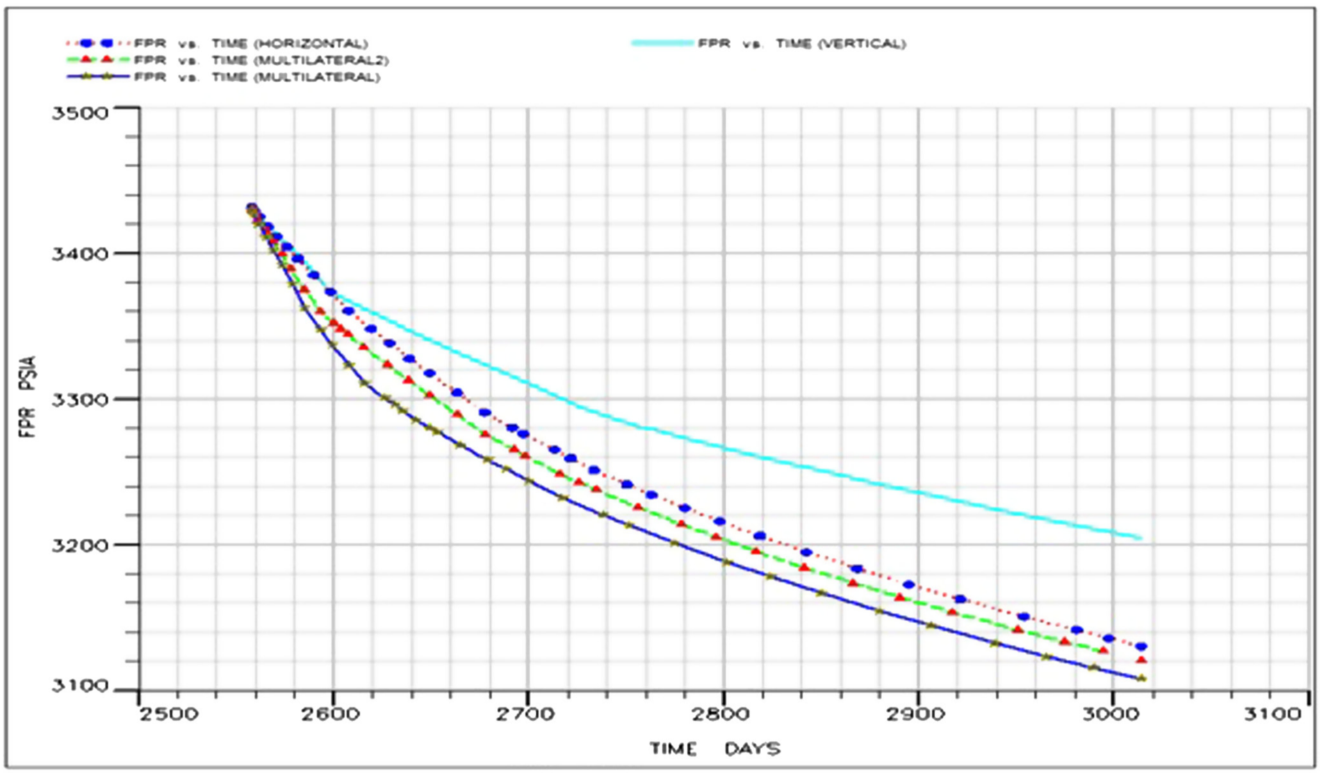

Figure 16 Field pressure rate for all kinds of well (multi lateral = planar dual-lateral and multi lateral2 = dual opposite lateral).

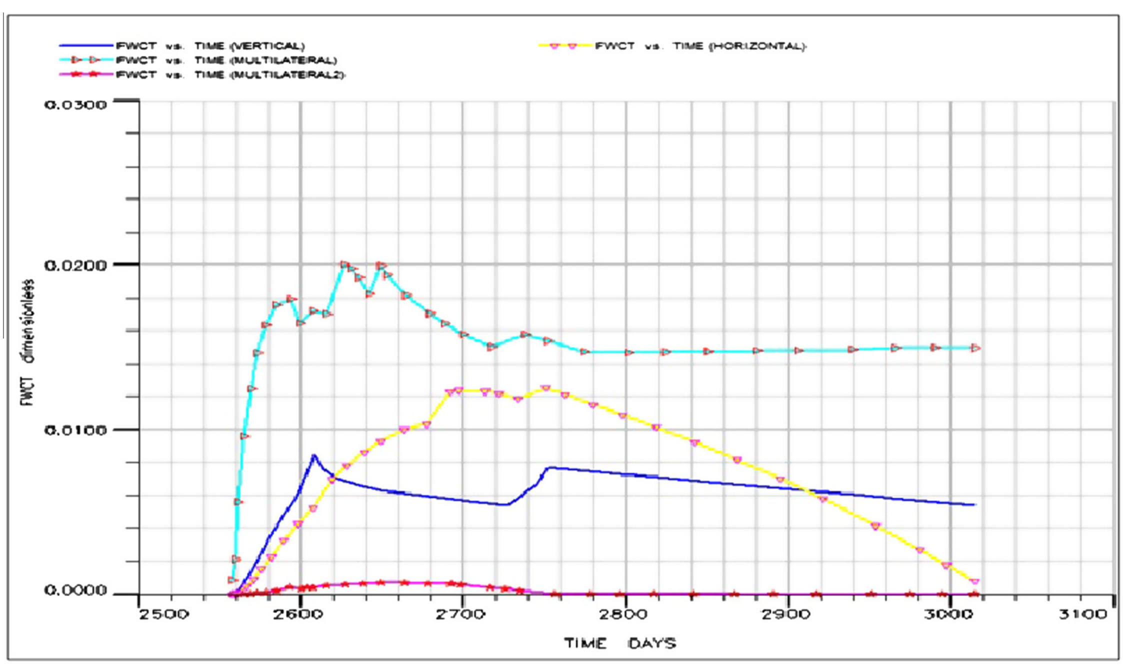

Figure 17 Field water cut for all kinds of well (multi lateral = planar dual-lateral and multi lateral2 = dual opposite lateral).

Acknowledgements

The author wish to thank his family for their unlimited supports, especially his father. I would like to extend my sincere thanks to the reviewers and the editors who helped me a lot, Tehran Science & Research Azad University, Research Institute Petroleum of Iran (RIPI).

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